RAE2026

Active Bodysuits for Adult Degenerative Scoliosis (ADS)

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Contents

Title: Active Bodysuits for Adult Degenerative Scoliosis

Descriptor

Adult degenerative scoliosis (ADS) patients often experience progressive lower back pain, deformity, and sagittal imbalance. While bracing is the most common non-invasive treatment, prolonged use can lead to paraspinal muscle deconditioning and worsening symptoms. To address these limitations and the unique needs of older ADS patients, an active training bodywear was developed, **combining passive and active corrective forces** with an **age-friendly design**.

A 3-month intervention study demonstrated significant improvements across all domains of the Brace Questionnaire, notably in vitality, emotional functioning, and physical functioning. The Scoliosis Research Society-22 questionnaire also showed marked improvements in all health-related quality of life domains, particularly pain and mental health. Additionally, the mean Oswestry low back pain disability score decreased from 23.3% to 18.2%.

The bodywear includes a vibrotactile feedback system that monitors sitting and standing postures, providing instant haptic feedback for suboptimal alignments. This helps users establish and maintain optimal posture. Post-intervention results revealed that most participants improved their posture and could maintain proper alignment with greater ease.

The combination of active self-correction and passive bracing in the bodysuit represents an advancement in brace development. The invention is protected by US Patent (US-11931282-B2). The results have been shared in multiple publications, including the *International Journal of Environmental Research and Public Health*, *Color Research and Application, IEEE Transactions on Neural Systems and Rehabilitation Engineering*, and *Proceedings of ISERD International Conference*. They were also presented at the *International Conference on Applied Human Factors and Ergonomics 2022* and featured at *the Asia Summit on Global Health 2022*. Additional disseminations, including a public seminar at the *Asia Pacific Institute of Healthy Aging* and a media feature on a local TV programme, have raised public awareness of this innovative solution for aging-related health issues, highlighting its potential to improve older adults' quality of life and engage the wider community.

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 research design and technical development of the active training bodywear, guiding material selection, garment construction, and the integration of passive, active, and vibrotactile corrective mechanisms.

Prof. Kit-Lun YICK

Professor, SFT, PolyU
Members of RISports, 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

Dr Kenny Kwan

Department Chairperson and Clinical Associate Professor of the Department of Orthopaedics and Traumatology, HKU

Expertise:
- Clinical management of AIS
- Radiographic assessment methodologies

Role in the Programme:
- Designs and oversees clinical trial implementation
- Validates efficacy through Cobb angle measurements

Research Questions

Question 1:

- **The braces available in the market are usually heavy and lack of breathability, while muscle deconditioning of the wearer is frequently reported [9]**
- **Brace-wearing may be strenuous and complicated for the older adults, the adversities in ability will lead to common perceptions of weakness and useless [10]**

Design and develop a **bodywear** that is **close fit**, **breathable**, **adaptive,** and can provide **effective pain management** by giving **extra support** to the wearers.

Question 2:

- Aches and pains of ADS patients are oftentimes rooted in **improper postural habits** which keeps affecting their spinal health[11]
- Individuals cannot be informed of his/her own **functional changes** consciously[12]

Design and develop a **vibrotactile feedback (VTF) system** to help wearers to maintain good postures by **monitoring spinal alignments** and **giving instant feedback.**

Research Outputs

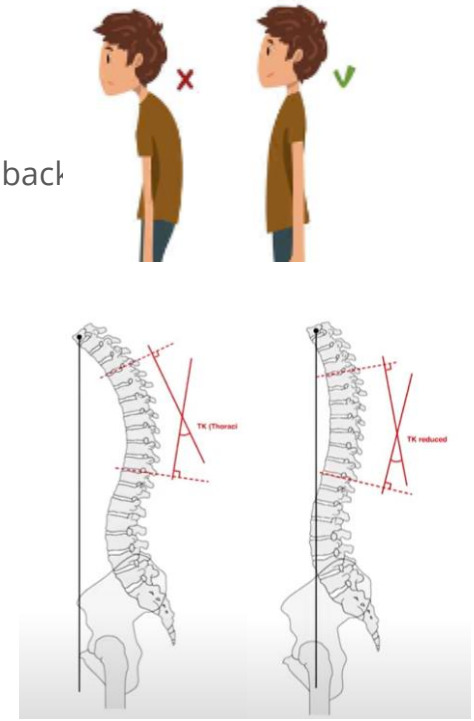
The Active Bodysuit (First published on16th February 2020)

A garment-based, with integrated use of rigid, semi-rigid and flexible materials for passive corrective force and sensor-based system for active training that aims to:

- Maintain patients' current level of body function
- Minimize symptom progression
- Support body alignment and pain management
- Address older adults' physical and psychological needs
- Incorporate active training through vibrotactile biofeedback

Bodysuit with rigid and semi-rigid materials to provide back and lumbar support

Active Corrective Forces



Active self-correction on habitual postures for better pain management

Research Outputs

Patents / Publications / Exhibitions / Interviews

Category	Details
US Patent	Invention title "Bracewear for spinal correction and system for posture training". Patent No.: US-11931282-B2. Publication date: 19 Mar 2024. Application no. 17/071,070. Filing date: 15 Oct 2020.
Journal Articles	Wan, F. K. W., Mak, A. T. H., Chung, C. W. Y., & **Yip, J. Y. W.** (2024). Development of a motion-based video game for postural training: a feasibility study on older adults with adult degenerative scoliosis. *IEEE transactions on neural systems and rehabilitation engineering : a publication of the IEEE Engineering in Medicine and Biology Society*, https://doi.org/10.1109/TNSRE.2024.3398029 Cheung, M. C., Law, D., **Yip, J**., & Cheung, J. P. Y. (2022). Adolescents' experience during brace treatment for scoliosis: A qualitative study. *International Journal of Environmental Research and Public Health*, *19*(17), 10585. https://doi.org/10.3390/ijerph191710585 Chung, W. Y. C., **Yip, J.**, Yick, K. L., & Ng, S. P. (2022). Affective association with and preference for flexible brace colors in older adults with spinal deformities. *Color Research and Application*, 47(1), 194–203. https://doi.org/10.1002/col.22706
Conference Articles	Sit, Y. L., **Yip, Y.W.**, Kenny, Kwan, (2020). A New Concept for Adult Degenerative Scoliosis: Posture Training Bracewear. In *Proceedings of ISERD International Conference*, Zurich, Switzerland (pp. 5-7). Available online at: https://www.worldresearchlibrary.org/up_proc/pdf/3717-15923689665-7.pdf Sit, Y. L., **Yip, Y.W**., Kenny, Kwan, (2021). Preliminary Wear Trial of Posture Training Bracewear For Older Adults With Degenerative Scoliosis (ADS). In *Advances in Human Factors and Ergonomics in Healthcare and Medical Devices (AHFE 2021)* (Vol. 263, pp. 81–87). Springer International Publishing AG. http://doi.org/10.1007/978-3-030-80744-3_11 Li, X., **Yip, J**., Liang, R., Zhang, J. (2023). Inclusive design for older adult with degenerative scoliosis: The integration of monitoring sensors and functional garment. In: Jay Kalra and Nancy Lightner (eds) Healthcare and Medical Devices. AHFE (2023) International Conference. AHFE Open Access, vol 79. AHFE International, USA. http://doi.org/10.54941/ahfe1003491

Research Outputs

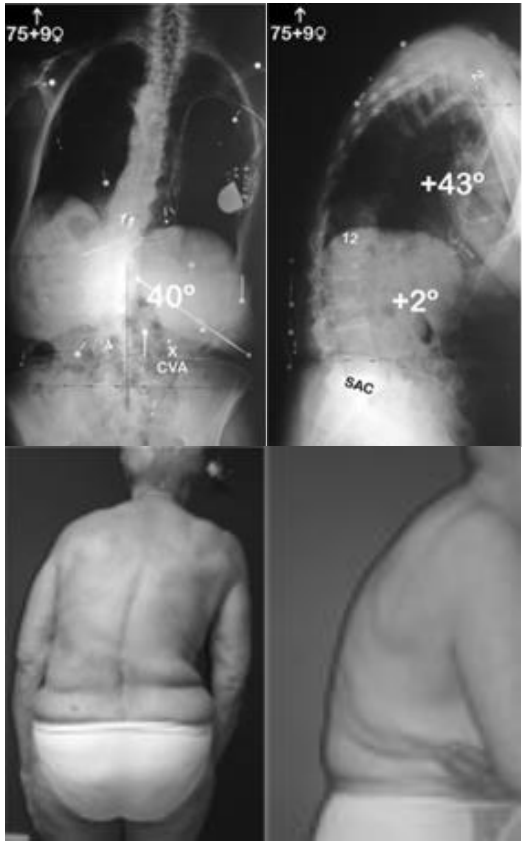
Patents / Publications / Exhibitions / Interviews

Category	Details
Thesis	Sit, Y. L. (2021). *Posture training bracewear for older adults with degenerative scoliosis (ADS)*. Hong Kong Polytechnic University. Chung, W. Y. C. (2022). *Active bodysuit for adult degenerative scoliosis (ADS)*. Hong Kong Polytechnic University.
Public Seminar	Presented by **Prof. Joanne Yip**. Title: *Technology for Aging Population*. Asia Pacific Institute of Healthy Aging, Shop A, 1/F, Hong Kong Pacific Center. 30 October 2024
Exhibition	2022 Asia Summit on global Health (ASGH) showcases. Hong Kong Convention and Exhibition Centre. 10-11, November 2022.
Media Reports	Tech Showcase - Interview conducted by Research and Innovation Office, PolyU Available online at https://www.youtube.com/watch?v=Ke2bbmIHjUU. TVB創科導航 ｜ 未來影院／脊柱側彎. 無綫財經·資訊台. Published on 23 February 2023, https://www.youtube.com/watch?v=wD3NqrBCWIQ.

Research Field & Key References

Adult Degenerative Scoliosis (ADS)

- **A condition of the ageing population caused by degenerative changes without pre-existing spinal deformities [1,2]**
- **Osteoporosis, degenerative disc disease, and iatrogenic instability are risk factors that contribute to ADS development [3]**
- **Increased concerns about the health effects of ADS: increasing prevalence ranges anywhere from 6% to 68% [4]**
- **Patients with ADS usually have progressive lower back pain, symptomatic lumbar stenosis, progressive deformity and symptoms of sagittal imbalance [1,5]**



Radiographic images of an ADS patient

Research Field & Key References

Current Non-invasive interventions to ADS

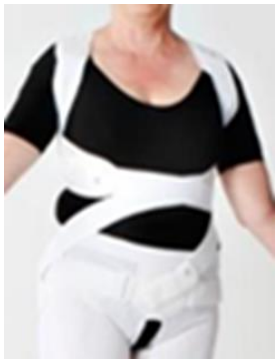
Older adults have greater risk of complications with surgical treatment [6], due to:

- Higher level of disability
- Greater severity of pain in the low back and leg
- Worse health status

Bracing is the most traditional non-invasive application recommended for ADS treatment which provide **good support of the painful spine area** [7]. Different brace upholds different mechanical principles of correction by applying external forces to restore the alignment of spine and posture.

- Physio-logic brace®

However, these braces do not encourage active self correction. They **may provide immediate relief to lower back pain, but** may also cause **muscle atrophy**, **pressure marks**, **skin irritation**, **breathing effects** which worsen the deformity and symptoms in the long run [8].



SpineCor®

- **ScoliSMART**

Research Methods, Prototypes & Materials

Implementation Plan

Milestone 1 - Design and Develop Posture Training Bodywear for Adult Patients with Degenerative Scoliosis and Optimise Passive Corrective Forces

Task 1.1:	Task 1.2:	Task 1.3:
Design and develop posture training bodywear for older adults with degenerative scoliosis	Select fabric materials and perform testing on them and test a specially-engineered wear system for posture training bodywear	Optimise passive corrective forces from posture training bodywear with supportive components

Milestone 2 - Design and Optimise Vibrotactile Feedback (VTF) System to Actively Provide Corrective Forces on Patients with Adult Degenerative Scoliosis

Task 2.1:	Task 2.2:	Task 2.3:
Select sensors for posture training bodywear	Optimise the location of sensors and their reference points from surface electromyography (sEMG) signals.	Validate hardware and carry out pilot testing on entire VTF system

Milestone 3 - Overall Evaluation of Effectiveness of Posture Training Bodywear for Patients with Adult Degenerative Scoliosis

Task 3.1:	Task 3.2:	Task 3.3:
Subject Recruitment	Preliminary Tests	Clinical Trials

Research Methods, Prototypes & Materials

Gait and Balance Evaluation

Purpose: to evaluate the gait and balance of the ***ADS patients*** and compare with those of ***asymptomatic individuals***

Three aspects:

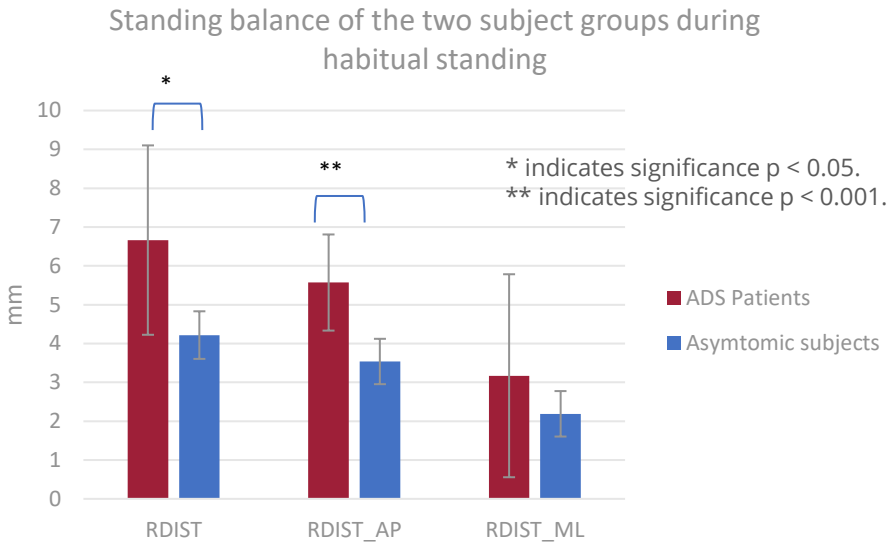
- **Ground reaction force** during standing and walking
- Three-dimensional **motion analysis** during standing, sitting and walking
- **Myoelectric activity** of the paraspinal muscles during standing and sitting

Demographic information of the ADS and asymptomatic subjects

		ADS subjects	Asymptomatic subjects	p-values
No. of subjects		10 (All females)	10 (All females)	
Age	Range	53 - 65	52 - 60	0.07
	Mean (S. D.)	60.67 (± 4.23)	56.0 (±2.83)	
Height (cm)	Range	147 - 164	153 - 159	0.52
	Mean (S. D.)	156.83 (± 5.98)	154.9 (± 2.36)	
Weight (kg)	Range	46.0 – 61.7	43.5 – 55.0	0.28
	Mean (S. D.)	54.78 (± 6.77)	50.7 (± 4.41)	
BMI	Range	18.13 - 25.38	18.22 – 22.35	0.44
	Mean (S. D.)	22.31 (± 2.86)	21.12 (± 1.66)	

Standing balance

- **Stand barefoot in a natural posture as still as possible and feet on adjacent force plates**
- **Heel-to-heel distance at 11% of their height and toe-out angle of 14°**
- **Eyes aimed at a point marked in the front at eye level**
- **Arms are relaxed at the side of the body**



Main Observations: ADS patients had **much poorer standing balance** in the anterior-posterior (AP) direction when compared to asymptomatic individuals.

Research Methods, Prototypes & Materials

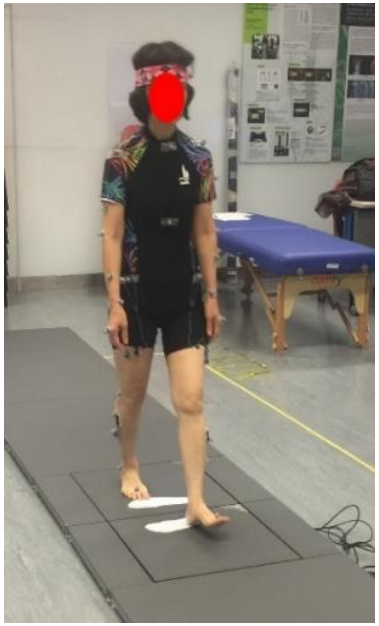
Gait and Balance Evaluation

Normal gait

- Perform normal walking in **barefoot** along a **5 m straight walkway** at **their self-selected pace**
- Eyes looking at a reference mark placed on the wall in the front at eye level
- Subjects were required to walk back and forth along the walkway for around 3-4 minutes until more than **10 clear strikes** on force plate were recorded for each foot

Gait variables	ADS Subjects Mean (S. D.)	Asymptomatic Subjects Mean (S. D.)	p-values
Walking Speed (m/s)	0.912 (± 0.088)	0.996 (± 0.176)	0.166
Cadence (steps/min)	102.661 (± 5.913)	110.176 (± 8.744)	0.092
Step Length (m)	0.532 (± 0.046)	0.541 (± 0.056)	0.328
Step Width (m)	0.143 (± 0.019)	0.137 (± 0.015)	0.195
Step Time (s)	0.584 (± 0.036)	0.545 (± 0.046)	0.113
Stride length (m)	1.067 (± 0.094)	1.080 (± 0113)	0.340
Stride Time (s)	1.173 (± 0.066)	1.095 (± 0.087)	0.093
Stance (% of a stride cycle)	62.148 (± 1.411)	60.194 (± 1.070)	0.003 *
Double Support Time (s)	0.288 (± 0.045)	0.225 (± 0.039)	0.008 *

* indicates statistical significance at $p < 0.05$.



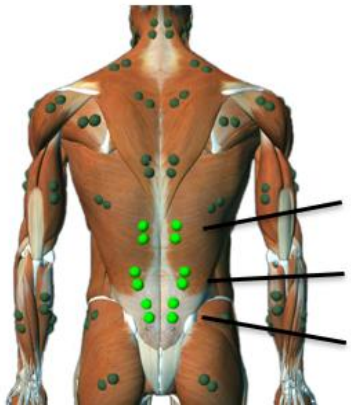
Normal gait

Main Observations: the percentage of the **stance phase in the stride cycle** and the **double support time** have significant difference between the two subject groups

Research Methods, Prototypes & Materials

Evaluation of Paraspinal Muscle Utilization

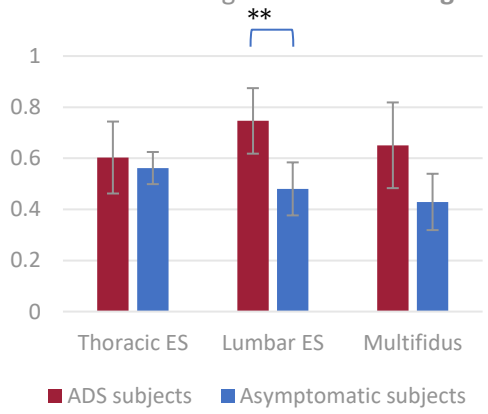
Purpose: to understand how the paraspinal muscles were utilized in ADS patients during natural standing and sitting



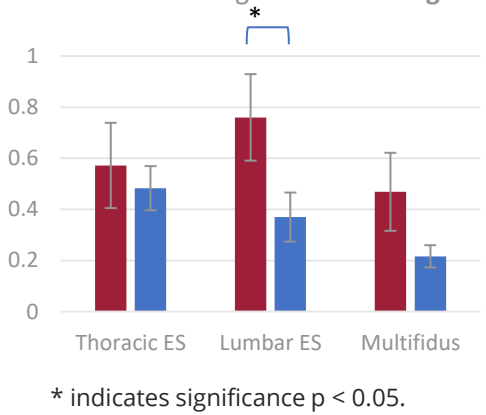
Surface electromyography (sEMG) sensors are used to record the muscle activities of three pairs of paraspinal muscles during trials of habitual sitting and standing

$$\text{Muscle Symmetry Ratio} = \left| \frac{\text{Muscle Activity}_{\text{Left}} - \text{Muscle Activity}_{\text{Right}}}{\frac{1}{2} \times \left(\text{Muscle Activity}_{\text{Left}} + \text{Muscle Activity}_{\text{Right}}\right)} \right|$$

Muscle Symmetry Ratio of the three pairs of para-spinal muscles during **habitual standing**



Muscle Asymmetry Ratio of the three pairs of para-spinal muscles during **habitual sitting**



* indicates significance $p < 0.05$.
** indicates significance $p < 0.005$

Main Observations:

1. The paired t-test comparison showed that the **muscle activity profiles** of the two subject groups **do not differ significantly** during habitual standing and sitting

2. ADS subject group had **significantly higher muscle asymmetry ratio** in in the **lumbar erector spinae** during both sitting and standing indicating more imbalanced between-side muscle activities were acquired.

Research Methods, Prototypes & Materials

Bodysuit for Passive Correction

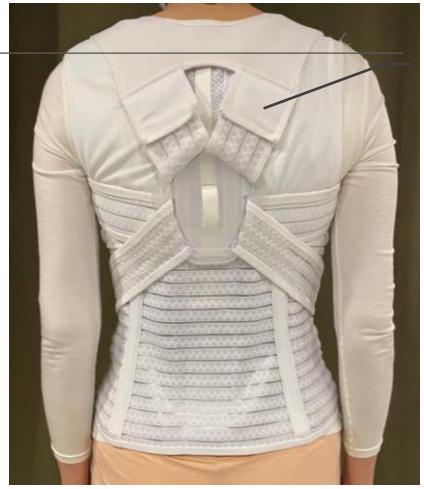
Inner layer

- Detachable supportive bones
- Tailor-made to fit user's spinal curves
- 3D printed with carbon reinforced nylon

- Open chest design for chest expansion in breathing
- Magnetic zipper for easy put on

Outer layer

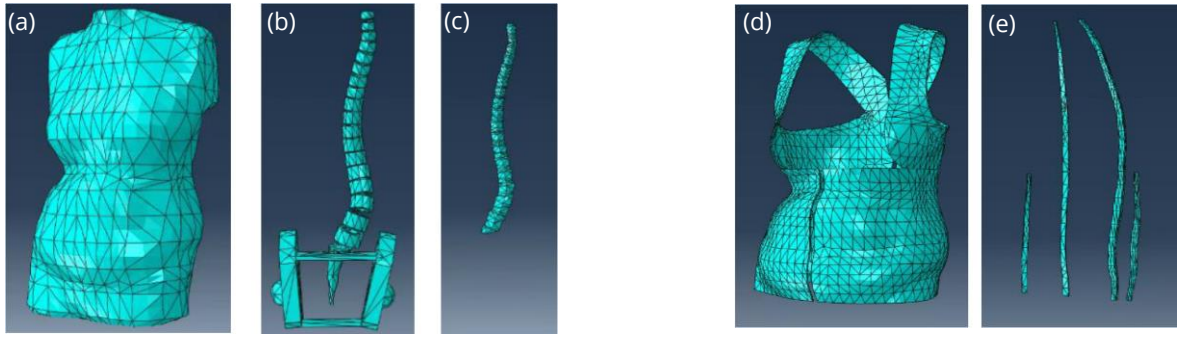
- Velcro fastening for easy put on
- Wide waistband to provide lumbar support



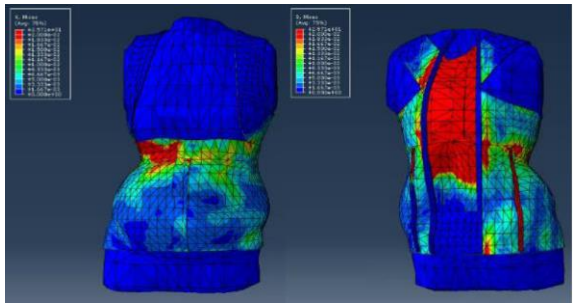
- Adjustable shoulder straps to widen chest and improve rounded shoulders

Research Methods, Prototypes & Materials

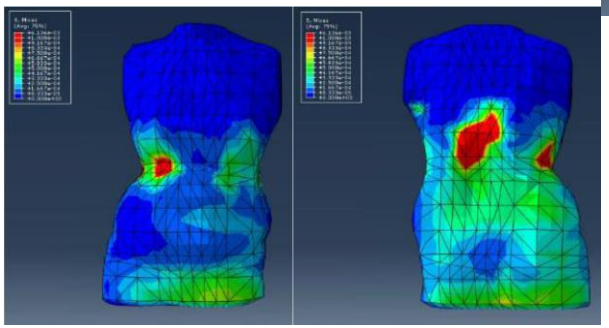
FE sub-models to evaluate the compressive stresses produced at the spine and the bodysuit

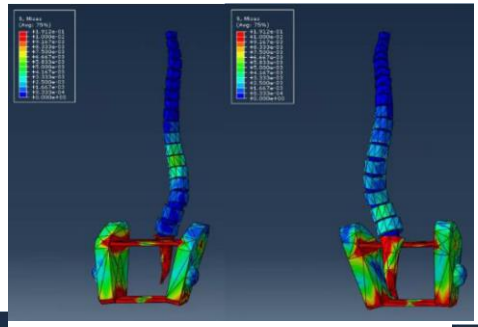


Meshed model of (a) scoliotic torso body, (b) skeletal structure, (c) intervertebral disc, (d) bodysuit, and (e) supportive bones

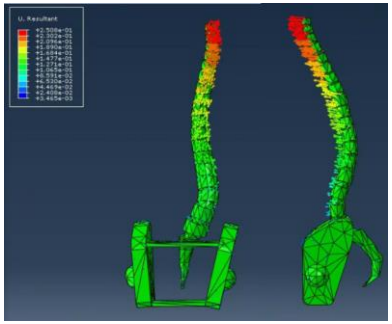


Stress distribution of the bodysuit (up) and torso (right)



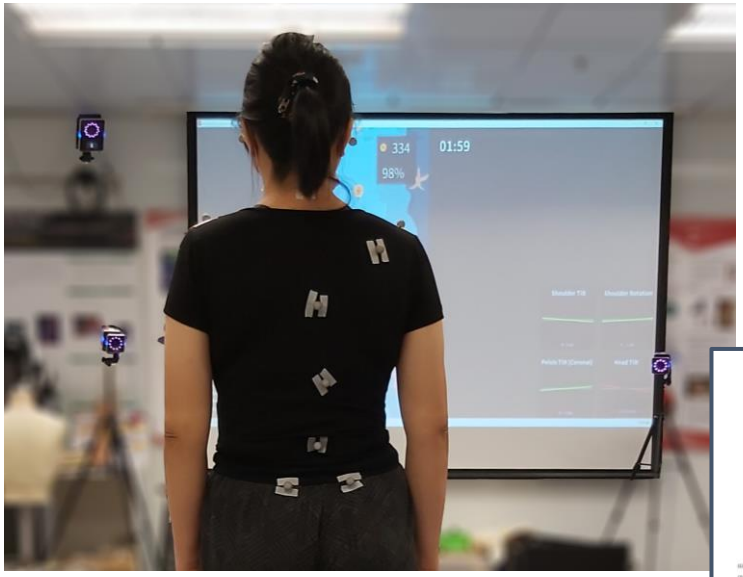


Stress distribution (left) and displacement (bottom) of the skeletal model

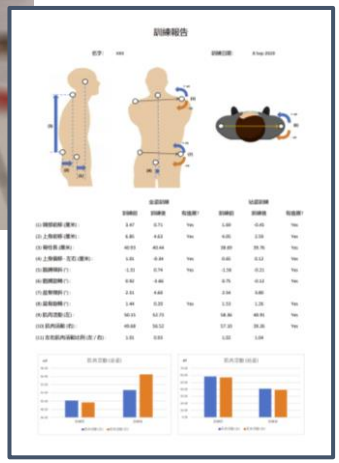


Research Methods, Prototypes & Materials

Active Game for Laboratory-based Postural Training



- **Positions of 11 body landmarks are measured by a 10-camera Vicon motion capture system**
- **11 postural features are monitored**
- **Game character's running speed and horizontal position is determined by the player's sagittal and coronal balance respectively.**
- **Player adjust postures to collect as many coins as possible**
- **Applicable to both standing and sitting postures**



Training report given to the participants after each training session

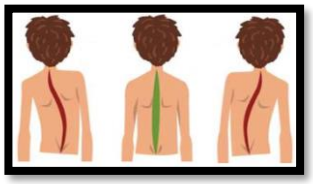
Coin counter - shows the number of coins collected.

Speed meter - shows current running speed, ranges from 0 – 100, is determined by player's sagittal balance.

Timer – to count down the 5 mins training.

Coins – come down from the centre of the path

Game character



Game character's horizontal position is controlled by player's coronal balance

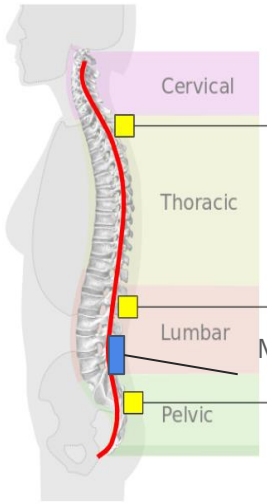
Research Methods, Prototypes & Materials

Vibrotactile feedback (VTF) system and *mobile application* for home-based postural training

Demonstration video of the active bodysuit

Vibrotactile Feedback (VTF) system with IMU sensors for postural monitoring

Detachable vibration motor on the collar bone to provide instant haptic feedback



Detachable strap

Research Methods, Prototypes & Materials

3-months Clinical Wear Trials

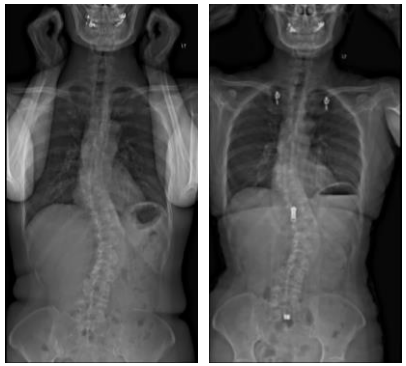
Location: The Hong Kong Polytechnic University

Number of subjects recruited: 10

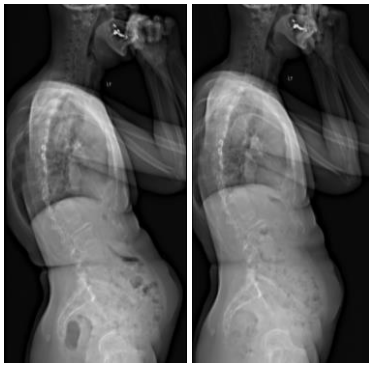
Inclusion criteria:

- **Aged between 50-70**
- **Diagnosed with degenerative scoliosis with Cobb angle > 10 °**
- **Have reported chronic (> 24 months) lower back pain**
- **have limited mobility due to degenerative scoliosis**

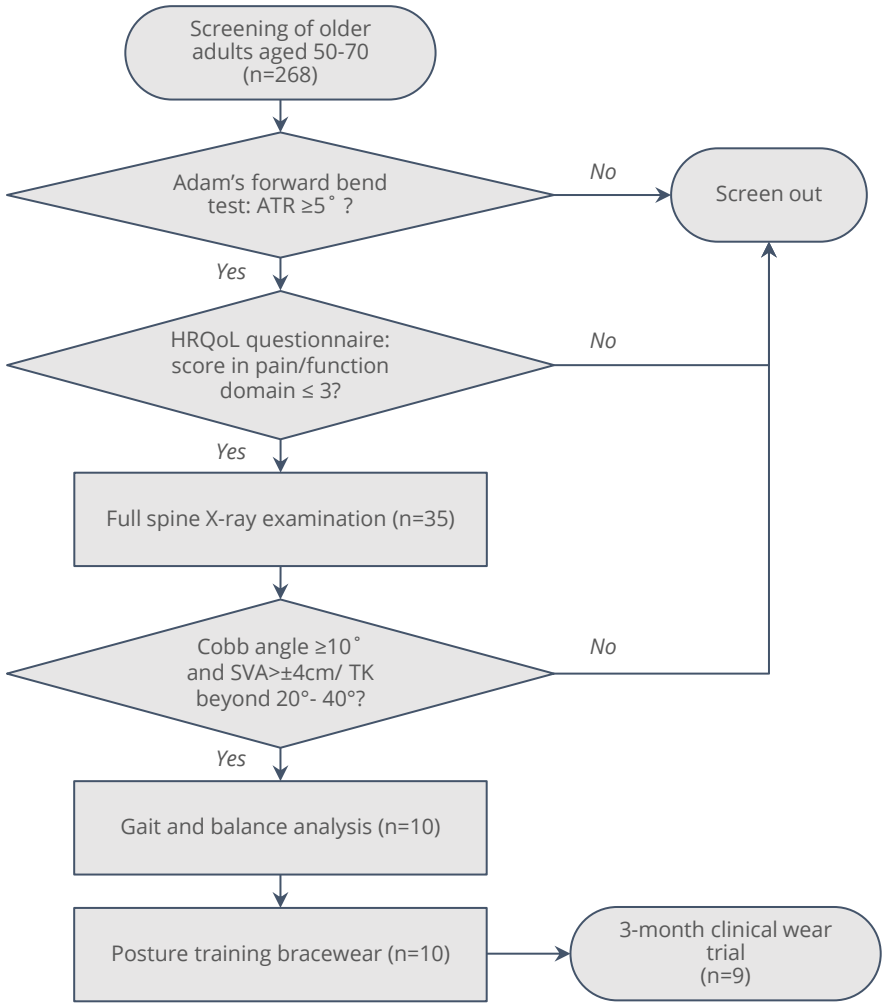
- **Pre- and post- intervention assessments:**
  - **Radiographic images (0-month, 3-month, 6-month)**
  - **Brace Questionnaire (BrQ)**
  - **Oswestry Low Back Pain Disability questionnaire (ODI)**
  - **Scoliosis Research Society-22 (SRS-22) questionnaire**
  - **Standing and sitting postures**



Pre Post



Pre Post



Research Outcomes, Findings & Further Research

Post-Intervention outcomes:

On pain management and health-related quality of life:

- Improvements were seen in all the 8 domains defined by the **Brace Questionnaire (BrQ),** with the highest percentage increase in vitality (+19.5%), followed by emotional functioning (+13.91%) and physical functioning (+11.09%).
- The mean **Oswestry Low Back Pain Disability questionnaire (ODI)** score has been reduced from 23.29% to 18.17%. One subject who was classified to had severe disability (56%) before the intervention had improved ODI score to moderate disability (34%).
- **As for Scoliosis Research Society-22 (SRS-22) questionnaire,** improvements were shown in all domains of the health-related quality of life, among which pain (+9.5%) and mental health (+7.2%) domains experienced the greatest improvement.

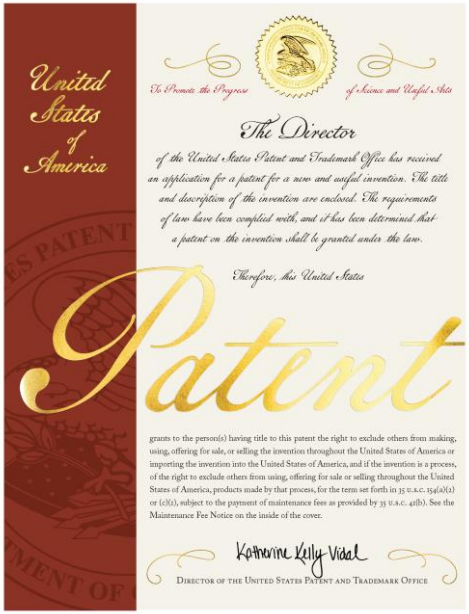
On sitting and standing postures:

- **Improved sagittal balance**
- **Smaller forward shifts were observed on the head and upper body**
- **More balanced between-side muscle utilization during sitting**

Research Dissemination

US Patent

Title: "Bracewear for spinal correction and system for posture training“
Patent No.: US-11931282-B2
Publication date: 19 Mar 2024.



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The Director

of the United States Patent and Trademark Office has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

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Patent

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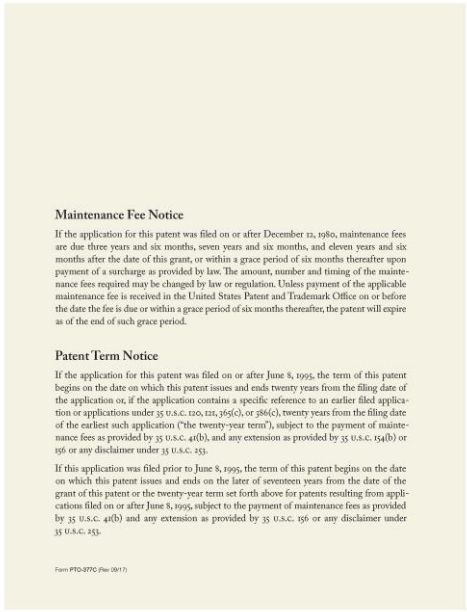

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If the application for this patent was filed on or after June 8, 1995, the term of this patent begins on the date on which this patent issues and ends twenty years from the filing date of the application or, if the application contains a specific reference to an earlier filed application or applications under 35 U.S.C. 120, 121, 365(c), or 386(c), twenty years from the filing date of the earliest such application ("the twenty-year term"), subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b), and any extension as provided by 35 U.S.C. 154(b) or 156 or any disclaimer under 35 U.S.C. 253.

If this application was filed prior to June 8, 1995, the term of this patent begins on the date on which this patent issues and ends on the later of seventeen years from the date of the grant of this patent or the twenty-year term set forth above for patents resulting from applications filed on or after June 8, 1995, subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b) and any extension as provided by 35 U.S.C. 156 or any disclaimer under 35 U.S.C. 253.

Form PTO-377C (Rev. 09/17)

(12) **United States Patent**
Yip et al.

(10) **Patent No.: US 11,931,282 B2**
(45) **Date of Patent: Mar. 19, 2024**

(54) **BRACEWEAR FOR SPINAL CORRECTION AND SYSTEM FOR POSTURE TRAINING**

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(73) Assignee: **The Hong Kong Polytechnic University**, Hong Kong (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 815 days.

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(22) Filed: **Oct. 15, 2020**

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A61F 5/02 (2006.01)
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CPC ***A61F 5/026*** (2013.01); ***A61B 5/4561*** (2013.01); ***A61B 5/486*** (2013.01); ***A61B 5/6805*** (2013.01); ***A61B 5/7405*** (2013.01); ***A61B 5/742*** (2013.01); ***A61B 5/7455*** (2013.01); ***A61F 5/024*** (2013.01); *A61B 2562/0219* (2013.01)

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CPC A61F 5/024; A61F 5/026; A61F 5/02–028; A61B 5/6805; A61B 5/1116; A61B 5/4561; A61B 5/486; A61B 5/7405; A61B 5/742; A61B 5/7455; A61B 2562/0219; A61B 5/6804; Y10S 2/913; A41D 1/04; A41D 1/00–22
USPC 602/19
See application file for complete search history.

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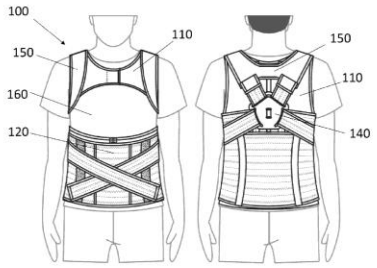
(Continued)

Primary Examiner — Rachael E Bredefeld
Assistant Examiner — Seth R. Brown
(74) *Attorney, Agent, or Firm* — Spruson & Ferguson (Hong Kong) Limited

(57) **ABSTRACT**

The present disclosure provides a bracewear for spinal correction and a system for posture training. The system for posture training involves both active and passive corrective forces by using the bracewear and a biofeedback system to address the spinal correction, which can eliminate the adversity of conventional hard braces and reduce the psychological and physiological barriers to treatment.

16 Claims, 12 Drawing Sheets



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Research Dissemination

Publications – Journal Articles

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Development of a motion-based video game for postural training: a feasibility study on older adults with adult degenerative scoliosis

Frances K. W. Wan, Alex T. H. Mak, Claire W. Y. Chung, and Joanne Y. W. Yip

Abstract— Forward sagittal alignment affects physical performance, is associated with pain and impacts the health-related quality of life of the elderly. Interventions that help seniors to improve sagittal balance are needed to inhibit the progression of pain and disability. A motion-sensing video game (active game) is developed in this study to monitor sitting and standing postures in real-time and facilitate the postural learning process by using optical sensors to measure body movement and a video game to provide visual feedback. Ten female subjects (mean age: 60.0 ± 5.2 years old; mean BMI: 21.4 ± 1.9) with adult degenerative scoliosis (mean major Cobb's angle: 38.1° ± 22.7°) participate in a 6-week postural training programme with three one-hour postural training sessions a week. Eleven body alignment measurements of their perceived "ideal" sitting and standing postures are obtained before and after each training session to evaluate the effectiveness of postural learning with the game. The participants learn to sit and stand with increased sagittal alignment with a raised chest and more retracted head position. The forward shift of their head and upper body is significantly reduced after each training session. Although this immediate effect only partially sustained after the 6-week program, the participants learned to adjust their shoulder and pelvis level for a better lateral alignment in standing. The proposed postural training system, which is presented as a gameplay with real-time visual feedback, can effectively help players to improve their postures. This pilot feasibility study explores the development and initial assessment of a motion-based video game designed for postural training in older adults with adult degenerative scoliosis, and demonstrates the usability and benefits of active gameplay in motor training.

Index Terms— Active games, adult degenerative scoliosis, body alignments, pain management, posture training

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I. INTRODUCTION

WITH the population ageing very quickly in most developed countries, health-care costs have been rising rapidly in parallel. Maintaining health-related quality of life (HRQOL) of the elderly population and extending their healthy life expectancy have become one of the most discussed issues in public health policies.

As demonstrated in medical research, sagittal imbalance, which generally refers to the forward displacement of the C7-S1 sagittal vertical axis (SVA), is correlated with physical function impairment [1, 2] and HRQOL [3] in the elderly population. This forward shift is found to be the greatest predictor of pain and disability in adults with spinal deformities [4]. As individuals age, they may lean forward progressively and develop kyphosis, a spinal degeneration due to the weakening of the spinal bones [5] and further worsen their health status. Therefore, educating seniors to actively self-manage their posture and maintain sagittal alignment habitually may increase their HRQOL as well as age in a healthy manner.

To improve postural alignment habitually, an individual must first develop postural awareness – the subjective and conscious awareness of body posture that is mainly based on proprioceptive feedback from the peripheries of the body to the central nervous system [6], and maintain a sense of "good" posture [7] which helps us to identify whether our posture is in good alignment, and hence, self-correct when necessary. Learning how to place the spine in "good" alignment, however, is not that easy and straight forward, but requires prolonged and frequent practice to internalize the perception of correct alignment and the corresponding muscle utilization pattern. Traditionally, healthcare practitioners would ask their patients to practice good sitting or standing postures in front of a mirror, or stand with their back against a wall. However, without objective measurements, the learning goal - "good" posture – is not well-defined. Moreover, like many rehabilitation exercises, the learning process could be very tedious.

To monitor the sitting and standing postures in real-time and facilitate postural learning, an active game is developed in this study, which uses optical sensors to measure body movement and a video game to provide visual feedback to the user. Motion sensing technologies have long been used in developing active games that facilitate motor training during rehabilitation [8, 9, 10, 11] and physical training for the elderly

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Wan, F. K. W., Mak, A. T. H., Chung, C. W. Y., & **Yip, J. Y. W.** (2024). Development of a motion-based video game for postural training: a feasibility study on older adults with adult degenerative scoliosis. *IEEE transactions on neural systems and rehabilitation engineering : a publication of the IEEE Engineering in Medicine and Biology Society*, https://doi.org/10.1109/TNSRE.2024.3398029

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Article

Adolescents' Experience during Brace Treatment for Scoliosis: A Qualitative Study

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Abstract: This study aimed to explore the subjective experiences of adolescents with scoliosis during brace treatment in order to understand their obstacles and make recommendations to enhance brace compliance. Using purposive sampling, 15 adolescents (2 males and 13 females) with scoliosis aged from 10 to 16 years old during brace treatment were recruited to participate in semi-structured in-depth interviews. The data were recorded, transcribed, and coded using thematic analysis with the qualitative software NVivo 10. Significant statements and phrases were organized into categories and themes to understand adolescents' experiences during brace treatment for scoliosis. In general, the adolescents acknowledged that compliance with brace treatment was essential to reduce or prevent the progression of spinal curvature and tried their best to comply with the treatment. Regarding their subjective experiences during brace treatment, three themes were identified and emerged as obstacles negatively affecting their brace compliance, including physical discomfort due to brace materials and design, reluctance caused by the brace's visual appearance, and passive patient participation during the treatment process. This study reveals insights into the experiences of adolescents with scoliosis during brace treatment and what they perceive as hindrances to compliance. In order to have better brace compliance, adolescents' feelings and difficulties during brace treatment should be recognized and addressed. Therefore, active patient participation throughout the treatment process, involving the co-design of a customized brace, psychosocial interventions, and personalized appearance style management should be considered and promoted to facilitate a more acceptable bracing experience to achieve better brace compliance.

Keywords: adolescent idiopathic scoliosis; brace treatment; subjective experiences

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Citation: Cheung, M.-C.; Law, D.; Yip, J.; Cheung, J.P.Y. Adolescents' Experience during Brace Treatment for Scoliosis: A Qualitative Study. Int. J. Environ. Res. Public Health 2022, 19, 10585. https://doi.org/10.3390/ijerph191710585

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1. Introduction

Adolescent idiopathic scoliosis (AIS) is characterized by curvature of the spine and asymmetry in the shoulders and hips. The basic management of AIS consists of surgical treatment, orthotic spinal bracing, or clinical monitoring [1]. Since severe spinal deformities can considerably reduce pulmonary and cardiac functions, surgical treatment is generally recommended when the Cobb angle of the spine is greater than 45–50° [2]. The Cobb angle is the gold standard to assess the severity of the spinal deformity and is measured by the angle between the two most-tilted spinal vertebrae in the spinal curve. Non-surgical treatment, such as immobilization with a spinal brace, remains the most effective treatment modality to prevent the progression of spinal curvature for adolescents with a Cobb angle between 20° and 40° [3]. However, to effectively control the progression of spinal curvature, the brace should be worn for up to 23 h a day until the adolescent stops growing, which means that the treatment may last for 4–6 years [4].

Int. J. Environ. Res. Public Health 2022, 19, 10585. https://doi.org/10.3390/ijerph191710585 https://www.mdpi.com/journal/ijerph

Cheung, M. C., Law, D., **Yip, J.**, & Cheung, J. P. Y. (2022). Adolescents' experience during brace treatment for scoliosis: A qualitative study. *International Journal of Environmental Research and Public Health*, *19*(17), 10585. https://doi.org/10.3390/ijerph191710585

[Article]

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Chung, W. Y. C., **Yip, J.**, Yick, K. L., & Ng, S. P. (2022). Affective association with and preference for flexible brace colors in older adults with spinal deformities. *Color Research and Application*, 47(1), 194–203. https://doi.org/10.1002/col.22706

Research Dissemination

Publications – Conference Articles

A NEW CONCEPT FOR ADULT DEGENERATIVE SCOLIOSIS: POSTURE TRAINING BRACEWEAR

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Abstract - Guided by a design framework, a Posture Training Bracewear has been developed for degenerative scoliosis patients as a noninvasive method that focuses on strengthening the core of the body, training posture, reducing lower back pain, addressing the needs of older adults and considering their physiological concerns. Based on clinical applications, materials science, garment design, and wearable technologies, active and passive corrective forces are used to improve the body alignment of older adults with degenerative scoliosis. Thus, they benefit by maintaining their current level of physical function while minimizing their symptom progression.

Keywords - Degenerative Scoliosis, Flexible Brace, Smart Garment, Posture Training Bracewear.

I. INTRODUCTION

Adult degenerative scoliosis (ADS) is a spinal deformity in the ageing population caused by degenerative changes. ADS patients have a Cobb angle of 10 degrees or largerin the coronal plane [1]. Increased concerns about the health effects of ADS have been raised due to its increasing prevalence, which ranges from 6% to 68% of the population after the age of 40.Aside from an asymmetricaltrunk and imbalance in thesagittal plane, progressive pain in the lower back and symptomatic lumbar stenosis arealso symptoms [2], [3]. However, pain is the most frequently cited problem, especially lower back pain and radicular pain, which severely affect the daily activities and health of ADS patients. Due the deterioration of the overallhealth and bone quality of older adults compared to younger adults, ADS patients face greater risks if they undergo surgery as a form of treatment for ADS. Thus, bracing is the most typical non-invasive treatment recommended to them so that they not only receive better support of their spine but also the load is taken off the spinal column [4].

II. DESIGN LIMITATIONS IN CURRENT BRACING FOR ADS

Bracing is recommended for patients with ADS in order to avoid the progression of their spinal curvature. Bracing also provides support to the spine and pressure is taken off the spinal column [4]. There are specific types of spinal orthoses designed for ADS patients, which are either rigid or flexible braces based on the fabrication materials [5].The treatment that uses a rigid brace however has resulted inlow patient compliance which has thus been less effective in preventing the progression of the spinal deformity because it is bulky and uncomfortable to wear [6]. ADS patients experience the deconditioning syndrome of their spinal muscles which might be due to excessive reliance on passive corrective forces offered by rigid braces. Consequently, soft braces that are fabricated with textile materials have beendeveloped to provide another option for these patients.A higher level of perceived comfort while wearing the brace is possible with the useof soft materials. However, related studies have revealed that flexible braces can only help totemporarily relieve pain and there are doubtsofits efficacy in preventing the progression of the spinal curvature [7], [8]. Other issues like muscle atrophy, pressure marks, skin irritation, breathing issues and inconvenience topatients bylimiting their mobility are also concerns of treatment that prescribe braces [1], [9].

III. DESIGN FRAMEWORK OF POSTURE TRAINING BRACEWEAR

In order to enhance quality of life with medical orthoses, their technical, functional and performance requirements need to be addressed in the design stage of the garment[10]. Design frameworks and models have been recommended in the literature to organize the information and ideas during the design and development processes. Actual needs and problems have been identified to meet the requirements and expectations of the end-users. The concept of co-designing has also been proposed to incorporate the input of both brace designers and users in order to ensure that the final product meets both user needs and clinical standards [11].
The design theory forthe current market stipulates that consumer expectations should bealso taken into consideration during the process of developing a brace or in this study, the Posture Training Bracewear. After reviewing the existing brace designs, the negative results and physical problems can besummarized as follows:(1) there is only passive treatment for ADS patients, (2) there are a lack of studies on the effectiveness of flexible braces, and (3) deconditioning is experienced due to the degeneration of the paraspinal muscles. As a result, aprocess has been

Proceedings of ISERD International Conference, Zurich, Switzerland, 16th – 17th February, 2020
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Sit, Y. L., **Yip, Y.W.**, Kenny, Kwan, (2020). A New Concept for Adult Degenerative Scoliosis: Posture Training Bracewear. In *Proceedings of ISERD International Conference*, Zurich, Switzerland (pp. 5-7). Available online at: https://www.worldresearchlibrary.org/up_proc/pdf/3717-15923689665-7.pdf

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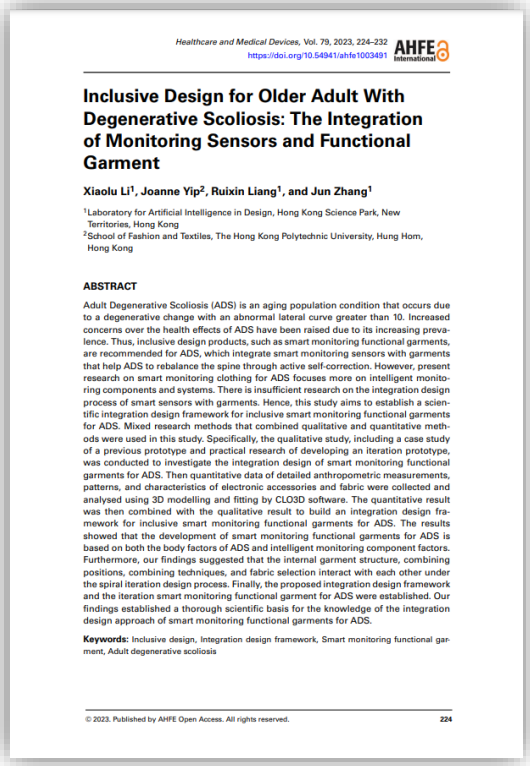
Sit, Y. L., **Yip, Y.W**., Kenny, Kwan, (2021). Preliminary Wear Trial of Posture Training Bracewear For Older Adults With Degenerative Scoliosis (ADS). In *Advances in Human Factors and Ergonomics in Healthcare and Medical Devices (AHFE 2021)* (Vol. 263, pp. 81–87). Springer International Publishing AG. https://doi.org/10.1007/978-3-030-80744-3_11



Healthcare and Medical Devices, Vol. 79, 2023, 224–232
https://doi.org/10.54941/ahfe1003491

Inclusive Design for Older Adult With Degenerative Scoliosis: The Integration of Monitoring Sensors and Functional Garment

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[2]School of Fashion and Textiles, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

ABSTRACT

Adult Degenerative Scoliosis (ADS) is an aging population condition that occurs due to a degenerative change with an abnormal lateral curve greater than 10. Increased concerns over the health effects of ADS have been raised due to its increasing prevalence. Thus, inclusive design products, such as smart monitoring functional garments, are recommended for ADS, which integrate smart monitoring sensors with garments that help ADS to rebalance the spine through active self-correction. However, present research on smart monitoring clothing for ADS focuses more on intelligent monitoring components and systems. There is insufficient research on the integration design process of smart sensors with garments. Hence, this study aims to establish a scientific integration design framework for inclusive smart monitoring functional garments for ADS. Mixed research methods that combined qualitative and quantitative methods were used in this study. Specifically, the qualitative study, including a case study of a previous prototype and practical research of developing an iteration prototype, was conducted to investigate the integration design of smart monitoring functional garments for ADS. Then quantitative data of detailed anthropometric measurements, patterns, and characteristics of electronic accessories and fabric were collected and analysed using 3D modelling and fitting by CLO3D software. The quantitative result was then combined with the qualitative result to build an integration design framework for inclusive smart monitoring functional garments for ADS. The results showed that the development of smart monitoring functional garments for ADS is based on both the body factors of ADS and intelligent monitoring component factors. Furthermore, our findings suggested that the internal garment structure, combining positions, combining techniques, and fabric selection interact with each other under the spiral iteration design process. Finally, the proposed integration design framework and the iteration smart monitoring functional garment for ADS were established. Our findings established a thorough scientific basis for the knowledge of the integration design approach of smart monitoring functional garments for ADS.

Keywords: Inclusive design, Integration design framework, Smart monitoring functional garment, Adult degenerative scoliosis

Li, X., **Yip, J**., Liang, R., Zhang, J. (2023). Inclusive design for older adult with degenerative scoliosis: The integration of monitoring sensors and functional garment. In: Jay Kalra and Nancy Lightner (eds) Healthcare and Medical Devices. AHFE (2023) International Conference. AHFE Open Access, vol 79. AHFE International, USA. http://doi.org/10.54941/ahfe1003491

Research Dissemination

Exhibitions

The research team members were introducing our invention at the Expo.

Professor Dong SUN, the Secretary for Innovation, Technology and Industry of HKSAR, visited our booth at the Expo.

Research Dissemination

Public Lectures

Technology for Aging Population

30 October 2024

Asia Pacific Institute of Healthy Aging, Shop A, 1/F, Hong Kong Pacific Center.

More information available at https://www.mtl-sft.com/news/prof-joanne-yip-delivered-insightful-talk-on-functional-clothing-for-adult-degenerative-scoliosis/

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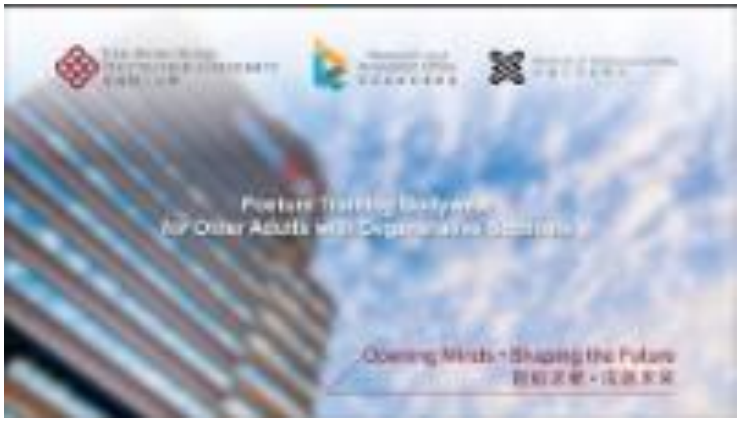

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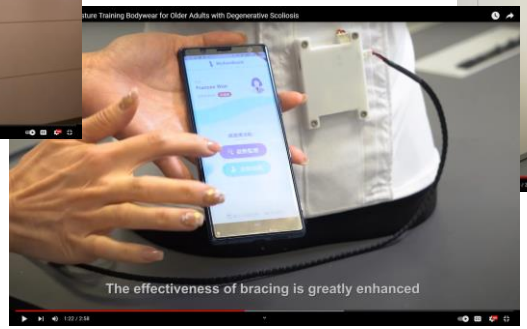

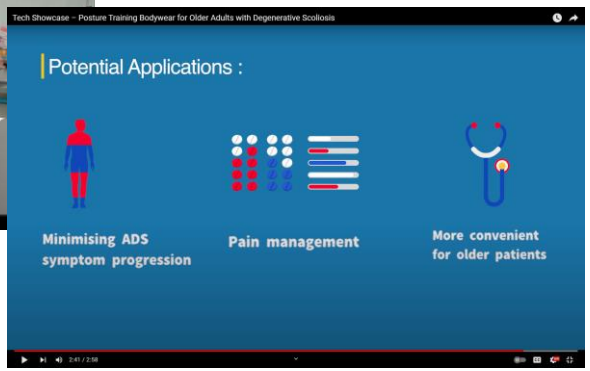

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