University of Southampton

WSA E-TEXTILE INNOVATION LAB

CO-DESIGN OF WEARABLE E-TEXTILE DEVICES for healthcare applications

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AGENDA

1. About the WSA E-Textile Innovation Lab
2. What is co-design?
3. Why is co-design important?
4. Co-design case studies:
    i) Fetal monitoring
    ii) Stroke rehabilitation
    iii) Osteoarthritis knee pain
5. Challenges and key takeaways

Hello

WSA
E-TEXTILE
INNOVATION LAB

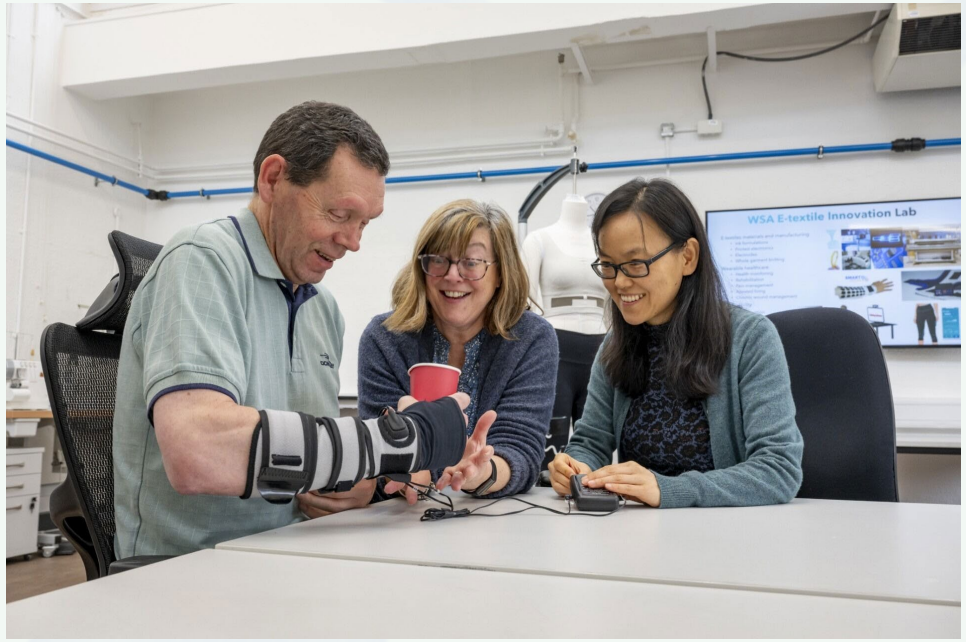
EST 2022

RESEARCH FOCUS

WSA
E-TEXTILE
INNOVATION LAB

1. E-TEXTILES FOR HEALTH + WELLBEING

- Health monitoring
- Wearable therapeutics
- User-centred design approach



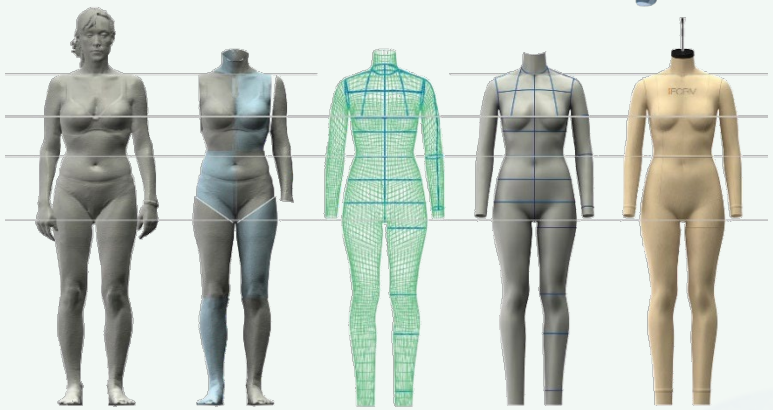
2. SUSTAINABLE MATERIALS + MANUFACTURING

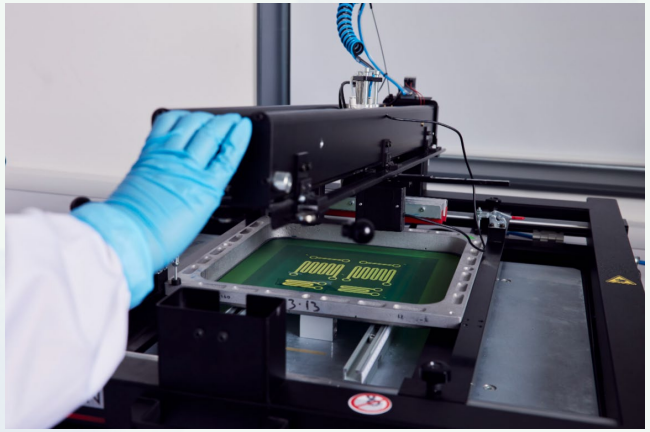
- Novel inks
- Sustainable textile materials
- Additive manufacturing
- Scalable manufacturing

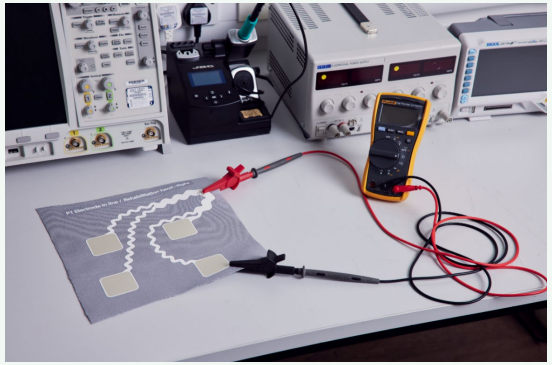
3. ENTERPRISE ACTIVITIES + COMMERCIALISATION

- Partnerships with HEIs, industry, healthcare providers + third sector

EQUIPMENT + MANUFACTURING





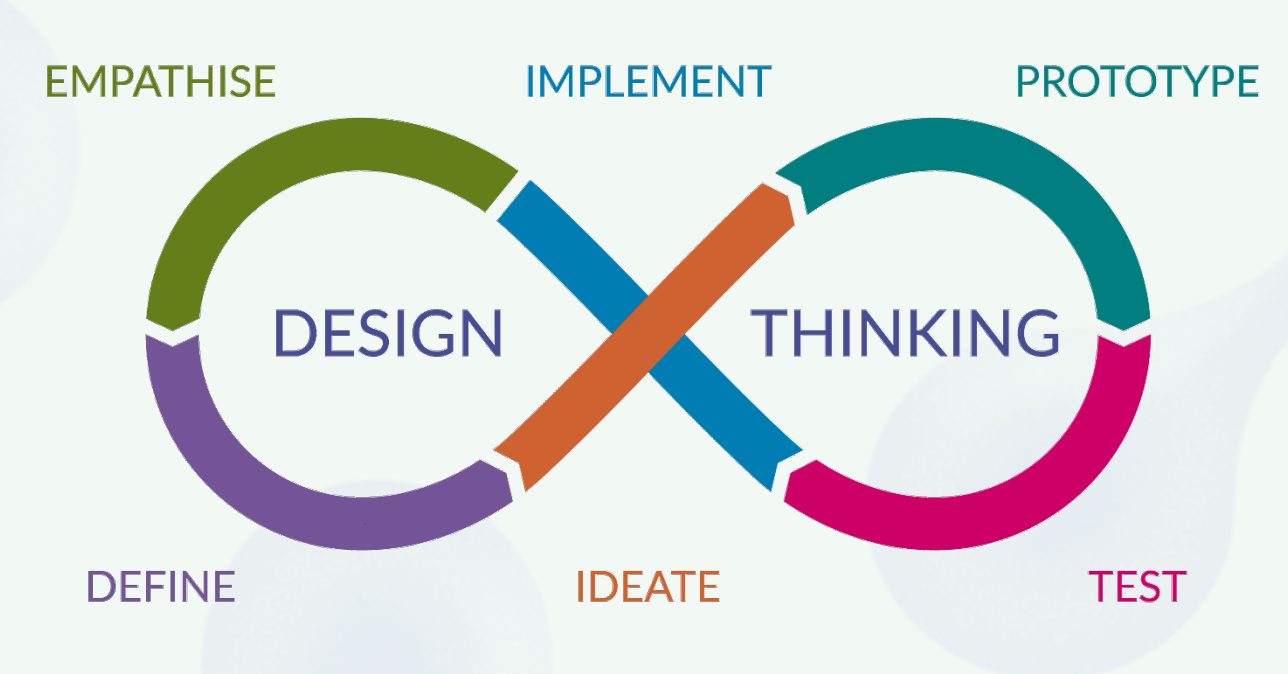


MULTI-DISCIPLINARY

WHAT IS CO-DESIGN?

Co-design is a **collaborative design approach** that involves end users and other stakeholders as **active partners** in the design process.

It ensures that products and systems are shaped by the **needs, experiences, and values** of the people who will use them.



KEY FEATURES OF CO-DESIGN

Active involvement

•Users as collaborators, not just consulted.

Iterative process

•Meaningful engagement at every stage of iterative design process

Collaboration

•Diverse group of stakeholders (patients/designers/clinicians/engineers) working together

•Aims to balance power between professionals and participants - facilitation

Context

•Designs reflect real-life user needs and environments – lived experience directly shapes design outcomes

Mutual learning and empowerment

•Empathy, understanding, insight

•Gives users influence in shaping solutions that affect them

WHY IS IT IMPORTANT?

More creative, innovative & inclusive design

- Diverse perspectives lead to unexpected ideas
- Reduces bias and supports equity in design

Improves usability and safety

- Human factors - reducing the risk of use errors

Adoption and compliance

- Solutions meet real user needs and suitable for real-life environments

Reduces development risks and costs

- Early feedback helps identify design flaws (complaints, product recalls)

Funding and regulatory approval

- Increasingly expect user involvement; co-design demonstrates a robust, user-centred process aligned with UKRI, MHRA, FDA, and NIHR expectations.

CO-DESIGN AT WSA E-TEXTILE LAB

We work ***with* users** by involving patients, carers/family, clinicians, and other stakeholders throughout the design process, to ensure our e-textile solutions are:

- Comfortable, usable, and accessible
- Aligned with real-world needs and contexts

Methods:

- Public and Patient Involvement and Engagement (PPIE)
- Interviews and focus groups
- Usability testing (lab and home settings)
- Iterative prototyping
- Surveys/questionnaires
- Diary studies

FETAL MONITORING

Project overview

•**Objective**: Develop a wearable, comfortable, and accurate fetal heart monitoring garment for home and clinical use.

• **Problem**: 10-30% of pregnancies classed as high or moderate risk. Existing devices are bulky, rigid, and/or not user friendly

• **Users**: Pregnant women, women with experience of being pregnant and HCPs

• **Co-design need**: Understand unmet need and improve usability, acceptability and functionality

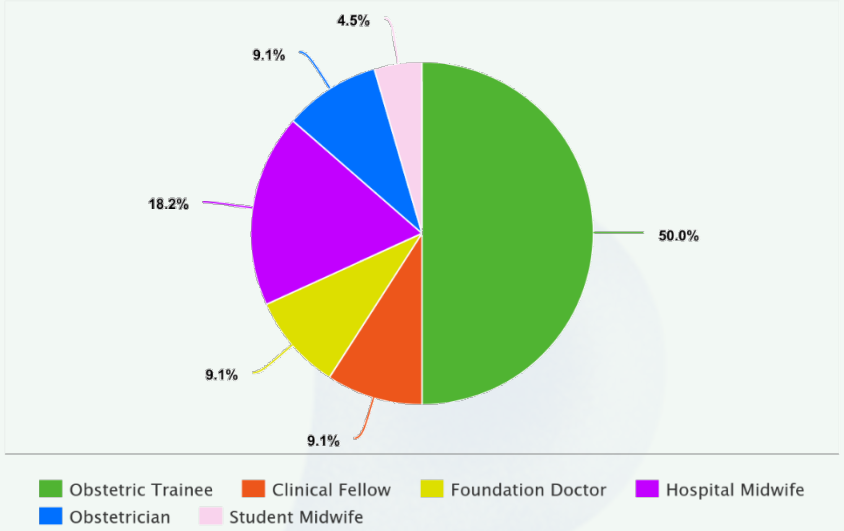
NHS
University Hospital Southampton
NHS Foundation Trust

University of Southampton
School of Electronics and Computer Science

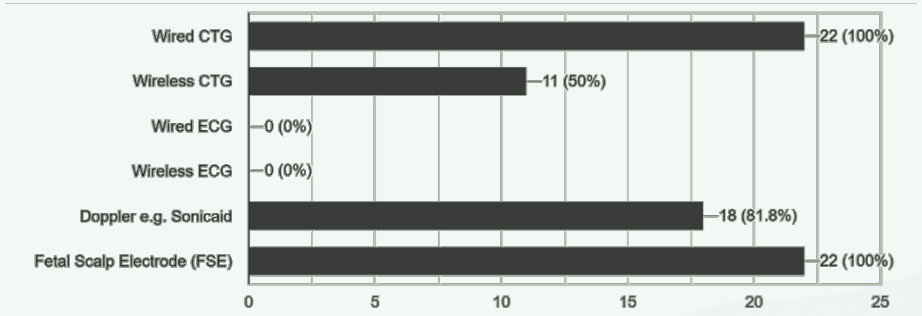
University of Southampton
School of Physics and Astronomy

FETAL MONITORING

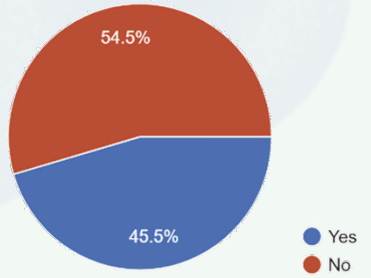
Co-design activities – Healthcare Professional (HCP) survey



What do you use for fetal monitoring currently? (You can indicate more than one option)



Are you satisfied with the fetal monitoring equipment you use currently?



FETAL MONITORING

Co-design activities – PPIE workshop

Help shape future study design, refine research questions

4 women engaged, aged 28-43

Activities:
•Discussion on existing devices and experiences
•Unmet needs
•Intro to e-textiles
•Hands-on interaction with the prototype.
•Unstructured group discussion (with prompts: comfort, usability, fit, aesthetics).
•Online survey with Likert scales for quantified feedback (comfort, aesthetics, usability) as well as open-ended questions

FETAL MONITORING

Results of HCP survey and PPIE session

Shared priorities

- Wireless, wearable, and discreet
- Improved comfort and mobility
- Reliable fetal heart rate detection
- Safe, non-invasive
- Easy to use

End users emphasised

- Anxiety from over-monitoring and need for professional reassurance
- Prototype rated low for comfort and aesthetics
- Preference for breathable, non-bulky materials
- Compatibility with stretch mark creams/oils
- Washability
- Concerns over battery safety
- Emergency removal and inclusive/adjustable sizing

HCPs emphasised

- Accuracy/reliability – early term, BMI,
- Concerns over signal loss, usability
- Linking to wifi/online platforms
- Lack of standardisation across NHS trusts – use error/use dependent
- Interest in waterproofing
- AI-based feedback

Insights only possible through co-design

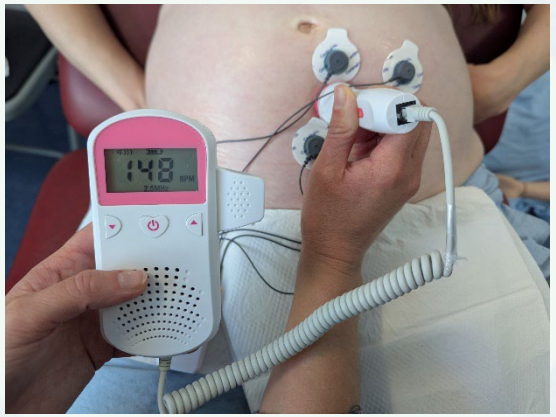
FETAL MONITORING

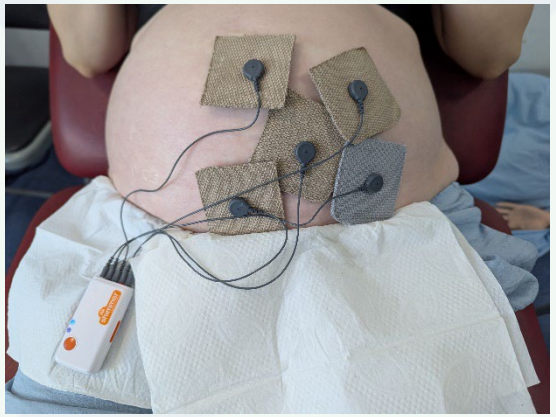
Co-design activities – end user testing

Ongoing – recruiting pregnant participants **(≥24 weeks)**

- **Session 1:**
  - Interview on experiences with fetal monitoring, unmet needs
  - Prototype try-on and feedback via Likert scales (comfort, aesthetics, user experience). Suggestions for fabric, fastenings and overall design.

- **Sessions 2–3:**
  - Measure maternal and fetal heart rate using clinical-grade equipment (benchmark) and commercial electrodes
  - Compare with readings from our knitted and printed e-textile electrodes
  - Assess accuracy and reliability





STROKE REHABILITATION

Project overview

Objective: Develop a sustainable e-textile garment with embedded functional electrical stimulation (FES) for post-stroke shoulder rehabilitation

Problem:

- 100,000 strokes per year / 1.4 million stroke survivors (UK)
- Societal cost = £26 billion per year, including £8.6 billion for NHS and social care
- Upper limb – loss of use; shoulder subluxation
- FES is recommended, but existing products are underused due to their **complexity** and **poor usability**, resulting in poor patient outcomes

Users: 12 people with stroke (PWS), 15 healthcare professionals (HCP)

UKRI Engineering and Physical Sciences Research Council

UWE Bristol University of the West of England

Bristol after stroke

Different Strokes

STROKE REHABILITATION – SHOULDER

Co-design activities

Advisory panel

- Helped shape the research question and design approach

Clinician interviews

- 15 Physios shared experiences with FES and unmet needs; provided feedback on early design concepts

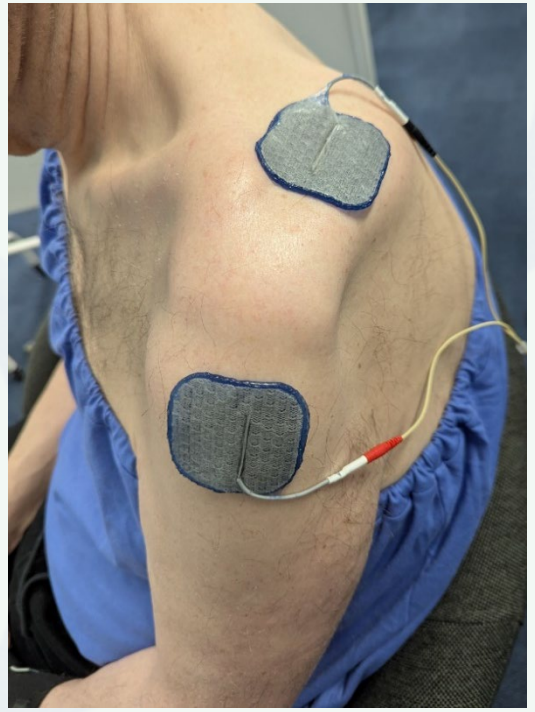
Stroke survivor focus groups

- Explored experiences with stroke, rehab, and FES; gathered user needs and expectations
- Prototype Iteration 1 - Presented to stroke survivors for feedback on comfort, usability, and function

Prototype iteration 2 + one-to-one lab testing

- Compared e-textile electrodes with commercial ones; assessed garment fit, fabric, comfort, and electrode placement/muscle activation
- Interview and Likert-scale questionnaires (usability, comfort, aesthetics), and timed donning/doffing for usability

Upcoming - workshops with clinicians and stroke survivors



STROKE REHABILITATION – SHOULDER

Results of HCP interviews

HCP interviews

- Stroke has a devastating impact on survivors, families, and healthcare systems
- Current care often falls short of **recommended rehabilitation standards**
- Challenges especially in **rural areas and people who live alone**
- FES viewed positively by those with experience - patients show improvements
- Barriers: **lack of training, funding, staffing and time**
- Home use hindered by **complex setup** and **need for clinician support**
- Garment feedback: reduce bulk, improve breathability, make electrodes adjustable; Velcro and one-handed donning appreciated
- Important to include **patient education** (demos, videos, clear instructions)
- Use anatomical landmarks to guide correct garment positioning and adjustments

STROKE REHABILITATION – SHOULDER

Results of interviews + workshops with PWS

Focus group insights

- **Mixed FES experience** - lower limb rehabilitation prioritized post-stroke
- **Common issues**: painful shoulder, limited mobility/strength, fatigue, cognitive problems
- **Home FES challenges**: disposable electrode positioning, ongoing costs, complexity

Prototype testing results

Usability & comfort:

- **Easy donning/doffing** - 51.6s average donning, 19s doffing time
- **Comfort rating**- 90% found garment comfortable
- **Independence use** - 80% felt confident using independently with one hand

Design deedback:

- **Physical support lacking** - bulky fabric didn't provide expected shoulder stabilisation
- **Aesthetics secondary** - 70% said appearance unimportant, functionality was priority

Electrode Performance

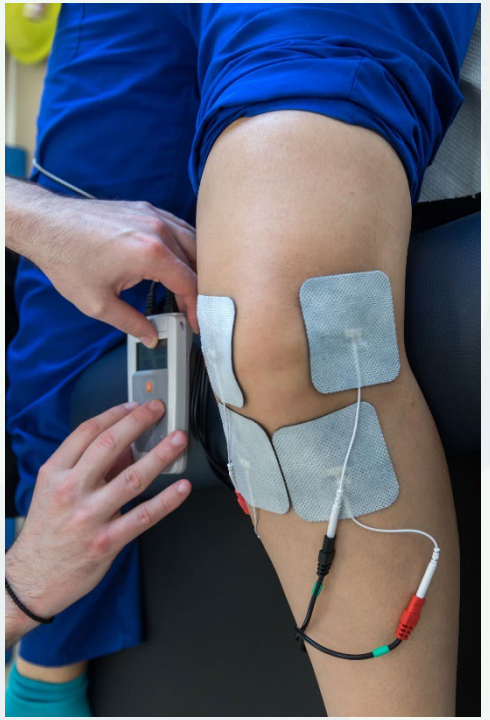
- **Stimulation levels** - dry electrodes matched commercial gel electrode performance
- **Positioning** - effective muscle activation achieved
- **Refinement needed** – Improve fit for consistent electrode-skin contact

KNEE PAIN MANAGEMENT

Objective: develop an e-textile garment with embedded TENS electrodes for osteoarthritis pain management

Problem: Knee osteoarthritis
- 5 million people in UK
- Main cause of 98% of knee replacements
- Costs the NHS around £800 million p.a.
- Impact – loss of productivity/quality of life

Users: Healthcare professionals and people experiencing knee osteoarthritis pain

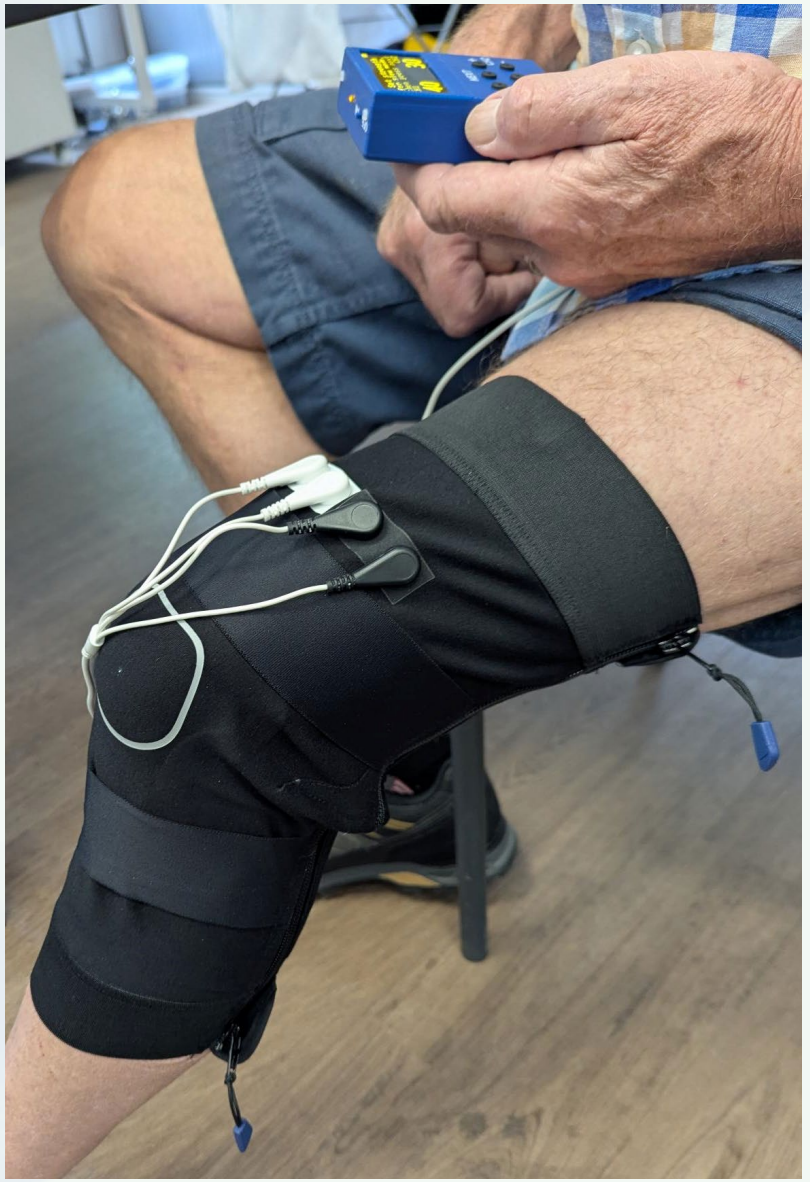


Medical Research Council

KNEE PAIN MANAGEMENT

Co-design activities

- **Interviews with HCPs** to understand their needs/views
- **Focus groups with end users** – to understand unmet needs in knee pain management and experiences with digital technology
- **Lab-based testing sessions** – basic safety, efficacy (VAS scale), usability, comfort, fit, aesthetics
- **Home usability test** – testing efficacy, usability and durability in a real-world environment. Instructions for use (IFU)
- **Pain/QoL scales, diary studies**



KNEE PAIN MANAGEMENT

Clinical validation

- Clinical trial – Pilot RCT trial to gauge clinical effectiveness and gain feedback on usability and user experience.
- 80 participants, 12 weeks
- Questionnaires at 1, 4, 8 and 12 weeks
- Closing interview for feedback
- Durability inspection/testing

MHRA
Regulating Medicines and Medical Devices

CO-DESIGN CHALLENGES

Time & resource intensive

- Longer development cycles
- Higher upfront costs
- Coordination complexity

User feedback challenges

- Conflicting requirements - Feature/scope creep
- Vocal minority bias
- Limited technical understanding

Methodological difficulties

- Recruitment barriers
- Sample size limitations
- Facilitator bias
- Translation gaps

KEY TAKEAWAYS

- Co-design has improved the **usability, functionality and user experience** of our projects – we've achieved results that would not have been possible without co-design
- Embed at **every stage of design thinking process** for maximum benefit
- However, requires **time, resources and funding** upfront to execute effectively
- Not always able to **act on user feedback** (e.g. not economical/feasible) and feedback can be challenging to interpret
- Overall positive cost-benefit

University of Southampton

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Thank you

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