**‘Can Cancer be Detected Earlier by Employing Wearable Technologies?’**

Workshop jointly organised by the [Precision Health Initiative](#) and the [Early Cancer Institute](#)

**Date:** Friday 20th October 2023, 9.00 – 16.00  
**Venue:** [Crausaz Wordsworth Building](#), Robinson College, Adams Rd, Cambridge, CB3 9AD

### AGENDA:

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Chaired by [Wendy Alderton](#):

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<td><a href="#">Rebecca Fitzgerald</a>: Welcome and Introduction</td>
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<td><a href="#">Cecilia Mascolo</a>: Opportunities and challenges of wearable health technologies</td>
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<td><a href="#">Kirsten Rennie</a>: Wearables and cancer in population-based studies: what do we know?</td>
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<td><a href="#">Veronica Martinez-Hernandez</a>: ML/AI for the identification of patterns of fatigue for earlier detection of myeloma</td>
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<td><a href="#">Suzanne Scott</a>: Symptoms, help-seeking and the use of wearables: considerations from behavioural science</td>
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<td><a href="#">Joss Langford</a> (<a href="#">Activinsights</a>): Real-world digital biomarkers from wearables</td>
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Chaired by [Caroline Watson](#):

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<td>Lightning Talk 2: <a href="#">Marco Vinicio Alban-Paccha</a> (University of Cambridge)</td>
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<td>13.45 – 14.30</td>
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Themed roundtable discussions

1. Incorporating wearables into early detection of cancer cohort studies/trials: what do we need to measure and why?  
   *facilitated by Kirsten Rennie, Caroline Watson and Irena Rao*

2. Challenges/opportunities of scale-up with linkages to other national health/administrative data. What are the immediate actions to build the link?  
   *facilitated by Antonis Antoniou, Talisia Quallo and Wendy Alderton*

3. Emerging technologies for and beyond wearables  
   *facilitated by Valerie Sills and Nan Li*

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<td><strong>Conclusion</strong></td>
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Rebecca Fitzgerald
Rebecca Fitzgerald is Director of the Early Cancer Institute and Professor of Cancer Prevention at the University of Cambridge. She practices medicine as Hon Consultant in Gastroenterology at Cambridge University Hospitals Trust. Her research group investigates malignant transformation in the oesophagus and stomach to inform the development of novel early detection technologies such as the Cytosponge™.

Andrew Flewitt
Andrew Flewitt is the Head of the Electrical Engineering Division, Dept of Engineering, and the academic lead of the Precision Health Initiative at the University of Cambridge. His research interests span a broad range of large-area electronics and related fields, including thin film transistors and MEMS devices. His research focuses on acoustic wave devices using thin film piezoelectrics, such as surface acoustic wave and film bulk acoustic resonator devices.

Cecilia Mascolo
Cecilia Mascolo is Professor of Mobile Systems in the Department of Computer Science and Technology and heads the Mobile Systems Research Laboratory. She is also Director for the Centre for Mobile, Wearable Systems and Augmented Intelligence. Her interests are in the study of mobile systems, the learning from their data offline and on the device and their applications, especially in terms of mobile health.

Opportunities and challenges of mobile and wearable health
Wearable devices have become pervasive and offer unprecedented opportunities for sensing human behaviour and health continuously and affordably, offering data at an unprecedented granular scale. However, their use comes with some challenges. In this talk I will introduce the value of wearable longitudinal data analysis by also discussing some examples of our projects, especially for disease progression and identification of behaviour changes. I will also talk about some of the challenges related to privacy, collection of data in free living and from heterogeneous devices, machine learning algorithms over this data and the use of closed source systems and algorithms.

Kirsten Rennie
Kirsten Rennie is a Senior Research Associate in the MRC Epidemiology Unit, University of Cambridge. Her research focuses on the incorporation of remote monitoring in population-based and patient studies using wearables and apps. She is particularly interested in the assessment of physical activity patterning and function to identify individuals who are at risk of adverse health outcomes.

Wearables and cancer in population-based studies: what do we know?
Wearable devices have been used in large-scale population-based studies, predominantly to measure longitudinal associations between physical activity and cancer incidence. Devices deployed at scale have focussed on accelerometer outputs. However, as the use of wearables with combined sensors becomes more feasible, there is the opportunity to measure more diverse physiological and behaviour features that could aid the early detection of cancers. There are also challenges ahead for applying this technology to early detection and adoption in clinical practice, particularly the risk of increasing healthcare inequalities by creating a digital divide.

Veronica Martinez-Hernandez
Veronica Martinez-Hernandez (FHEA) research clusters around the Digital Operations and Platforms, Service Innovation, Strategic Value Creation and User Experience in Manufacturing, Health and Space. Her research aims to develop innovative service solutions particularly for early detection by understanding the mechanisms that inform the customisation of ‘patient-centric’ treatments.

Machine learning and AI applied to the identification of patterns of fatigue for earlier detection of myeloma
Fatigue remains a poorly understood symptom of critical health conditions. Through setting up a longitudinal Artificial Intelligence (AI) study, we aim to explore signature fatigue patterns in participants across myeloma compared to a healthy control group. Vital levels such as sleep patterns and heart rates were collected through smart watch sensors while speed and movements were gathered through environment beacon sensors, giving a complete picture of patients during the study.
Further behavioural and thought activities were completed on an iPad during this time. Machine Learning (ML) analysis should categorise these patterns.

Antonis Antoniou

Antonis Antoniou is Professor of Cancer Risk Prediction at the University of Cambridge and Director of the CD3 initiative. His research group in the Department of Public Health and Primary Care focuses on the development of risk prediction tools such as CanRisk which is widely used in clinical practice.

The Cancer Data Driven Detection (CD3) initiative.

CD3 is a proposed new, national research initiative dedicated to using data to revolutionise our understanding of cancer risk. The vision of the CD3 initiative is to significantly enhance our capacity for equitable cancer prevention, early detection and diagnosis. This will be achieved by establishing an open and inclusive network of multidisciplinary researchers who will form the CD3 research community. This community will leverage the UK’s population-scale multimodal electronic health record infrastructure, its distinctive strengths in cancer genomics, epidemiology, and advanced analytics, and its participatory approach to research.

CRUK are leading the project with support from Health Data Research UK (HDR UK), The Alan Turing Institute, the Economic and Social Research Council’s Administrative Data Research UK programme (ADR UK) and the Engineering and Physical Sciences Research Council (EPSRC) and involvement of the National Institute for Health and Care Research (NIHR).

Suzanne Scott

Suzanne Scott is Professor of Health Psychology & Early Cancer Diagnosis, Queen Mary University of London. Her research focuses on symptom perception and help-seeking behaviour to understand why people wait before consulting healthcare professionals and uses this to design and evaluate interventions to encourage appropriate and timely healthcare use. She is also behavioural science lead on several international collaborations focusing on early detection of cancer.

Symptoms, help-seeking and the use of wearables: Considerations from behavioural science

The early diagnosis of cancer heavily relies on people’s ability to notice and attend to relevant bodily changes and consult a healthcare professional. The behavioural science perspective on the processes of symptom perception and help-seeking behaviour is considered alongside how wearables could offer solutions to timely detection of symptoms and monitoring of subtle changes that may otherwise be missed. Potential barriers to successful implementation are considered such as exacerbation of inequalities, and questions surrounding acceptability and uptake, and the potential for unintended consequences on individuals and healthcare services.

Joss Langford

Joss Langford is CTO of Activinsights, helping healthcare professionals to collect and analyse lifestyle data to support disease treatment and prevention. Joss holds a BSc in Cybernetics & Control Engineering and has an honorary research fellowship at the University of Exeter. He is a founding director of Coelition, an independent, non-profit organisation that promotes the responsible use of personal data and open data standards.

Real-world digital biomarkers from wearables

Data from wearable sensors have the potential to be used in digital biomarkers for the susceptibility or risk of developing a disease or medical condition. Wearables can be deployed for long periods with high levels of adherence and low participant burden. These objective data better represent the lived experience of the individual in their everyday environment with the prospect of increased measure sensitivity. Measures must be selected carefully to reveal meaningful aspects of health that can capture the results of pathogenic processes or changes in capacity.

Claire and Darren

Claire and Darren support various research studies across the biomedical research campus and are currently participating in research studies with the ACED Clinic Cambridge.
Alaina Shreves

Alaina Shreves is a National Institutes of Health (NIH OxCam) Scholar at the University of Oxford and the National Cancer Institute. Her research leverages machine learning and epidemiological methods to quantify accelerometer-measured activity for cancer risk models. Prior to joining Oxford, she earned a Master of Science in epidemiology from the Harvard T.H. Chan School of Public Health and a Bachelor of Science degree from the College of William and Mary, majoring in neuroscience and public health.

Accelerometer-measured Physical Activity and Cancer Risk Prediction in the UK Biobank Prospective Cohort

Ms. Alaina H. Shreves, M.S. 1,3; Dr. Scott R. Small, DPhil. 1,2,4; Dr. Ruth C. Travis, DPhil 5; Dr. Charles E. Matthews, Ph.D 3; Dr. Aiden Doherty, DPhil. 1,2
1 Nuffield Department of Population Health, University of Oxford, Oxford, UK.
2 Big Data Institute, Li Ka Shing Centre for Health Information and Discovery, University of Oxford, Oxford, UK.
3 Division of Cancer Epidemiology and Genetics, National Cancer Institute, National Institutes of Health, Bethesda, MD, USA.
4 Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, Oxford, UK.
5 Cancer Epidemiology Unit, Nuffield Department of Population Health, University of Oxford, Oxford, UK.

Background: Wearable accelerometers, like many consumer smartwatches, allow individuals to collect daily physical activity data. This data holds promising potential for the early detection of chronic diseases. In this study, we analysed if accelerometer-measured physical activity data could be a useful digital biomarker for early cancer detection.

Methods: We used data from cancer-free UK Biobank participants who wore wrist-based accelerometer devices for seven days. Machine learning models estimated total physical activity (vector magnitude), and cancer outcomes were obtained from national registries. Hazard ratios (HR) and 95% confidence intervals (CI) were calculated using Cox proportional hazard models, with age as the timescale and adjusting sex, ethnicity, smoking, alcohol, education, socioeconomic status, family cancer history, self-rated health, and cancer screening history.

Findings: Among 86,556 participants with valid accelerometer data (aged 43-78; 56% female; 97% white), those with lower total physical activity had a higher risk of cancer one year after device wear (807 cases, HR per 1-SD (-8.33 milligravity per day) 1.12, [95% CI, 1.04-1.19]). This association remained significant after two years (1,726 cases, HR per 1-SD 1.08, [95% CI, 1.03-1.13]) and five years (4,564 cases, HR per 1-SD 1.06, [95% CI, 1.03-1.09]). Similar patterns were observed for breast cancer risk after one year (159 cases, HR per 1-SD 1.19, [95% CI, 1.02-1.33]) and two years (346 cases, HR per 1-SD 1.15, [95% CI, 1.04-1.25]), but not after five years. No significant associations were observed for prostate, lung, or colorectal cancers.

Interpretation: Our findings suggest that accelerometer-measured activity could aid in predicting the risk of certain cancers, though the associations were relatively modest and attenuated over time. Future studies, with larger cohorts and longer monitoring periods, are critical for understanding the potential utility of wearable devices in cancer risk prediction models and exploring other accelerometer data’s role in enhancing early cancer detection.
Marco Vinicio Alban-Paccha

Marco Alban-Paccha is a Research Associate at both the Departments of Medicine and Engineering at the University of Cambridge. His research focuses on the intersection of electronics and medicine, specifically on the role of bioelectronic sensors, wearables, and artificial intelligence in living systems. His work for the ADVANTAGE Pain Consortium focuses on the use of wearables to further understand visceral pain.

Wearable Sensors and Mobile App Data for the Modelling and Classification of Visceral Pain Flares

Marco Vinicio Alban-Paccha, Nicholas Shenker, Christopher Geoffrey Woods, George G Malliaras

1 Division of Anaesthesia, Department of Medicine, University of Cambridge, Cambridge, UK
2 Electrical Engineering Division, Department of Engineering, University of Cambridge, Cambridge, UK
3 Division of Rheumatology, Department of Medicine, University of Cambridge, Cambridge, UK
4 Department of Medical Genetics, Cambridge Institute for Medical Research, University of Cambridge, Cambridge, UK

One in five individuals around the world suffer from visceral pain, which seriously impacts their quality of life. This condition frequently occurs during unpredictable episodes of pain flares that may require hospital admission. Despite its high prevalence and substantial impact, there is limited knowledge of how visceral pain connects to the human body and how it affects people's wellbeing. Likewise, wearable sensors are important tools in personalised medicine platforms for ubiquitous and mobile healthcare. These sensors can allow early diagnosis of diseases relating to multiple biological systems and may provide means to monitor the state of the body outside of clinical setups, that is, bringing the lab into the home, and enabling the measurement of body functions in free living conditions.

We are recruiting 500+ participants with severe pain caused by visceral diseases, such as Crohn's disease or endometriosis, and we are capturing ad-libitum and notification-based reports of their pain with the help of a mobile app. This allows us to assess the temporal nature of visceral pain, as well as the recognition of unpredictable pain flares. This is done while simultaneously collecting behavioural and physiological data with the use of a wearable sensor that captures posture, heart and respiratory rates, temperature, etc. By combining patient-reported feedback from the pain reporting app with the wearable sensor data, we seek to understand the impact of visceral pain flares on everyday life. Moreover, we aim to identify the physiological variables that vary significantly at the onset of a pain episode. The analysis of the data by ML algorithms will help us develop models of the previously unpredictable pain flares, that can serve as clinical decision tools for patients and physicians. We believe the proposed models can be used in the development of future medical solutions for people living with extreme pain conditions.

DNA Nanotechnology Enables Single-molecule Sensing of RNA in Blood

Mohammed Alawami *, Hendrik Runge, Ulrich F. Keyser
Cavendish Laboratory, University of Cambridge,JJ Thompson Avenue, Cambridge CB3 0HE, UK
*Presenting author

Early diagnosis of cancer and biomarker-based patient stratification for personalised treatment have substantially reduced mortality. Key limitations in the detection of nucleic acid biomarkers are high turnaround times, often weeks under real-world conditions, error rate and artifacts created during reverse transcription or amplification reactions, particularly when working with blood samples. We are developing rapid, enzyme-free direct detection and quantification methods for RNA from blood and tissues in minutes to hours depending on concentration. Currently, we focus on pathogen detection from bacteraemia and fungaemia as proof-of-concept for the identification of live cells directly from human blood. We combined nanopore sensing and DNA nanotechnology for direct, multi-plexed single-molecule RNA detection to speed up the test to a few hours. For proof-of-concept, animal blood was spiked with cultured E. coli DH5α to mimic blood infection and total RNA was extracted. Custom-designed, sequence-specific DNA probes were hybridised with multiple RNA targets in the total RNA extract to build DNA-RNA nanostructures. The single-molecule DNA-RNA nanostructures were detected with solid-state nanopore sensing. The nanostructures produce a characteristic positive current signature showing that this minimally invasive method can detect RNA from blood at the single-molecule level in just a few hours. The entire protocol from blood draw to result can be reduced to one hour and is amenable to full automation in point-of-care devices with further optimisation.
RNA:DNA Nanotechnology Enables the Detection of RNA Single-base Variations and Modifications

Yunxuan Li *, Ulrich F. Keyser
Cavendish Laboratory, University of Cambridge, JJ Thompson Avenue, Cambridge CB3 0HE, UK
*Presenting author

Disordered gene expression is a major hallmark of cancer and RNA expression and modification are critical for gene expression. The processing of RNA is systematically altered in cancer cells, relevant for tumorigenesis, growth, and progression. The change, addition, and deletion of a single nucleotide in RNA can influence its expression or promote tumorigenesis. Chemical modification is also a specific and efficient way to regulate the functions of RNA. It is highly important to develop an easy-to-operate approach that can detect single-base variations and modifications on native RNA without reverse transcription.

Here, we introduce a platform based on RNA:DNA nanotechnology combined with solid-state nanopore readout, which can tell details of sequences and structures of nucleic acid molecules by electrophoretically driving them through a nanoscale pore and monitoring temporary blockades in the ionic current. We use RNA:DNA assembly and nanoswitch technologies for the detection of nucleotide variations and 5-methylcytosine (m5C) modifications using MS2 RNA within hours. Our approach is currently adapted for the analysis of 28S rRNA m5C modifications that are associated with cancers like glioblastoma and others.
Hurdles for Digital Technology In Clinical Trials

Mia Sato Tackney *, Joseph Newman 2, Mark Toshner 2, Sofia Villar 1
1 MRC-Biostatistic Unit, University of Cambridge
2 Victor Phillip Dahdaleh Heart & Lung Research Institute (VDP HLRI), University of Cambridge
*Presenting author

Randomized clinical trials are the gold standard study design to assess whether a new intervention is effective. This requires measuring people’s health outcomes during the trial to assess whether they improve due to the intervention. Traditionally, health outcomes are measured at hospital appointments and provide a one-time snapshot of a person’s health. In contrast, Digital Health Technologies (DHTs) such as smartwatches or apps can measure health outcomes every minute, over extended periods of time and throughout people’s daily activities. DHTs can accurately measure outcomes, reflect people’s daily experiences, and reduce cost/burden for people participating in trials by reducing hospital visits.

The use of DHTs to measure health outcomes in trials bring important and unanswered statistical questions. How do we demonstrate that the digital approach is valid, accurate and reliable? How should we design clinical trials with a digital device? How should we analyse the high-frequency data provided by digital devices and how should we handle missing data? A methodological framework is needed to overcome statistical challenges in using DHTs.

This poster highlights (1) the prioritized statistical challenges, which were highlighted in a comment to the FDA’s draft guidelines on DHTs for Remote Data Acquisition in Clinical Investigations (2) previous work in handling missing accelerometer data, which addresses one of the challenges and (3) future work to overcome additional challenges, including a planned knowledge exchange event to engage multiple stakeholders.