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Identifying Physiological Biomarkers for Monitoring Dietary Behaviours

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Imperial College London

FoodSense Study

Identifying physiological biomarkers for monitoring dietary behaviours

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IRAS Project ID: 333281
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Imperial College London

Study Management Group

Chief Investigator: Dr Mingzhu Cai

Co-PI: Dr Mayue Shi

Clinical Queries

Clinical queries should be directed to Dr Mingzhu Cai who will direct the query to the appropriate person.

Sponsor

Imperial College London is the main research Sponsor for this study. For further information regarding the sponsorship conditions, please contact the Head of Regulatory Compliance at:

Research Governance and Integrity Team
Imperial College London and Imperial College Healthcare NHS Trust
Room 215, Level 2, Medical School Building
Norfolk Place
London, W2 1PG
Tel: **0207 594 1862**
Imperial College - Research Governance and Integrity Team (RGIT) Website

Funder

This study is funded by Dame Julia Higgins Postdoc Collaborative Research Fund.

This protocol describes the FoodSense study and provides information about procedures for entering participants. Every care was taken in its drafting, but corrections or amendments may be necessary. These will be circulated to investigators in the study. Problems relating to this study should be referred, in the first instance, to the Chief Investigator.

This study will adhere to the principles outlined in the UK Policy Frame Work for Health and Social Care Research. It will be conducted in compliance with the protocol, the Data Protection Act and other regulatory requirements as appropriate.

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KEYWORDS

Diet, health, food intake, sensors,

STUDY SUMMARY

TITLE Identifying physiological biomarkers for monitoring dietary behaviours

DESIGN Feasibility study/ Basic science study involving procedures with human volunteers

AIMS

- Investigating physiological changes during eating behaviours.
- Identifying physiological biomarkers for dietary behaviours and glycaemic outcomes.

OUTCOME MEASURES The primary outcome is the physiological features associated with dietary events (pre- vs post- meal).
Secondary outcomes include:

- Physiological and motor features associated with energy intake (high vs. low calorie meals).
- Physiological and motor features associated with glycaemic biomarkers, including blood glucose, insulin and hormonal levels

POPULATION Healthy adults

ELIGIBILITY Subjects aged 18-65 years with BMI of 18-30 kg/m2 and no significant health problems.

DURATION Each participant will participant in two 2-hour study visits within up to 8 weeks

1. INTRODUCTION

1.1. BACKGROUND

Assessing dietary intake across populations is a fundamental challenge in nutrition research. Traditional dietary assessment methods, such as food diaries, rely on self-reporting of individuals and suffer from poor accuracy and recall bias. Food records are estimated to cause 11-41% underestimations for energy intake (Burrows et al., 2019). Furthermore, traditional methods are labour- and time- intensive and requires participants to manually record their food intake (Shim et al., 2014). Adherence dietary self-reporting is challenging even with mobile-based applications e.g., MyFitnessPal (Cordeiro et al., 2015).

Wearable sensing technology is emerging to ease the procedure of food intake assessment. The most popular technique is accelerometer-based system, which captures eating gestures via monitoring wrist motions that correspond to the hand-to-mouth movements during eating (Bell et al., 2020, He et al., 2020). The advantages include its simple structure and ability in capturing eating episodes and detecting time, speed, and duration of eating. However, this system cannot provide information about the energy intake and how food affects physiological response after meal. This knowledge is essential for determining the interaction between diet and health.

Food intake and digestion increases metabolism, body temperature and intestinal oxygen consumption. Elevated skin temperature, increased pulse rate/ heart rate and lowered oxygen saturation are observed during or after meals (Westerterp, 2004, Sit and Chou, 1984, Sidery and Macdonald, 1994, Cassiani et al., 2011); the rise of pulse rate has significantly correlated to meal size ($r = 0.990$; $P = 0.008$) in six healthy volunteers (Parker et al., 1995). This raises the possibility of using these physiological responses as potential indicators of food and energy intake (Amft and Troster, 2009). One major problem is that the relationships can be altered by confounders such as exercise, while this challenge may be overcome by incorporating physiological parameters with existing motor sensors, which recognized eating episodes with F-scores of 76.1% in precision and recall rates (Thomaz et al., 2015). It is hypothesized that integrating and physiological parameters and existing motor sensors may provide an objective tool for both detecting eating movement and estimating food consumption.

Our project aims to investigate the relationships between physiological responses and food and energy intake. Importantly, these physiological parameters can be measured using readily available, cost-effective sensors and products (e.g., smartwatch); thus, our findings may promote an accelerated development of a wearable tool for dietary assessment in future.

2. RATIONALE FOR CURRENT STUDY

Primary objective:

to investigate the feasibility of monitoring dietary behaviours by tracking physiological changes such as skin temperature, blood oxygen saturation, pulse rate and heart rate?

Secondary objectives:

- To examine the association between these physiological features and energy loads (high vs. low-calorie meals).
- To explore the relationship between these physiological features and glycaemic biomarkers, including blood glucose levels, insulin levels, and hormonal levels.

3. STUDY METHODOLOGY

3.1. PARTICIPANTS

10 healthy male and female participants. This is a pilot study in a new area and therefore a formal power calculation is not possible.

3.2. RECRUITMENT

Participants will be recruited from existing healthy volunteer databases and by advertisement in public places. Adverts will be placed in newspapers and put up in public buildings. A contact number on the advert will enable potential participants to contact the research team at Imperial College London. Participation in the study will be entirely voluntary. No undue influence will be exerted by the researchers. Participants will be free to withdraw from the study at any time.

3.3. STUDY DESIGN

Number of subjects: 10

Pre-Screening Questionnaire：

A pre-screening questionnaire considering the inclusion and exclusion criteria (see section 3) will be completed to establish eligibility. For subjects who complete the questionnaire but do not continue to participate, their data will not be saved. Participants will have a minimum of 48 hours to consider participation before providing consent.

Informed Consent: All participants will sign informed consent before starting the study (at the beginning of the 1st main study visit).

Main Study Visits:

Ten healthy subjects will attend two study visits at Clinical Research Facility. They will consume a high- and low-calorie meal designed by nutritional researchers, in a randomised order. Randomization will be performed using the 'sealed envelope' website by an independent researcher (i.e., not linked to the study). During eating events, physiological changes such as skin temperature, blood oxygen saturation, pulse rate etc and eating movements will be measured via a CE marked bedside monitor (Philips Healthcare) and non-invasive, wearable sensors. Blood samples will be taken at pre-determined time-points, starting 5 minutes before the meal and lasting for 60 minutes postprandially (at -5, +15, +30, +45, +60 min). A total of 25 ml blood will be taken per visit.

Sensor Data Acquisition and Recording

Participant will be invited to wear a multi-sensor monitor (please see the appendix 1 for the diagram) and recording of physiological and activity data during eating. Sensors on the monitor include:

- **Skin Surface Temperature Sensors**: Integrate skin surface temperature sensors to monitor changes in skin temperature during eating events. This data will provide insights into metabolic responses to food intake.
- **Pulse Rate Sensors**: Employ commercial pulse rate sensors, to continuously monitor participants' heart rates. Variations in pulse rate can indicate the intensity of eating episodes and physiological responses to food.
- **Oxygen Level Sensors**: Integrate oxygen level sensors, such as pulse oximeters, to measure blood oxygen saturation levels during eating events. Changes in oxygen levels can provide valuable information about participants' respiratory patterns and metabolic responses to food.
- **Blood Glucose Sensors**: The multi-sensor monitor will be equipped with non-invasive blood glucose sensors to continuously measure and record participants' blood glucose levels during eating episodes. This data is pivotal for understanding the impact of different foods on blood sugar regulation and insulin responses in individuals.
- **Movement Measurement Sensors**: Inertial Measurement Units (IMU) and accelerometers will be used to track the posture and movement of participants' hands during tests and to record the features of eating behaviours.
- **Force sensors:** The wearable monitor will include force sensors to monitor the wearing status (tightness) of the sensors themselves. Ensuring that the sensors are securely fastened is essential to maintain data accuracy. Force sensor data will serve as a quality control mechanism to guarantee that the sensors remain in optimal contact with the skin throughout the testing period.

Duration

End of the trial will be the last visit of the last participant in the study. The duration of each participant's involvement with the study will be up to 8 weeks. Participants will be part of the study for two separate visits. Each visit will last for no more than two hours.

3.4. STUDY OUTCOME MEASURES

The primary outcome is the physiological features associated with dietary events (pre- vs post- meal).

Secondary outcomes include:

- Physiological features associated with energy intake (high vs. low calorie meals).
- Physiological features associated with glycaemic biomarkers, including blood glucose, insulin and hormonal levels

4. INCLUSION/EXCLUSION CRITERIA

4.1. INCLUSION CRITERIA

- Male or female
- Age between 18-65 years (inclusive)
- Body mass index (BMI) of 18-30 kg/m^2
- Willingness and ability to give written informed consent.
- Willingness and ability to understand, to participate and to comply with the study requirements

4.2. EXCLUSION CRITERIA

- Outside of specified age and BMI range
- Chronic medical conditions including for eating disorders, diabetes, obesity, hypertension, cancer, acute infectious disease, renal disease, cardiovascular disease, and chronic gastrointestinal condition.
- Taking part in another research study or donating any blood in the last 3 months

4.3. WITHDRAWAL CRITERIA

Each participant has the right to withdraw from the trial at any time. In addition, the Investigator may discontinue a participant from the trial at any time if the Investigator considers it necessary for any reason including:

- An adverse event which requires discontinuation of the trial application or results in inability to continue to comply with trial procedures.
- Loss of capacity to consent. The only reason a participant may be withdrawn from study follow-up is in the event of withdrawal of consent, loss of capacity to consent or an adverse event which in the opinion of the Investigator was related to the study. Participants that are withdrawn from the study will be replaced by eligible participants. If a patient withdraws consent or loses capacity such that they are unable to consent to continue in the study then data collected up until that point will still be used in the analysis. Reason for not completing the study will also be collected. Further information will not be collected from patients who have withdrawn from the study.

5. ADVERSE EVENTS

5.1. DEFINITIONS

Adverse Event (AE): any untoward medical occurrence in a patient or clinical study subject.

Serious Adverse Event (SAE): any untoward medical occurrence or effect that:

- **Results in death**
- **Is life-threatening** – *refers to an event in which the subject was at risk of death at the time of the event; it does not refer to an event which hypothetically might have caused death if it were more severe*
- **Requires hospitalisation, or prolongation of existing inpatients' hospitalisation**
- **Results in persistent or significant disability or incapacity**
- **Is a congenital anomaly or birth defect**

Medical judgement should be exercised in deciding whether an AE is serious in other situations. Important AEs that are not immediately life-threatening or do not result in death or hospitalisation but may jeopardise the subject or may require intervention to prevent one of the other outcomes listed in the definition above, should also be considered serious.

5.2. REPORTING PROCEDURES

All adverse events should be reported. Depending on the nature of the event the reporting procedures below should be followed. Any questions concerning adverse event reporting should be directed to the Chief Investigator in the first instance.

4.3.1 Non serious AEs

All such events, whether expected or not, should be recorded- it should be specified if only some non-serious AEs will be recorded, any reporting should be consistent with the purpose of the trial end points.

4.3.2 Serious AEs

An SAE form should be completed and emailed to the Chief Investigator within 24 hours. However, relapse and death and hospitalisations for elective treatment of a pre-existing condition do not need reporting as SAEs.

All SAEs should be reported to the London Westminster Research Ethics Committee. where in the opinion of the Chief Investigator, the event was:

- 'related', ie resulted from the administration of any of the research procedures; and
- 'unexpected', ie an event that is not listed in the protocol as an expected occurrence

Reports of related and unexpected SAEs should be submitted within 15 days of the Chief Investigator becoming aware of the event, using the NRES SAE form for non-IMP studies. The Chief Investigator must also notify the Sponsor of all related and unexpected SAEs.

Local investigators should report any SAEs as required by their Local Research Ethics Committee, Sponsor and/or Research & Development Office.

Contact details for reporting SAEs

RGIT@imperial.ac.uk
CI email (and contact details below)
Email：m.cai18@imperial.ac.uk, attention Dr Mingzhu Cai
Please send SAE forms to: Dr Mingzhu Cai
Tel: 07395757128 (Mon to Fri 09.00 – 17.00)

6. ASSESSMENT AND FOLLOW-UP

There will not be follow-up visits. However, participants will be contacted via emails after study visits to identify incidental cases. Incidental cases will be reported to the GP.

7. DATA STORAGE

Data and all appropriate documentation will be stored for a minimum of 10 years after the completion of the study, including the follow-up period. Data recorded by the wearable sensors will be transmitted to a College-owned PC terminal for storage and further analysis. A dedicated data logging program will be developed to ensure efficient data recording and storage in a secure and organized manner. Data analysis will be performed using College computers.

8. REGULATORY ISSUES

8.1. ETHICS APPROVAL

The Study Coordination Centre has obtained approval from the London Westminster Research Ethics Committee (REC) and Health Research Authority (HRA). The study must also receive confirmation of capacity and capability from each participating NHS Trust before accepting participants into the study or any research activity is carried out. The study will be conducted in accordance with the recommendations for physicians involved in research on human subjects adopted by the 18th World Medical Assembly, Helsinki 1964 and later revisions.

8.2. CONSENT

Consent to enter the study must be sought from each participant only after a full explanation has been given, an information leaflet offered and time allowed for consideration. Signed participant consent should be obtained. The right of the participant to refuse to participate without giving reasons must be respected. After the participant has entered the study, the clinician remains free to give alternative treatment to that specified in the protocol at any stage if he/she feels it is in the participant's best interest, but the reasons for doing so should be recorded. In these cases the participants remain within the study for the purposes of follow-up and data analysis. All participants are free to withdraw at any time from the protocol treatment without giving reasons and without prejudicing further treatment.

8.3. CONFIDENTIALITY

Confidentiality will be maintained by pseudonymised data. Patients will be assigned an individual identification number from their consent form, and this will be used to record any further data. Signed consent forms will be kept in a locked filing cabinet in a locked office in the Section of Investigative Medicine, Imperial College London. These forms will contain the patient names and an individual study code. Patient contact details will be stored electronically on a password protected shared drive within the ICHNT network that is only available to the research team. All other data will contain the individual study code and no other participant identifying information. This will make forms pseudonymised except for the researchers. All data stored electronically will be password protected.

The Chief Investigator must ensure that the subject's confidentiality is maintained. On the eCRF or other documents submitted to the Sponsor, subjects will be identified by a subject ID number only. Documents that are not submitted to the Sponsor (e.g. signed informed consent form) should be kept in a strictly confidential file by the site investigator.
The Chief Investigator will preserve the confidentiality of participants taking part in the study and is registered under the Data Protection Act.

8.4. INDEMNITY

Imperial College London holds negligent harm and non-negligent harm insurance policies which apply to this study.

8.5. SPONSOR

Imperial College London will act as the main Sponsor for this study. Delegated responsibilities will be assigned to the NHS trusts taking part in this study.

8.6. FINANCE

Funding source-This study is funded by Dame Julia Higgins Postdoc Collaborative Research Fund.

Participant payments-Participants will not be paid to participant in this study. To recompense to travel and time expenses, £50 will be made available for participants upon completion of the study.

The researchers will not receive any personal payment over and above normal salary, or any other benefits or incentives, for taking part in this research.

8.7. AUDITS

The study may be subject to audit by Imperial College London under their remit as sponsor and other regulatory bodies to ensure adherence to GCP and the UK Policy Frame Work for Health and Social Care Research.

9. STUDY MANAGEMENT

The day-to-day management of the study will be co-ordinated by Dr Mingzhu Cai.

Study Management Group	
Chief Investigator	
Principal Investigator	Dr Mingzhu Cai
Co-investigators	Dr Mayue Shi

10. PUBLICATION POLICY

The findings of the research will be presented at scientific conferences and published in an open-access, peer-reviewed journal. In addition, we will be collaborating with patient groups and professional groups to disseminate the findings via multiple media channels such as patient association publications, print and broadcast media. No participants' identifiable data will be included.

11. REFERENCES

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Appendix 1. Diagram of the multi-sensor system

Wearable Sensing Arm Band Design Documentation

Designed by: Dr Mayue Shi
Date: 15 Jan 2024
Version: W1.02

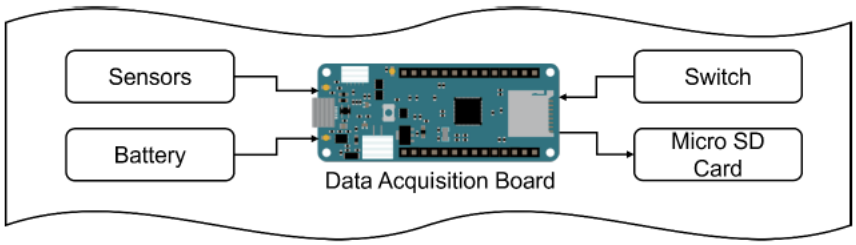

Figure 1 System design of the sensing band

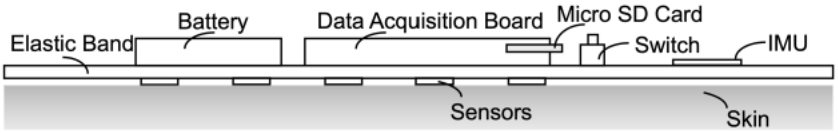

Figure 2 Assembly of components (Side view)

Notes:

- DAQ board is sewn on fabric band via through-holes at corners.
- Sensor PCBs are fixed on the fabric band with adhesive.
- Digital sensors communicate with the Data Acquisition Board via I^2C communication ports with standard jumper wires. Analogue sensors communicate via analogue inputs (AIs) on the Data Acquisition Board with standard jumper wires.

Each commercial sensor is originally located on a small printed circuit board (PCB) with a standard output port. The PCBs with sensors will be combined on the belt with adhesive, without changing the original wiring on the PCBs. All sensors will be connected to the standard input ports on the data acquisition board with jumper wires.