

B-IOOP

This is a smart wristband for diabetic to help them achieve their fitness goals through self-monitoring and exercise guidance, thereby improving the condition.



Diabetic



Fitness equipment



IoT

PDE Major project

2021

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**THE GLASGOW
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Background

People in the UK living with diabetes



UK

People in China living with diabetes



China



Spent on diabetes annually by the NHS

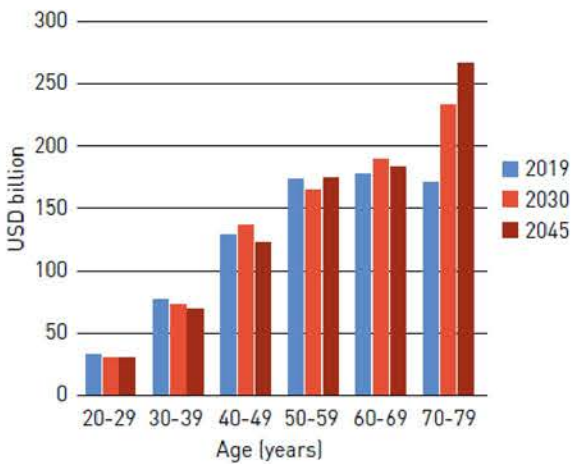


People in China living with pre-diabetes

It can be seen that the number of diabetic people is large both in the UK and China, while the people living with pre-diabetes are even much more.

Basic data of diabetes (Data from WHO, 2021 [1] & CCTV NEWS, 2021 [2])

Figure 3.14 Total diabetes-related health expenditure (USD billion) by age group



From the data by NHS, the medical expenditure on diabetes is high every year. For individuals, the diabetes - related health expenditure increases with age. And every ten years, the expenditure increases sharply. What's more, the health expenses also significantly goes up with the time. Expenses in 2045 will be around two-thirds more than in 2019 for patients in 70-79.

Hence, rehabilitation for diabetes is crucial, especially in its early stages, which is significant to both reversal of diabetes and the reduction on diabetes - related expenditure.

(Source from: IDF diabetes atlas, p.65, 2019 [3])

Problem



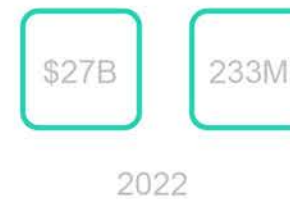
A health diet, regular physical activity, medication and regular screening and treatment for complications are four main ways to improve the diabetes [4].

However, diabetic patients are different from normal people in blood sugar regulation. They cannot keep their blood sugar stable by producing insulin on their own. When people do physical activity, muscle movement consumes sugar from the body. It is difficult for diabetic people to control their blood sugar level during exercise, which may cause safety issues like hypoglycemic shock. Besides, different fitness programs have different levels of intensity, which increases the difficulty of their safe fitness.

Using smart wearable devices to monitor daily activities has become a major trend for consumers to keep track of their health and fitness. Smart-wear devices such as Fitbit, Apple Watch, and Xiaomi have experienced tremendous growth in recent years [5].



The growth in the global wearables market during was up by 5.5% compared to 2017 with 27.9 million units sold.



worldwide smart wearable device sales will double by 2022, becoming a \$27 billion market with an expected 233 million units sold.

(Source from: "Smart Wearables Market To Double By 2022: \$27 Billion Industry Forecast", Forbes, 2018.[6])

User research



Name: Pang Wang
Age: 25
Job: Programmer
 Diagnosed in 2020,
 Healing process began in 2020
 Stop medication in 2021



“When I was diagnosed with diabetes, I **immediately started** my healing process, which mainly included diet and fitness plans. My process is very effective. However, I remember once I increased the amount of exercise during resistance training, which caused me high blood sugar. This phenomenon is caused by **improper exercise methods** (for example, high-intensity, intense anaerobic exercise) and **excessive exercise**. But sometimes **it is difficult to control**.”



Name: Liz Cromwell
Age: 47
Job: Powerlifter
 Diagnosed in 2009,
 Healing process began in 2015
 Stop medication in 2020



“After diagnosis, I put on more weight and lived with depression. One day, a friend told me her husband was setting up a CrossFit gym. CrossFit is a form of high intensity interval training that combines **strength and conditioning exercises**. I'd never done any exercise before. I signed up to a **10-week plan along with nine others**. At CrossFit, I discovered **talents and abilities** I never imagined I'd have. I **felt good** in myself. After a while, I realised I was progressing.”

Key findings

- The earlier the healing process starts, the better effect will be.
- Exercise has safety issues(improper exercise methods , excessive exercise).
- Plan the exercise ahead can help a lot.
- Exercise can bring confidence and satisfaction.

Literature review



Emma Elvin
 Senior Clinical Advisor
 Diabetes UK

“The thought of being more active might be overwhelming, but once you start people have told me how great it makes them feel. You won't just see the benefits now. It's about building a healthier future too - we know **being active** helps protect your body **against diabetes complications** and can help you lead **a happier and healthier life**.”



Neil Gibson
 Senior Physical Activity Advisor
 Diabetes UK

“You don't have to do traditional exercise, **simply moving more** is good for your health and your diabetes. It's amazing how quickly **small changes** can add up and lead to a physically active life.”



Dr. Singh
 Practicing Physician
 Stanford Medicine

“Try to push people **early** on in the intermediate phase, which would really make a difference and decrease the amount of medication.”

WHY

It can be seen from the opinions of experts that fitness is of great significance to diabetes. And exercise in the early and middle stages is better for improving the condition and saving medical expenses.

Focus board

Life style



Environment



Parallel concept/products



- Diet & exercise
- Medication & insulin injections
- Eat & drink a lot
- Notable drops in energy
- Home
- Gym
- Outdoor public fitness area
- Wearable equipment
- Smart fitness equipment

Interview

In the desk research, I have found some user's pain points. Then In order to better understand the needs of people with diabetes during fitness, I conducted a one-on-one in-depth interview with a patient who regularly exercises.



Name: Min
 Gender: Female
 Age: 37
 Gym frequency: 2-3 times / week
 Daily method to measure blood sugar: CGM+Mobile phone

1/ What does fitness mean for your diabetes?

I like sports and have the habit of going to the gym before diagnosis. Besides, fitness can increase insulin sensitivity and increase muscles, which are good for diabetes.

2/ Have you encountered any adverse reactions in the process of fitness because you did not control the amount of exercise?

Yes, especially in the beginning, there are a lot of cases like this.

3/ What measures do you take during exercise?

Before exercise, I will check my blood sugar. If my blood sugar is too low, I will supplement slow carbs. During exercise, I will frequently monitor my blood sugar through CGM.

4/ How do you control the amount of exercise each time?

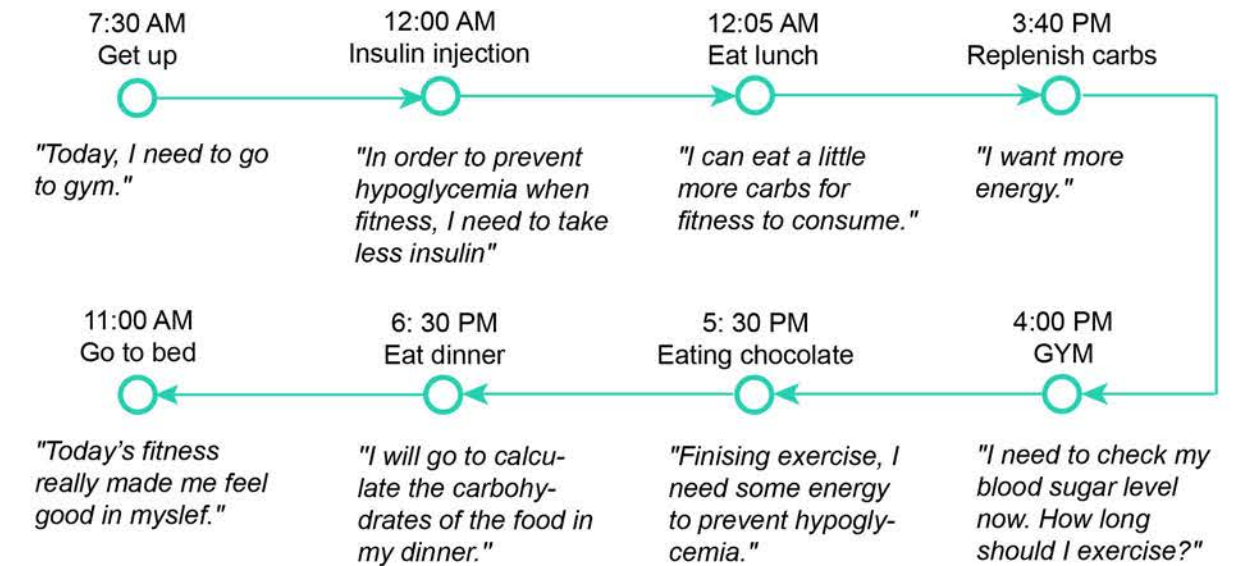
Aerobic exercise(40min-1h20min): stop when blood sugar drops to around 5 mmol/L.
 Anaerobic exercise(1h): The amount of exercise will not be too much, mainly with light and medium weight.

5/ Are there any exercise scenarios that make you feel inconvenient?

Swimming, because I can't see my blood sugar data under water.

Current experience when go to gym

From interview, I summarized a day of going to the gym.



Summary

Pain points

Sometimes, I may forget my schedule and disrupt my fitness plan.

Not sure how long I should keep exercising.

I need to check my blood sugar level on my mobile phone frequently.

I want to look back today's exercise and plan for next time exercise.

Opportunities

Have a fitness plan ahead. To remind the user.

To tell the user the suggested exercise time.

To inform the user of changes in blood sugar in a more convenient way.

To generate data graphs and give feedback to user.

Persona

My targeted user group: diabetic patients at the early and mid-term stage.
Age: 13-19 teenagers (type 1); 20-50 adults (type2)



Nick Male 26
In the early stages of diabetes

"I have the habit of going to the gym. But since I got diabetes, I can't control my blood sugar well. So I often have low blood sugar when I exercise"

- **Feature:** Feel unsafe to exercise
- **Pain Points:**
 1. Not sure about the safe and correct way.
 2. Worry about changes in blood sugar.



Jessica Female 35
In the early stages of diabetes

"My obesity caused me to develop diabetes. My doctor told me that I need to lose weight to control my condition, but I am new to fitness and don't know how to start."

- **Feature:** Need to manage weight
- **Pain Points:**
 1. Have no clear goals and plans.
 2. Worry about changes in blood sugar.



Jackson Male 49
In the middle stages of diabetes

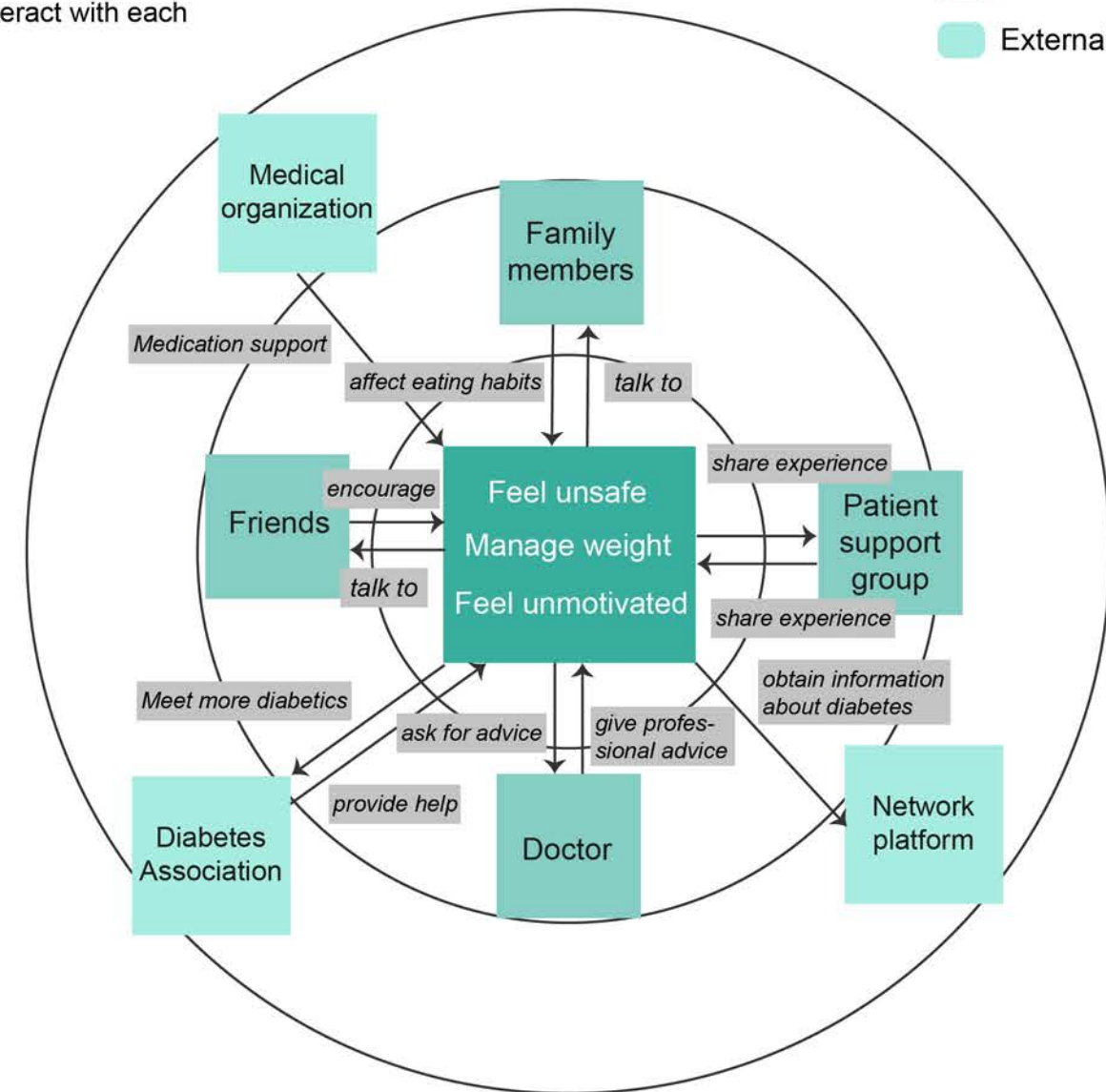
"Diabetes makes it easy for me to feel tired and lose interest in things, which makes it difficult for me to persist in doing one thing."

- **Feature:** Feel unmotivated to exercise
- **Pain Points:**
 1. Easy to give up exercise.
 2. Worry about changes in blood sugar.

Stakeholder map

This maps analyzes the relationship between stakeholders and how they interact with each other.

- Core users
- Internal stakeholder
- External stakeholder



Design goals

After research and design analysis, I defined two goals for my project:

1. This product can help diabetic users adjust the fitness intensity according to their blood sugar level.
2. This product needs to make users feel safe when fitness. Some functional needs to be considered such as providing exercise guidance and monitoring the blood sugar.



Goals



Safe



Attainable & Sustainable

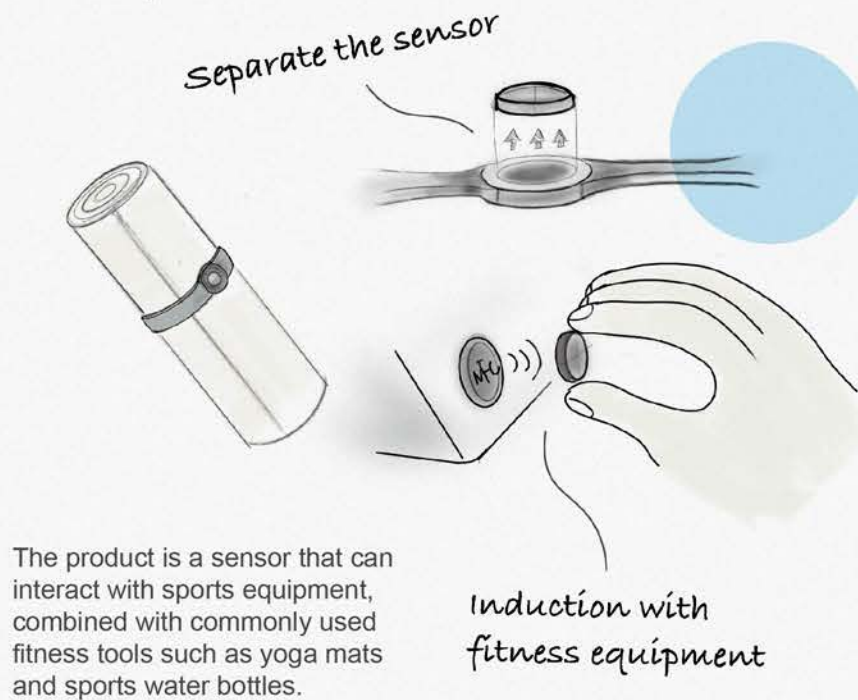


Convenient

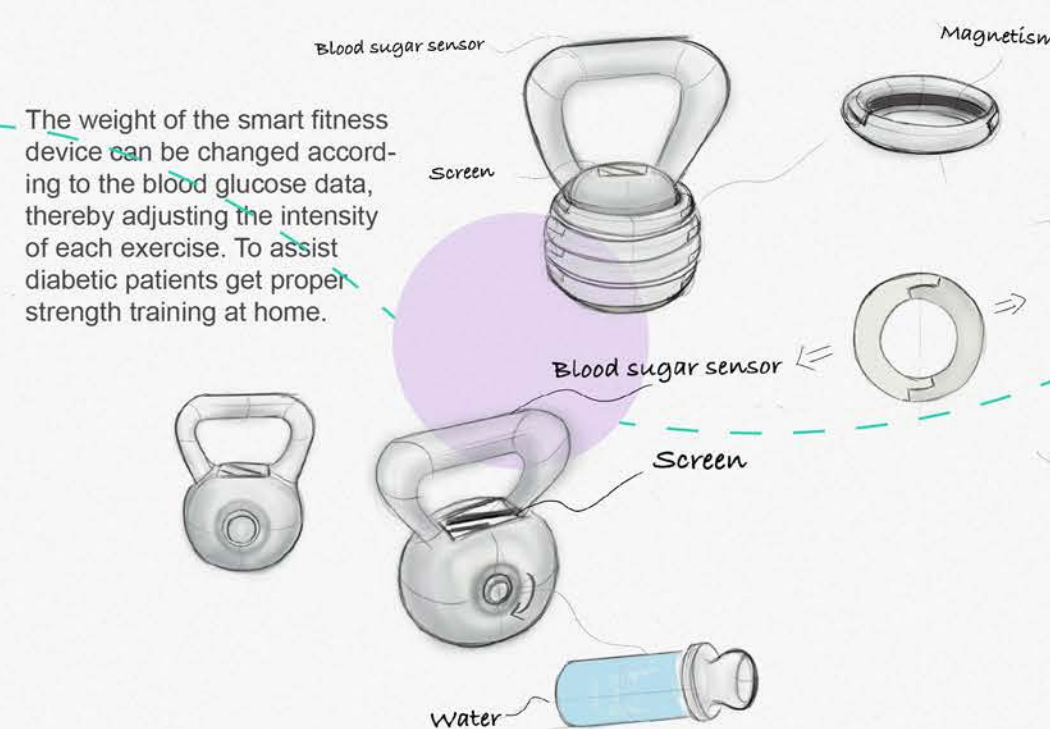
There is a gap between diabetic patients and a variety of fitness programs in different intensity. I considered **What if** there is a product that can help prevent bad results before the diabetic start to exercise? Is there a product that can help the diabetics user exercise by self-monitor and provide exercise guidance according to personal condition and goals?

Ideation

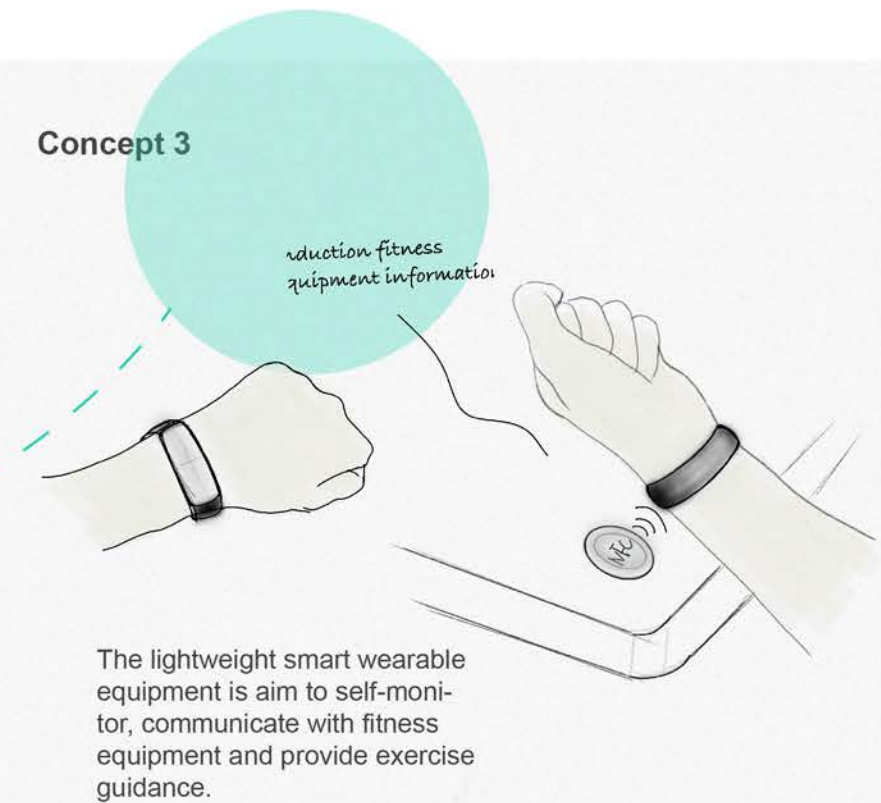
Concept 1



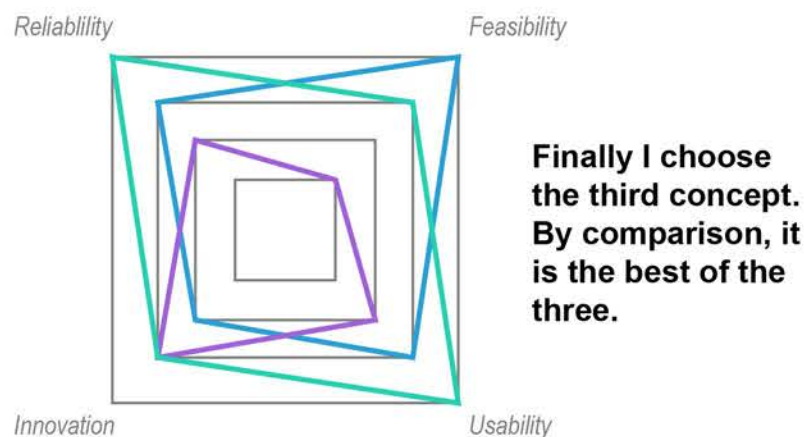
Concept 2



Concept 3



Evaluation



The difference

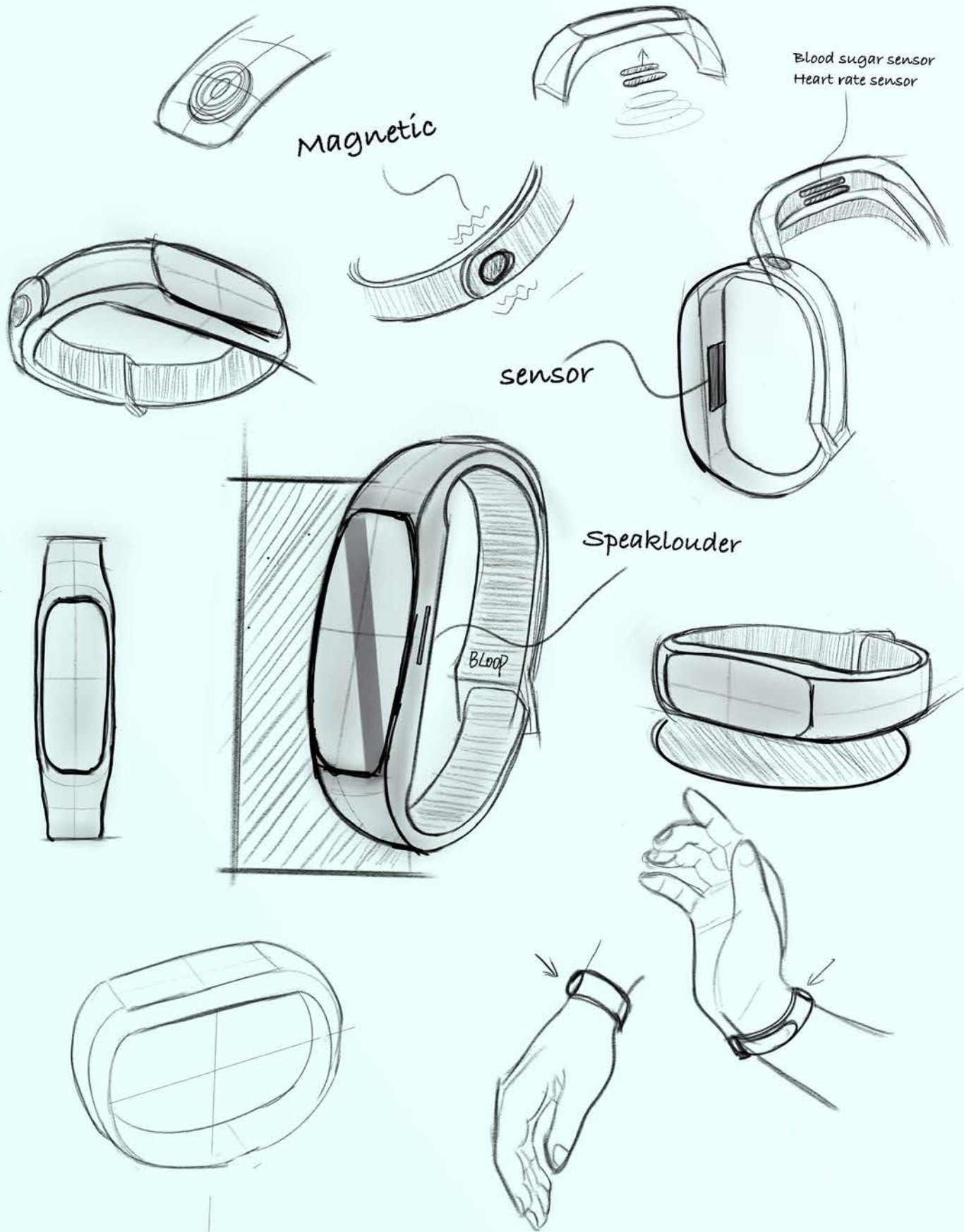
There are already many smart sports watches on the market, such as Apple Watch and Xiaomi wristband. These sports watches are very powerful, with many functions. Compared to these products, B-IOP is specifically designed to assist diabetic patients with fitness. Hence:

- The function and application scenario of B-IOP are more single but more targeted. Also, the required technology and parts will be much less than other general smart sports watch, so the required cost will also reduce a lot.

Because of the reduction in the number of related internal parts, the overall product can be smaller and lighter, which is better for sports-wear.

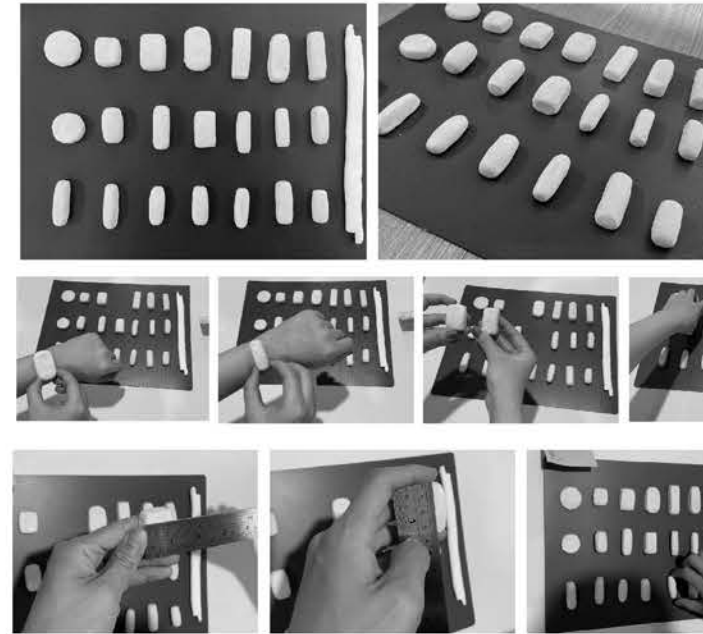
This smart wristband connects the user and fitness equipment, which broadens the application scenarios of the Internet of Things technology, allowing more users to enjoy the convenience brought by the intelligence of hardware products.

Sketch



Prototype test

Modelling clay - to explore shape

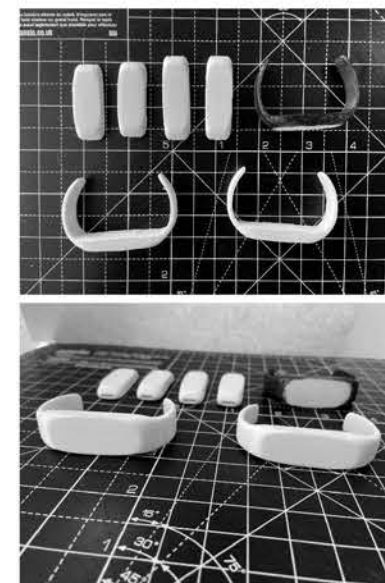


I make the prototype of screen in different sizes and shapes in order to explore a shape that fit for sports wear, and it should be smaller and lighter because the internal parts is less.

"I think this shape is the most suitable for people to wear for exercise, because it is smaller and lighter while the screen is big enough to see."

"I prefer this shape to the round shape, because the round shape will make the elbow joint uncomfortable when do some movements."

3D printing - to explore interaction



"For the elliptical machine, it is a bit inconvenient to hold the wristband close to the NFC tag when swinging."



"In dangerous situations, people with diabetes may have their senses dulled, so strong interactions are required to alert users."

Technical support

As for medical research, I put it on my design journal. I explain how to turn calories burned into the blood sugar consumption and make a calculation using the data of the diabetic patient I interviewed.



In this project, the wristband needs to communication with the fitness equipment and the mobile phone, which broadens the application of IoT.

There are many communication technology such as WIFI, Bluetooth, Zigbee, NFC, NB-IoT and so on. I finally choose NFC for the communication between wristband and fitness equipment, and NB-IoT for the communication between wristband and mobile phone terminal.

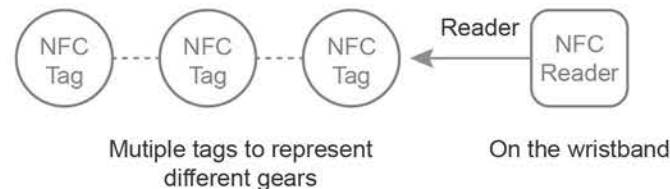
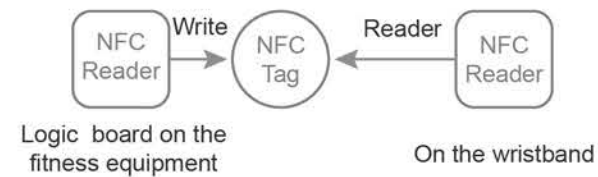
NFC



In my project, NFC technology is used for communication between wristband and fitness equipment. When the wristband gets close to the NFC tag that attached to the fitness equipment, it will sense the data in the NFC tag. There is an NFC reader in the wristband. The NFC tags contain the information (Serial number, MET) of the fitness equipment.

I defined two types of fitness equipment. The first type is the ones with logic board inside like treadmill, and another type is the ones without logic board like barbell.

- Short-distance
- High-frequency
- 10-cm communication distance
- safer
- Lower transport power consumption than Bluetooth



Methods of blood sugar detection



Finger-Pricking

Price: £12.95
Principle: Blood sample collection

Its price is relatively cheap, But this measurement method is very troublesome and requires a needle every time.



CGM

Price: £ 48/pack(14 days)
Principle: use a small sensor just under your skin to measure glucose in the fluid around your body's cells (interstitial fluid).

It is much more convenient than finger-pricking and it doesn't cause pain, which greatly increases the user experience. Besides, I estimated CGM and diabetes-related health expenditure to clarify that it makes sense to use this technology to improve or reverse diabetes, even though it needs to cost much money for several months or years.



Blood sugar sensor

Photonic sensing: Si/SiO₂-layers with a central liquid-filled defect layer as a blood sugar concentration biosensor in the visible region. The transmission spectrum is calculated numerically by using the transfer matrix method [7].

infrared sensing: the IR204 infrared LED to transmit infrared light with a wavelength of 850940 nm and use PD204 photodiode for the receiver [8].

The development of prototype of blood glucose sensors has made great progress, and there are already blood glucose sensors that used as self-monitoring tools on the market. For smart wearable equipment, this method to monitor blood sugar level is more suitable.

As for the former type, there needs to be NFC reader on the logic board of the fitness equipment. This NFC reader can rewrite the information of the NFC tag when user changes the related value of the fitness equipment from the control panel. As for the latter type, it just attaches the tag on the fitness equipment which do not need to be modified. But there are some exercise machines that can manually adjust weight or strength. For example, the weight of the barbell can be changed by adding weights, so there will be several different MET values of one fitness equipment. In this case, consider several tags to indicate different gears for users to choose the selected gear.

Final design

This is a lightweight smart wristband designed for diabetic patients to allow them to have a safer and more effective fitness healing journey. B-IOOP can communicate with fitness equipment and mobile phone to form a personalized feedback loop for the user.

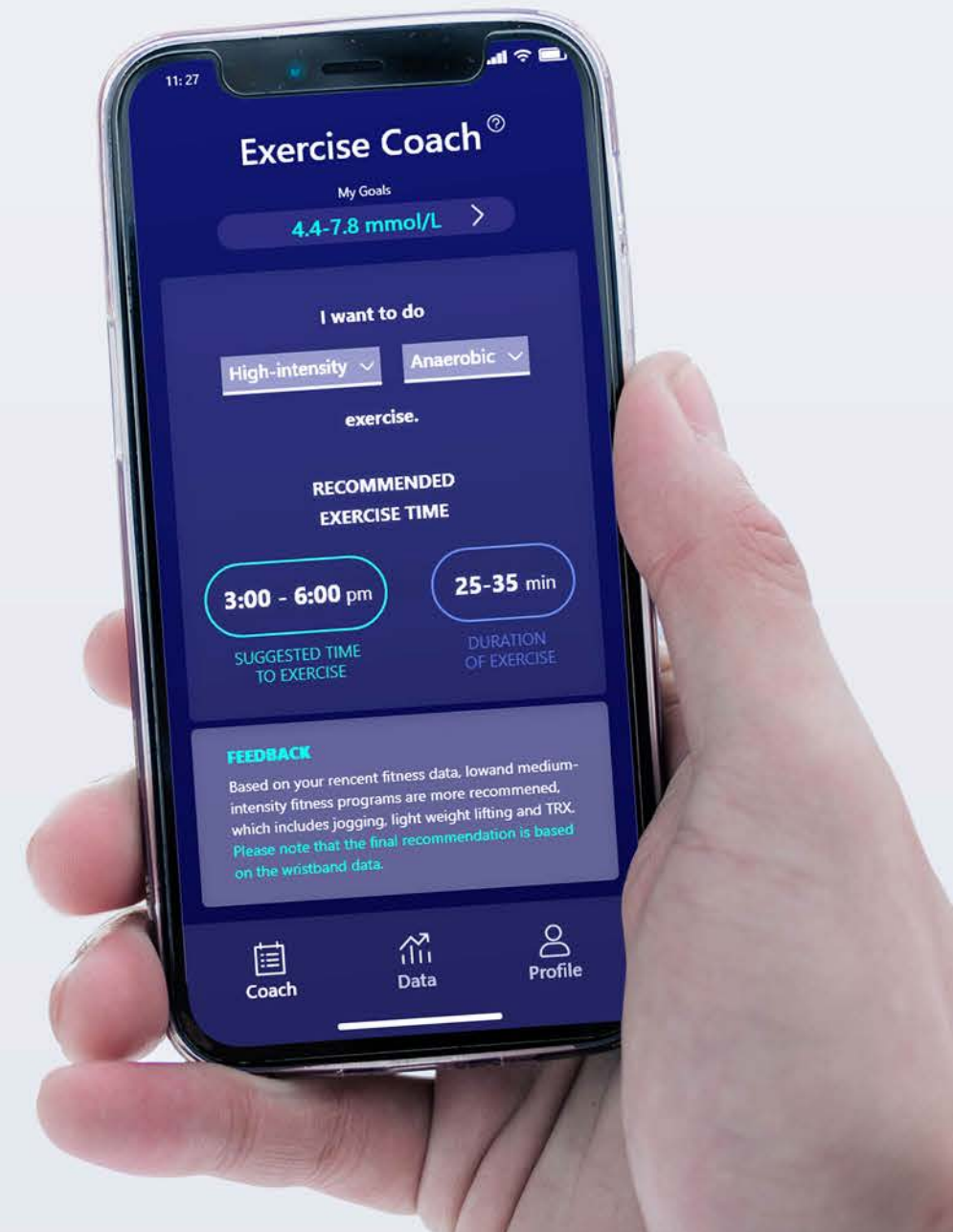


The strap uses a magnetic connection.



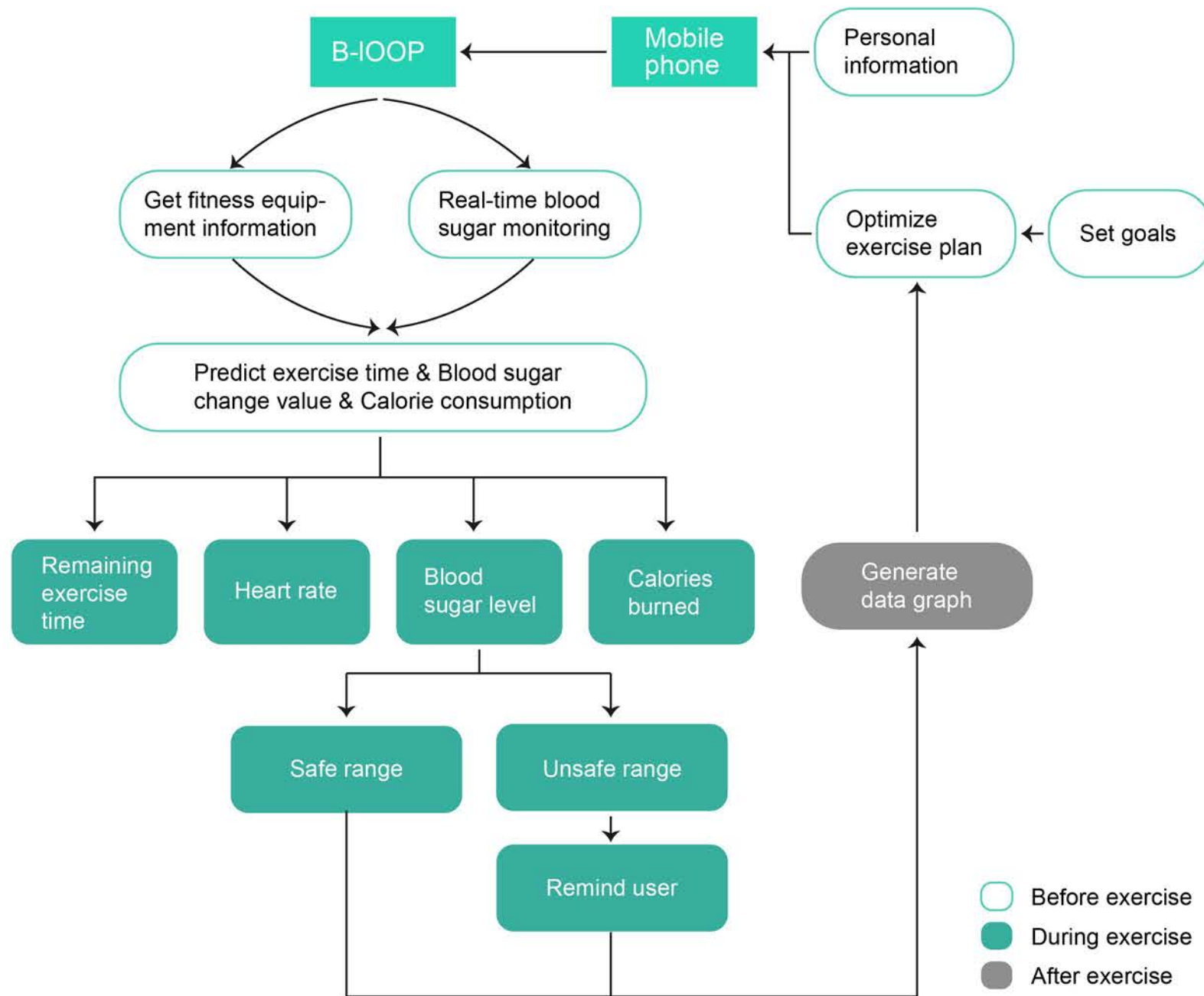
The heart rate sensor and blood sugar sensor are on the back of the wristband.

There is a "Exercise Coach" on the mobile phone terminal, where the users can set their goals and choose what type of exercise they plan to do. Based on user personal health information and recent fitness data collected by the B-IOOP, it could tell users the recommended exercise time as well as the feedback.

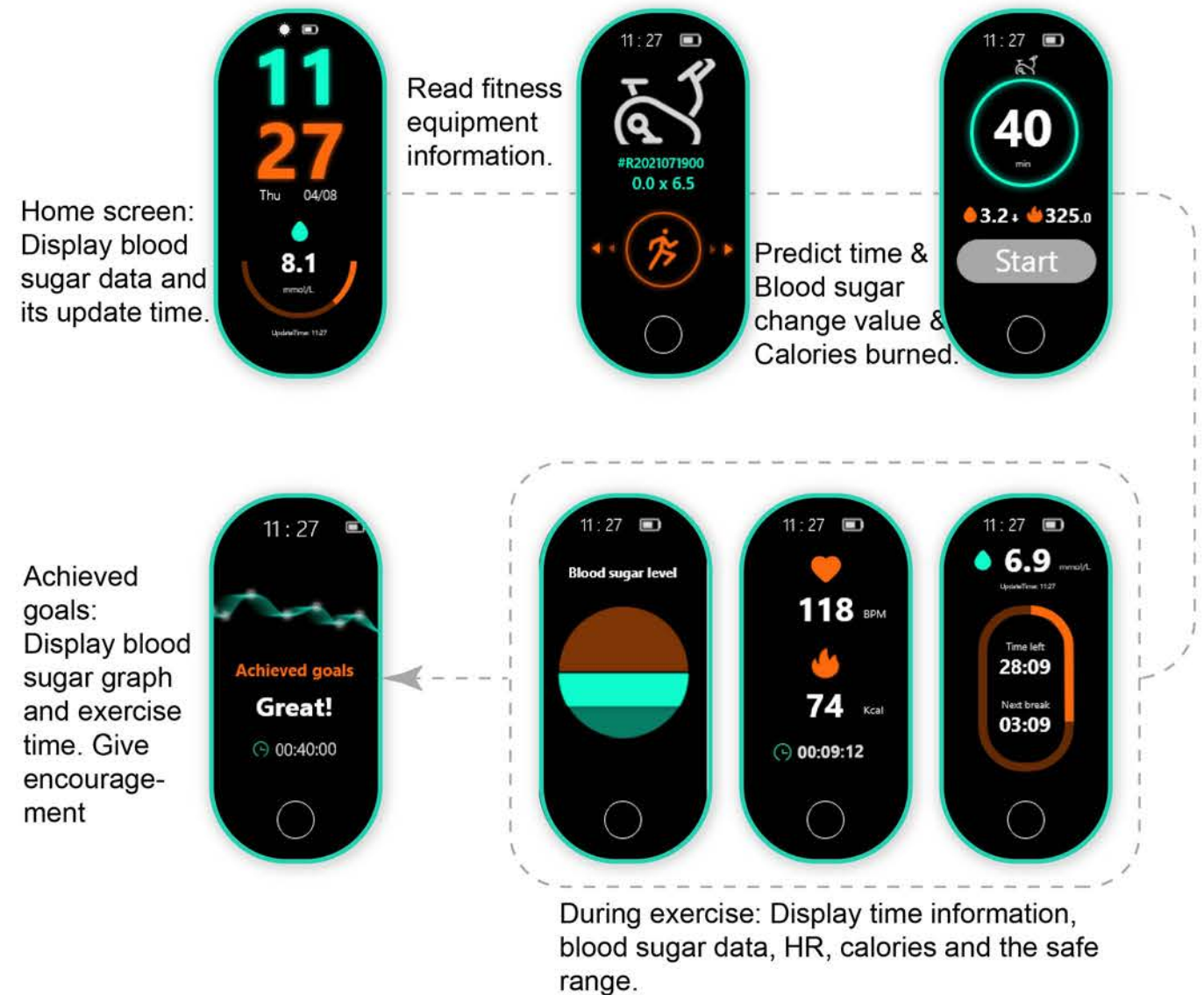


Personalized feedback loop

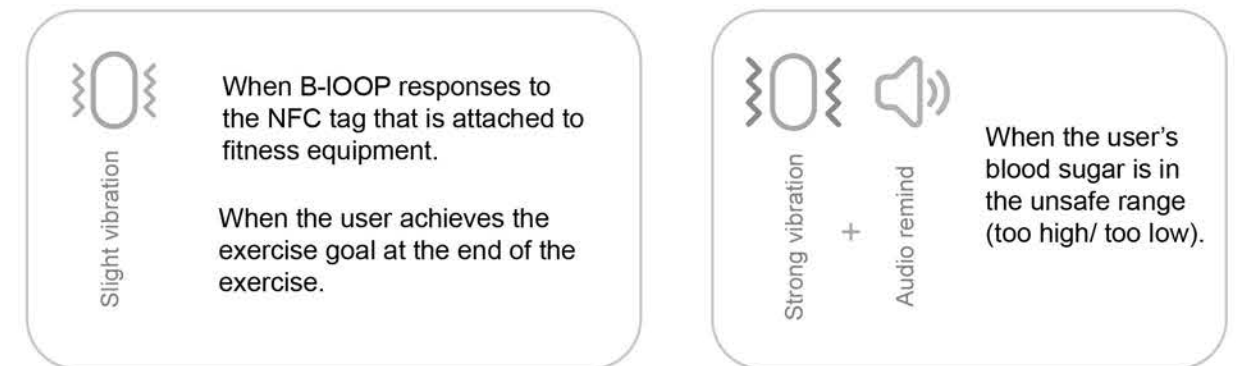
This feedback loop shows how this project system works. The users input their personal information including height, weight, age, ICR and ISF, and their goals on the App in the mobile terminal. Then the mobile phone will send the data to B-ILOOP. When fitness, B-ILOOP will monitor the user's data and remind the user. After the exercise, B-ILOOP will transmit the fitness data back to the mobile phone and generate data graphs to optimize the exercise plan and give the user feedback.



B-ILOOP interface flow



Interaction in different scenarios



■ Story board



1/ "Exercise Coach" can provide the user the exercise guidance and feedback before fitness.



2/ Place B-IOP close to the NFC tag to obtain fitness equipment information.



3/ After seeing the predicted exercise and body data, click "Start".



4/ Start to exercise. B-IOP monitors the user's body data during the exercise.



5/ Check the blood sugar level and other information during exercise.



6/ Remind the user by both sound and strong vibration when blood sugar level is in dangerous range.



7/ Slight vibration tells the user that the exercise goal has been achieved.



8/ Generate exercise reports and optimize the exercise plan.

EXPLODED VIEW



