Hong Kong Student Science Project Competition 2023
Marymount Secondary School (Abstract)

Team Number: SCBC104
Project Title: FabriK (發布)
Project Type: Invention Design Proposal
To our best knowledge, there ~~are~~ / are no similar works in the market;*
The enhancement our project proposed / the difference with related products are: N/A

I. Background

Target Audience: Diabetics

Background Information:
A person who has had diabetes for several years may develop neuropathy, a reduced or complete lack of ability to feel pain in certain parts of the body due to nerve damage caused by elevated blood glucose levels over time. A lack of sensation within the lower parts of the body, especially the foot, may lead to an unnoticed open sore or wound that may develop into a foot ulcer. Diabetic foot ulcers are a severe and common condition in diabetics, with an estimated cumulative lifetime incidence of 15-25%[1][2].
Ulcers form due to a variety of factors, including poor circulation, foot deformities, irritation (friction or pressure), trauma, as well as the duration of diabetes. Complications due to lack of attention to the injury may arise as a result of neuropathy, increasing the risk of infection and the severity of the foot ulcer. In severe cases, nontraumatic lower extremity amputations may be necessary to mitigate the damage caused. It has been calculated that about 5% of patients with diabetes mellitus develop foot ulcers, with approximately 14-24% of them needing an amputation. In 2021, diabetes was the leading cause of non-traumatic amputations in the US.[3][4]

Overview of Product Design:
A footwear (fabric material) is designed to be able to detect blood (from wounds and scabs) to mitigate the effects of diabetic neuropathy and allow faster responses for treatment of injuries to prevent development of foot ulcers.

Research/Technology Gap to be Filled:
Currently the most common methods of detecting diabetic foot ulcers are through analysing blood circulations, plantar foot pressure, and foot neuropathy. While it is more accurate, these methods require the patient to visit the hospital regularly to conduct blood tests, MRI or X-ray scans, making it intrusive, costly and inconvenient. This disincentives diabetics from conducting regular assessments[2].
Nonetheless, with the rapid development of technology, researchers have been exploring alternative methods of detecting diabetic foot ulcers through smartphone programmes and footwear, such as utilising thermal cameras on smartphones[2] or machine learning[5]. Yet, at present, there is no method developed for diabetics to assess foot ulcers passively, all existing products need constant attention and thoughtfulness from the patient. As such, there is a need for a design that allows diabetics to conduct self-assessment without requiring extensive knowledge on the disease.

II. Objective(s)

As diabetic foot ulcers are a prevalent and concerning health problem among diabetics, early detection is crucial before the complications develop into more dire stages that require amputation. **This project aims to create a fabric (called FabriK) that can detect the presence of blood on the skin of the foot to act as an indicator for the possible development of diabetic foot ulcers, such that diabetics can discover foot ulcers at an earlier stage and get adequate treatment.** It also reduces the severity of the consequences of diabetic foot ulcers.

III. Methodology

Blood Indicator:
Phenolphthalein is a prospective indicative chemical capable of providing the astute observation of whether blood is present or not in a particular area of interest. It detects the presence of haemoglobin by relying on the peroxidase-like activity of haemoglobin in blood to catalyse the oxidation of phenolphthalein (the colourless, reduced form of phenolphthalein) into phenolphthalein, which is visible as a bright pink colour. This is a technique commonly employed by forensics crime labs in the chemical identification of blood, being dubbed as the Kassel-Meyer test.[6]

Approach:
To attach related indicative chemicals to fabric in a process similar to dyeing, such that the chemicals would be affixed towards the polymer and be able to detect the suitable changes upon the foot.
The dyeing process could be described as the interaction between a dye and a fibre, being the integration of dye into the internal fibres of the fabric by the means of adsorption (the transfer of dyes from the aqueous solution onto the fibre surface) and diffusion (dyes diffused into the fibre).[7] In a similar approach to the conventional means of dyeing, the process of ingraining the chemicals of phenolphthalein onto our desired fabric would comprise of:

1. Movement of the phenolphthalein molecules from solution to the substrate surface.
2. Adsorption of phenolphthalein on the substrate surface.
3. Diffusion of the phenolphthalein from the substrate surface to the internal fibre through its amorphous regions.
4. Fixation of the phenolphthalein within the substrate via covalent bonds, hydrogen bonds, ion-exchange or van der Waals forces, or through insolubilisation of the phenolphthalein.[8]

Experiment:

I. Testing the Colour-Changing Intensity of Phenolphthalein
II. Testing if Phenolphthalein could be Absorbed and Diffused into the FabriK

Materials Needed:

- Kastle-Meyer Reagent (prepared by ourselves in the laboratory)
- Phenolphthalein
- Hydrogen peroxide
- Different textiles and fabrics, e.g., FabriK
- Blood sample (due to the ethical issue of human testing and the availability in the wet market, chicken blood is used instead of human blood)

Equipment:

- Desiccator
- Beakers
- Dropper
- Glass rod
- Test tubes
- Measuring cylinder
- Swab
- Heat plate
- Electronic balance

Procedure for Testing of a blood sample:

1. Collect a blood sample with a swab.
2. Add a drop of phenolphthalein reagent to the sample.
3. Add a drop of hydrogen peroxide to the swab.

Expected Results:
If the swab turns pink rapidly, it is said to test presumptive positive for blood.

IV. Design of Invention

V. Application / Market Need

Application and function of invention
The FabriK will be worn by diabetics, or people with neuropathy who have difficulty in sensing the sensation of pain in the foot. It changes colours when it detects blood, indicating a possibility of developing diabetic foot ulcers.

Market needs and potential impact of FabriK
In 2022, the annual incidence of diabetic foot ulcers worldwide is between 9.1 to 26.1 million, indicating that there is a large potential market for products able to mitigate the damages caused diabetic foot ulcers. The FabriK would mitigate the effects of foot ulcers by alerting diabetics of their presence, allowing them to receive early treatment and decreasing the need for amputation and hospitalisation, thus reducing the overcrowding of hospitals.

Limitations
The FabriK simply gives diabetics a possible indicator of developing diabetic foot ulcers and not an accurate analysis of their current condition. It cannot fully substitute the need for regular hospital visits for the diabetics and diabetics using the product should continue going to necessary medical examinations. Moreover, the principle behind the FabriK, the Kastle-Meyer test, has a few limitations as well, some other chemical oxidants such as copper and nickel salts may cause the reagent to change colour of the indicator without the presence of blood. Furthermore, the test is not specific to only human blood as it is dependent on the presence of haemoglobin, any other haemoglobin-based blood may alter the results. Thus, it is possible that the blood test can generate false positive results.

VI. If your team will compete for the Sustainable Development Award, please indicate the specific sustainable development goal the project is related to, and provide justification for competing for this award. *(Word limit: 300 words)*

From the Hospital Authorities 2022-2027 strategic plan[9], the Task Group on Sustainability formed under the HA Board is working out methods to tackle the issue of overcrowding hospitals in order to develop a sustainable future for HA. Since the FabriK allows the diabetics to conduct simple self-assessments as well as the early detection of diabetic foot ulcers, diabetics would not have to rely on regular visits to the hospital to assess their risk of developing diabetic foot ulcers. Moreover, the FabriK would decrease the risk of diabetic foot ulcers developing to a stage where amputation or surgery is required. As such, resources can be saved and the waiting time for hospitals would be reduced, promoting sustainable development in hospitals.

VII. If your team will compete for the Social Innovation Award, please list the target group or social issue the project focuses on, and provide justification for competing for this award. *(Word limit: 300 words)*

This project focuses on diabetics as well as people with neuropathy who have difficulty in sensing the sensation of pain in the foot. If the diabetic foot ulcer cannot be detected early enough, clinicians may resort to amputation. Amputation may severely impact the patient's quality of life[10]. A study[11] found an inverse relationship between health-related quality of life indices and number of foot ulcers in diabetics, due to the disruption of leisure activity. Another study[12] showed that there was a relation between the incidence of depression and the patient's perceptions of unpredictable outcomes. With the FabriK allowing not only a prompt detection of diabetic foot ulcers to reduce the risk of needing amputation or surgery, but also giving diabetics an accessible and simple way of self-assessment, it gives them assurance on the state of their condition, reducing feelings of unsteadiness and possibly improving their quality of life.
By extension, FabriK also targets the worsening social issue of overcrowding hospitals in Hong Kong. Overcrowding of hospitals is a concerning issue that is prevalent among all social classes and groups, with countless affected by this problem. Not only that, there are 9.1 to 26.1 million people worldwide affected by diabetic foot ulcers in 2022. Thus, there is a large social demand for an innovative product that can not only alleviate the stress on the healthcare system as well as its individual diabetic patients.

VIII. Conclusion

In conclusion, we believe that the FabriK can alleviate the consequences of foot ulcers by allowing preemptive warning of their development and providing diabetics the chance to revive proper treatments before the exacerbation of their injury. This can prevent foot ulcers from progressing into a severe state where amputation is necessary as well as lessen the burden of the healthcare system.

In the future, we hope to improve upon the efficiency of injury detection, expanding towards not only sensing the presence of blood but also pus, extracellular fluid and other materials involved in injuries, refining upon the identification of even minor injuries. We believe that this FabriK is important to not only the diabetic community but also the medicinal world as a whole, relieving them of the strain of dire medical care.

References

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