

New Zealand Artificial Limb Service Final Report

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Project title: Product design of a pair of ergonomic crutches

Executive Summary

Traditional full length crutches have fallen out of favour with the medical profession and consumers as they routinely cause arm injuries (blistering, broken vessels in the veins and swelling) and can sometimes lead to a condition known as crutch paralysis, or crutch palsy, which arises from the pressure put on nerves in the armpit, or axilla. Many consumers use forearm crutches, but these have their own disadvantages in that the load on the body during their use is not evenly dispersed, resulting in huge strain being placed on the shoulder, neck and back. The purpose of this project was to research and design a viable alternative to traditional crutches based on the muscular system of a human leg. The crutch would incorporate a shock absorbing feature to reduce jarring and repetitive strain on the body of the user. An ergonomic crutch was designed, featuring a curved centre pole, as opposed to a straight central pole. The researcher is currently working towards the development of a prototype of the crutch made of carbon fibre, with the aim of taking it to a clinical trial at the WDHB.

Background

This project came about after the researcher observed the pain and discomfort a colleague encountered when using standard DHB-issued crutches for even a short amount of time. As a product designer the researcher began to consider what a viable alternative to traditional crutches could look like. Standard crutches assigned by DHBs to patients with foot or leg injuries are generally used for a period of four to six weeks. However, people with amputations involving the foot or leg will generally need to use crutches for a longer period of time. It is therefore essential that the ergonomic crutches can perform at a higher level of comfort.

Aims and Objectives

The aim of this project was to design and build a pair of ergonomic crutches that would be suitable for a range of users of different ages and with different kinds of leg amputations. The crutches would provide an important means of mobilisation from the stage of amputation (healing and recovery) to the stage when a new artificial limb is fitted. The researcher would explore the application of advanced composite materials to enhance the crutches' form and function, thereby reducing the strain and discomfort associated with the use of traditional crutches.

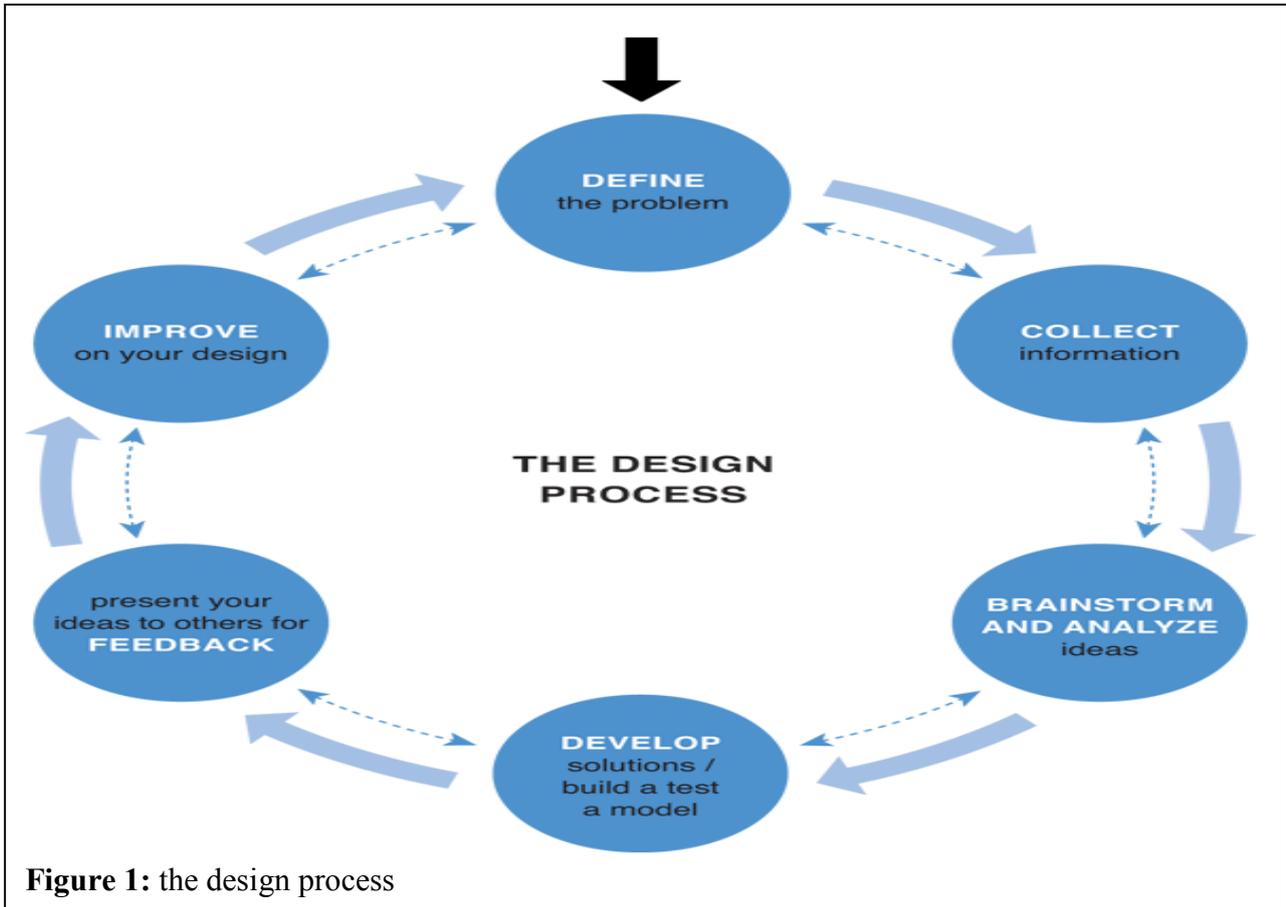


Figure 1: the design process

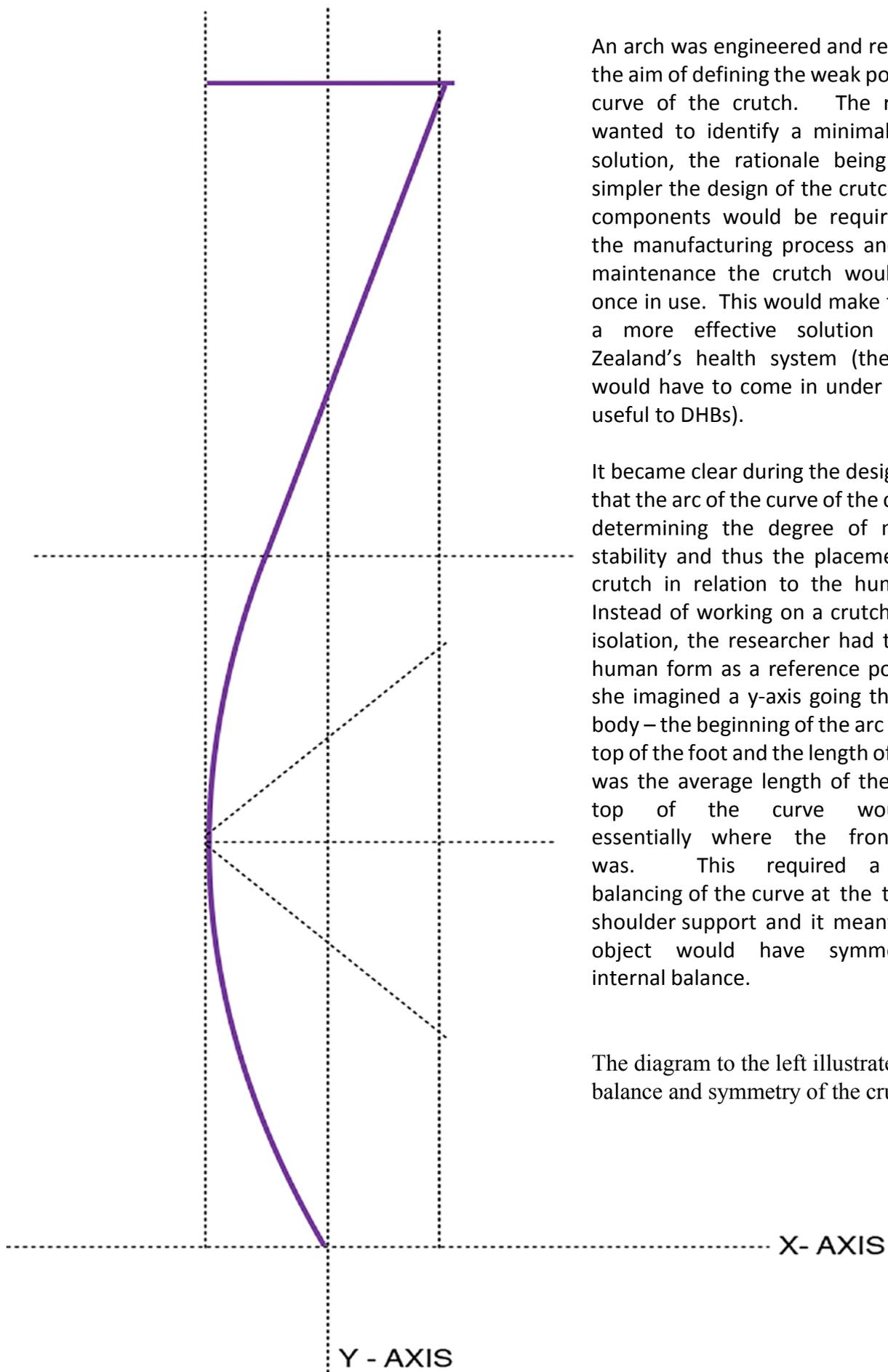
The idea behind the design of the new generation crutch was to include a shock absorbing feature to reduce jarring and repetitive strain on the body of the user. The design process involved identifying a non-mechanical shock absorbing solution as the researcher didn't want to incorporate a spring (the means by which mechanical energy would usually be stored).

The focus of the design of the crutch was on a curved centre pole, as opposed to a straight central pole. In theory, when force is applied to the curve the pole will bend, reducing the amount of impact on the user's body. Most of the design process involved calculating the mathematical arc of the curve and trying to find its mid-point (refer Figure 2²).

Figure 2: Hooke's law is a principle of physics that states that the force F needed to extend or compress a spring by some distance X is proportional to that distance. That is: $F = -kX$, where k is a constant factor characteristic of the spring, its stiffness. Hooke's law is only a first order linear approximation to the real response of springs and other elastic bodies to applied forces. It must eventually fail once the forces exceed some limit, since no material can be compressed beyond a certain minimum size, or stretched beyond a maximum size, without some permanent deformation or change of state. In fact, many materials will noticeably deviate from Hooke's law well before those elastic limits are reached. The modern theory of elasticity generalizes Hooke's law to say that the strain (deformation) of an elastic object or material is proportional to the stress applied to it.

¹ <http://discoverdesign.org/design/process>

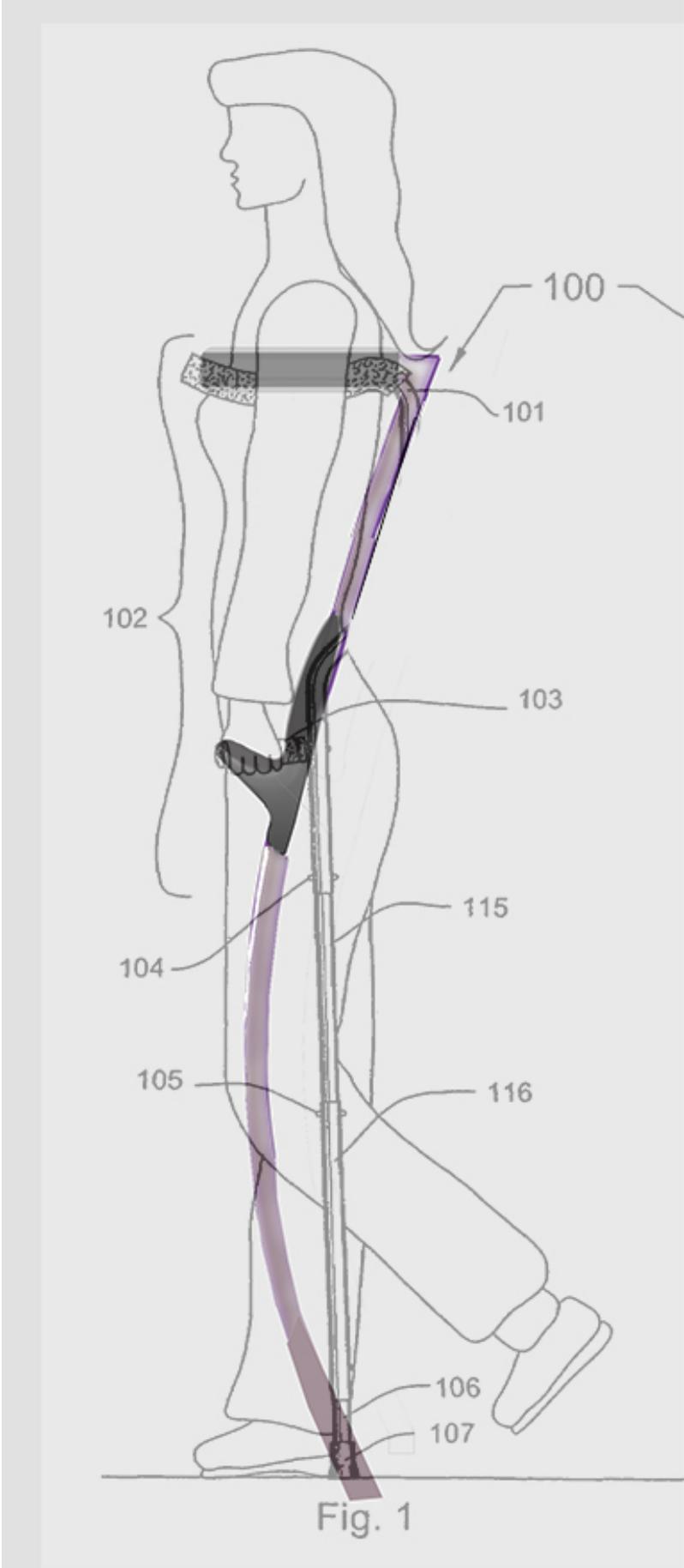
² https://en.wikipedia.org/wiki/Hooke%27s_law



An arch was engineered and refined with the aim of defining the weak points of the curve of the crutch. The researcher wanted to identify a minimalist, purist solution, the rationale being that the simpler the design of the crutch, the less components would be required during the manufacturing process and the less maintenance the crutch would require once in use. This would make the crutch a more effective solution for New Zealand's health system (the crutches would have to come in under \$50 to be useful to DHBs).

It became clear during the design process that the arc of the curve of the crutch was determining the degree of movement stability and thus the placement of the crutch in relation to the human form. Instead of working on a crutch design in isolation, the researcher had to use the human form as a reference point. Thus she imagined a y-axis going through the body – the beginning of the arc was at the top of the foot and the length of the curve was the average length of the leg. The top of the curve would end essentially where the front handle was. This required a counterbalancing of the curve at the top at the shoulder support and it meant that the object would have symmetry and internal balance.

The diagram to the left illustrates the balance and symmetry of the crutch.



Above: Counter crutch interface with the human form.

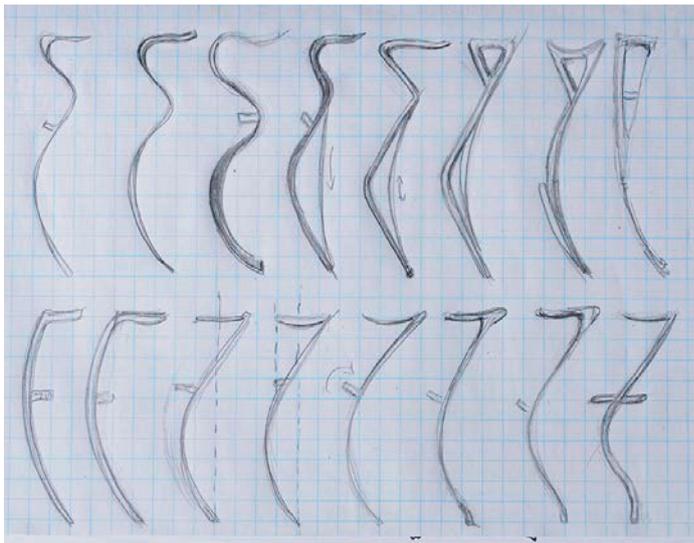
Conclusions/future work

Overall the researcher considers that the project has met its stated objectives, however as an end product the crutch is not quite ready. The researcher is happy with the form of the crutches, but she is still considering their performance. Is carbon fibre the appropriate material? What about aluminium? Would another crutch altogether pose a better solution? If she was to explore this project more, she would probably look at another hydraulic mechanism, which is semi-mechanical. Maybe a fluid shock absorber system with a straight pole? The researcher would like to be able to focus more on the finer details.

The next phase of the project would also involve focussing on personalising the settings of the crutch. This would mean that users would be able to adjust the angle and height of the crutches according to their personal preference.

When the design of the crutches is finalised, they would need to be tested on able bodied people as a first step towards getting approval to use them in a clinical trial at the WDHB. The applicant would like to enter the crutches into the Waitemata District Health Board's annual Health Excellence Award scheme.

Supporting images



The concept drawings (left) demonstrate how the curvature of the crutch was explored

Below: full scale drawings of the crutch design



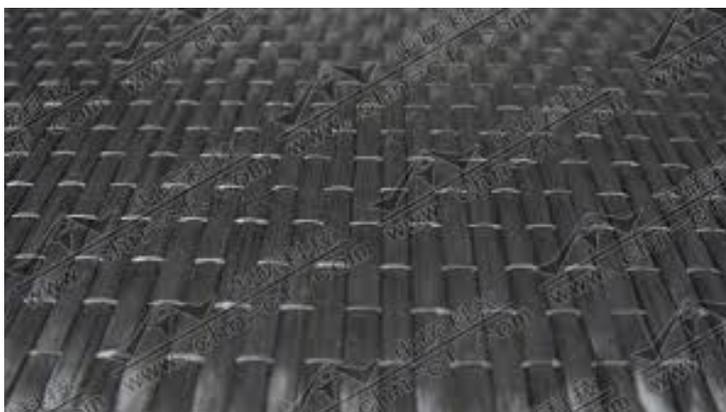


Above left: transferring the drawings into wire frame, full scale models. Above right: a first prototype exploring the radius of the curve using more solid materials.

Below left: exploring the ergonomic shapes for the crutch handles (grip) and embodying a wrist support. Below Right: experimenting with different shapes and tread textures for the rubber foot.



Below: a jig (a base which has the crutch curve and into which the carbon fibre was laminated) for the crutch. Each laminate was applied and then the crutch was tested for its flexibility. There was a total of eight to 10 laminates.



Above: close up of the fibre carbon.

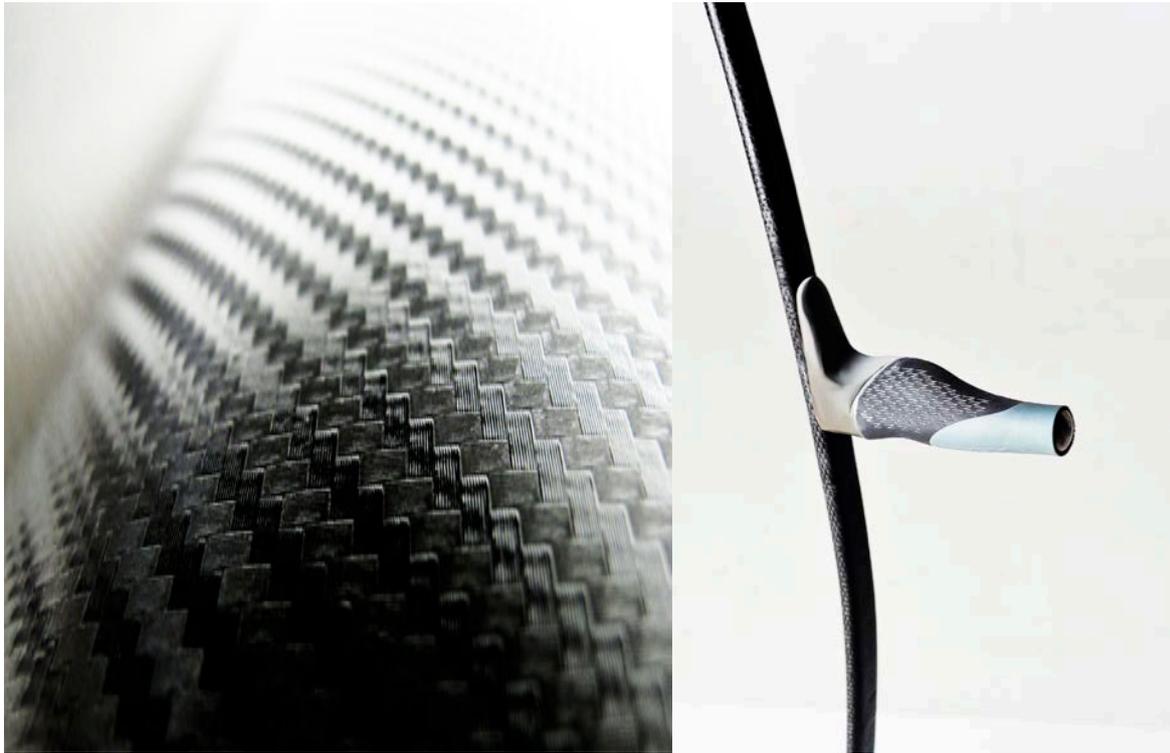


Above: the finished crutch!

Right: The finished crutch



Above: the angle of the forearm corresponds exactly with the angle of the crutch, providing a lot more support and reducing the strain on the body.



Above: close ups of the crutch handle. The aesthetic was modelled on a sports styling.

Below: shows how the palm is cradled.





Left: two images overlaid on top of each other. Estimating a 10-20% flexibility in the carbon fibre response, which is based on the researcher's own weight. If she was heavier, it would be more. NB: the researcher has so far been the only one to trial the crutch.



Above: the normal position of the crutch and then photo overlay of it in motion.



Above: illustrates that the crutch is very light weight.