# DESIGN OF A PORTABLE EXERCISE DEVICE FOR THE DIABETIC COMMUNITY

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## ABSTRACT

A person without diabetes manages their blood sugar level by way of their pancreas. The pancreas releases a hormone called insulin, and this hormone effects blood sugar control. Blood sugar levels must be kept within a certain range. If blood sugar levels are allowed outside this range the body may experience either Ketoacidosis (the effects due to low blood sugar levels) or Hypoglycaemia (the effects due to excessively high blood sugar levels)

Diabetes is an affliction whereby the body fails manage its blood sugar levels effectively. There are two main forms of diabetes and these are commonly termed type-one diabetes (sometimes called juvenile or insulin dependent diabetes) and type-two diabetes. Type-one diabetes affects more young people than does type-two. What separates these two main forms of diabetes is the cause for poor blood sugar control within the body. Type-one diabetes is a result of the body failing to release insulin. It is common for the patients immune system to have malfunctioned, causing it to attack the pancreas, preventing it from releasing insulin. Type one patients are frequently required to manage their diabetes by way of regular insulin injections.

Type-two diabetics frequently have a functioning pancreas. The cause for their condition stems from either inadequate volumes of insulin being provided to the body's cells, or a reaction by the body's cells preventing adequate uptake of insulin (termed insulin resistance).

Exercise forms an important part of a diabetics lifestyle for several reasons. A diabetic should assist the up-take of blood sugar after eating by exercising and with weight control being particularly important for diabetics, exercise can assist with this also.

The need for an exercise machine specifically for the needs of diabetics stems from when diabetics need to exercise and where they may be when they need to undertake such exercise. Many people are not comfortable exercising outdoors after dark, and often weather prohibits people from exercising when they need to. The portable exercise device for the diabetic community seeks to overcome these issues by providing a machine specifically for diabetics that is highly portable, easy to use and easy to assemble when needed. What follows is an outline of the research study performed, the design path taken, the design proposition and the continuing work required for this design's success.

## RESEARCH

To satisfy the needs and desires of diabetics requires some understanding of diabetes and those with the condition. It was recognised that given the special nature of the intended product, special attention would be required in both gathering information pertinent to design and then feeding this information into the design process.

Statistical research formed the cornerstone of the research undertaken and it illustrated both the merits for this project along with the direction required for its ultimate success. What follows is a brief discussion of the conclusions and facts that emerged as a result of the research undertaken.

With approximately fifty percent of diabetics being over the age of 65, diabetics are predominantly elderly people. The demographics also show a significantly higher prevalence of diabetes amongst indigenous Australians and overall, diabetics constitute around 4 percent of the wider Australian population. Around 86 percent of diabetics are of type-two, however this correlation between type-two and type-one diabetes varies with age since type-two becomes more prevalent as age increases. Poor weight control is more common amongst the diabetic population with around twice as many diabetics being considered overweight when compared to the non-diabetic population. In a similar fashion there are more than twice as many diabetics with cholesterol problems and nearly twice as many physically inactive persons in the diabetic community.

In addition to our research findings, the process of research introduced the team to doctors and specialists prepared to participate, scrutinise and discuss developments and design issues. The above summary issues of physical inactivity, obesity, high cholesterol levels and the ever increasing prevalence of diabetes over time suggests that there is a definite need for diabetics to increase their level of physical activity. This conclusion has been supported through correspondence with medical professionals specialising in diabetes. Also, the fact that so many diabetics are of type 2 indicates that exercise will be a significant benefit to the overwhelming majority of diabetics, since type 2 diabetics commonly have a functional pancreas, yet the cells are not responding well to blood sugar. Our findings showed that exercise is proven to improve the uptake of blood sugar, hence the significant opportunity for an improved condition through exercise. Further to this, it is recognised that exercise can lead to better weight control, hence that insulin produced by the body is better utilised. Based on the fact that circulatory problems form one of the biggest reasons diabetics have to go to hospital, this exercise should be of a cardiovascular (aerobic) nature. Finally, based on the age distribution and the socio-economic information, our design must address the fact that the bulk of the diabetic community is not wealthy and not particularly young.

Overall, the statistics shown here, coupled with the statistical benefits exercise offers, allow us to assert that through exercise, diabetics are likely to improve their condition, and reduce the chance of the long-term effects of diabetes such as amputations, vascular problems and heart disease. It is also clear that those who do not have diabetes but are at risk of developing the condition through say family history, are statistically shown to reduce their chance of developing diabetes if they exercise on a regular basis.

## CLARIFICATION OF DESIGN TASK

Research showed that foot sores and amputations are more common amongst diabetics than non-diabetics. This alone illustrates that the conventional walking treadmill imposes restrictions and has problems that may be overcome through a different design concept. A new objective was defined and the project was established to be to design, analyse and build a compact, portable exercise device specifically for the diabetic community.

Several key research findings fed directly into the conceptual design phase and the corresponding design principles were received favourably by medical specialists involved in the project. Most importantly, it was established that a recumbent exercise technique was most appropriate for the objective. The recumbent technique removes the static component of the load (due to the users body mass) from the knees, hips and feet. A medical expert agreed that it would be not difficult to show that this alone would reduce the likelihood of foot sores during exercise (which are more common and pose a significant problem for diabetics).

It was clear from this early stage that the recumbent design offered a greater capacity for the machine to be made compact and portable when compared to other exercise techniques. This is partly due to the users centre of gravity being much closer to the ground whilst using the machine. Considerable emphasis was placed on the design possibilities for the resistance device and after constructing a model of human leg motion it was shown that a resistance device for human leg motion appealed to a fluid resistance mechanism. This also proved to be a cost effective design solution. There were several options for the recumbent position, namely recumbent rowing motion, recumbent cycling and out-of-phase recumbent rowing. Due to the design requirement of a portable device, the recumbent rowing motion was shown to appeal to our design task more than our other options. The recumbent rowing motion lead us to a simpler, more elegant design, with fewer moving parts and with greater flexibility in how the machine could be used. In summary, the conceptual design phase showed that a recumbent rowing machine utilising a fluid resistance would provide the most effective outcome to the design task.

## DETAILED DESIGN

### Design For Manufacture

After the completion of the conceptual design phase, feedback was sought for two main reasons – to refine design components so that manufacture could be more easily (and cost effectively) achieved and to refine design components so that the end product better suited its intended users.

At concept level, our design employed a two-channel design (see figure 1). Each side of the seat was supported on two rollers. Each roller incorporated 2 deep-groove ball bearings and on either side of the seat, pairs of rollers bared their load onto a channel. This gave a total of 4 rollers, 8 rolling element bearings and two channels. Rollers were retained in position by an extruded guide which guided the rollers whilst in operation and a roller shield which prevented the rollers from falling out of position whilst the machine was stowed or not being used.

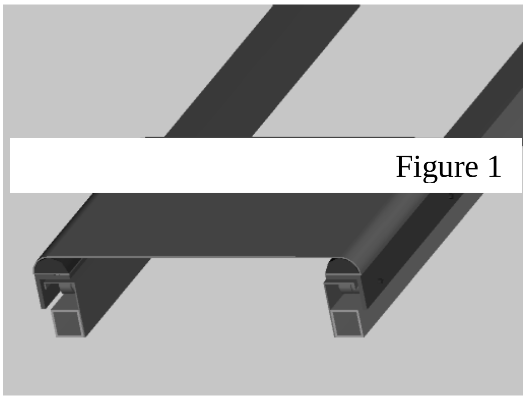

Figure 1

This concept was refined considerably by introducing a single channel design (see figure 2). This enabled us to achieve the same overall outcome, but with a simpler system consisting of far fewer parts.

The single channel design supports the seat by way of 3 rollers. Each roller incorporates 2 rolling element bearings. The rollers are supported by one square-section channel and the nature of the lay out means retaining the rollers in position is not required as it was in the initial concept.

The net result of this process was to reduce the number of rolling element bearings from 8 to 6, the number of rollers and roller shafts from 4 to 3, reduce the number of channels from 2 to 1 and totally eliminate the need for roller shields and guides. The new design also removed the need for hinges all together, and introduced pinned joins as a means of making the machine portable and compact for moving around. Removing hinges reduced the number of required parts, reduced the complexity of the system and made fabrication considerably more simple.

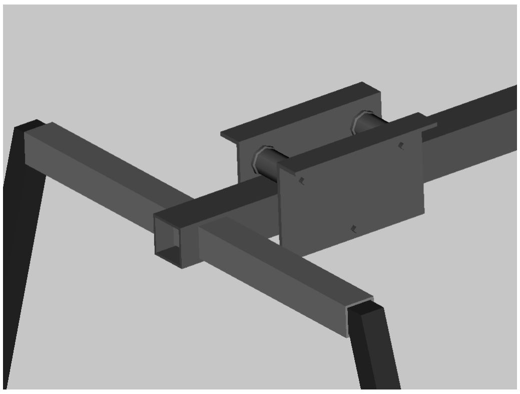

Figure 2

Feedback form expert doctors suggested an effort to elevate the machine off ground level should be made. The reason for this is that it may be difficult for users to get down to and off the ground for each exercise session particularly if the user is elderly. Appealing to every day items, we made sure that the seat height of our machine could be set to the same height as a standard double bed. The aim was that it should be no more difficult to get onto our machine than it would be to sit on a bed. Elevating the chassis was achieved by way of four legs that are pinned into place as illustrated.

### Design for fatigue life

The nature of usage for our design is such that cyclic loads are present in all parts of the chassis. Fatigue analysis for the chassis was based on a model for maximum usage. The model for maximum usage is a 200kg person using the machine for 3 hours per day, every day for 5 years. Every part of the chassis has been designed to accommodate this loading criterion and this hence defines the fatigue life.

Throughout the chassis welds have been avoided where possible. From fracture mechanics, we understand that all welds contain small discontinuities that could be critical under service conditions. Without knowing the size and shape of such discontinuities we can not ascertain the effects that welding could have on reducing the fatigue life. Further to this, the material we are using here has been heat-treated to a T6 condition so that any welding will effect a change in the microstructure in the vicinity of the weld (HAZ). Throughout the main channel, no joining is by way of welds. Mechanical fasteners have been employed, with the quantity and arrangement being so that the maximum usage model could be satisfied for each and every stress raiser arising from its corresponding fastener.

Welding was employed on the 4 support legs, and here we analysed the strength and fatigue life of the weld joint by considering that the heat affected zone had brought the material to its softest (annealed) state.

Design of resistance device

Conceptual design uncovered a definite superiority in fluid based resistance devices. Having observed that many commercial rowing machines incorporate a fan to effect such a fluid resistance, the merits of this possibility were assessed. It quickly became apparent that incorporating a fan would not be realistic for our design task because of the size restraints imposed for our task. Hydraulics were assessed also. Through a local hydraulics supplier a small pump was sourced and analysis was performed to determine its effectiveness for our task. The objective was to design a system where we could drive the pump, and effect resistance by way of a return loop incorporating a restriction valve.

This analysis enabled us to determine the flow restriction required for our hydraulic circuit and gave us information on the expected heat dissipation from the device. Gear ratios were also determined (for the necessary speed required to drive the pump) and v-belts, pulleys and bearings were selected accordingly. Finally, the analysis showed that the hydraulic resistance would provide a smooth feeling leg motion whilst being used.

FINAL DESIGN AND FEATURES

Consider figure 3. The 4 support legs are held in place by cotter pins, which pass through the cross brace shown. The Cross Brace is slotted into the main channel; a large rivet prevents the Cross Brace from passing too far through the Main Channel and is pinned in place by a removable cotter pin on the other side of the main channel. The seat is mounted on top of the roller assembly (not shown), and is removed when the device is disassembled for carrying. The roller assembly is free to glide up and down the main channel between the cross braces, which are far enough apart to allow even the tallest person to fully straighten their legs. The extension of the main channel beyond the second Cross Brace provides the mounting points for the hydraulic system, the v-belt system, and the drive mechanism (not shown). The drive mechanism (which is similar to the starter cord assembly of a lawn mower) allows the user to pull on its cord while pushing away with their legs and when relaxing their legs, the drive mechanism retracts the chord into its in-built spool ready for the next stroke. The users feet are supported in moulded foot supports which are attached to the furthest cross brace as viewed in figure 3.

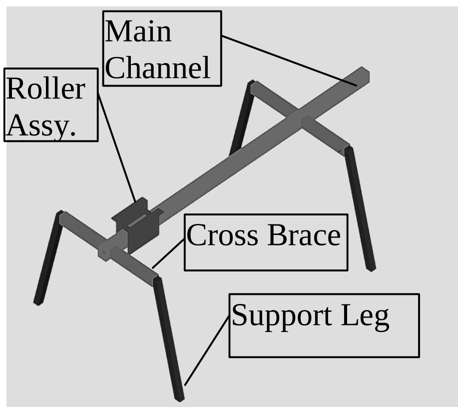

Figure 3

## ON GOING WORK AND PROJECT DIRECTION

Currently, a full-scale prototype of the diabetic rowing machine is being built. In parallel with this is an FMEA study of the machine. Once the prototype has been built and is functional in every aspect, a testing phase is required. In accordance with industry standards, destructive fatigue life testing is intended to ensure our maximum usage model is satisfied. Testing needs to be performed on every aspect of the design from the seat strength to the effectiveness of the hydraulics.

At this point the join in the main channel has been designed but has not yet been made. Construction of this component will be required before testing can be commenced. Particular emphasis will be placed on the analysis of the welded sections in the support legs also. Appropriate guarding will need to be designed and built for the pulley system. This will be required to meet the relevant Australian standards.

Upon satisfactory completion of the testing phase, a marketing pilot programme will be required. The aim of this is to gather market feedback on the design and to establish feedback on pricing. This pricing information coupled with manufacturing information will establish the potential for the future development of the diabetic exercise machine as a viable business venture. Due to the nature of this single-person project, as discussed, the majority of these tasks will need to be performed in the following year's project group.

## ACKNOWLEDGEMENTS

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