Agile
10 Page Summary

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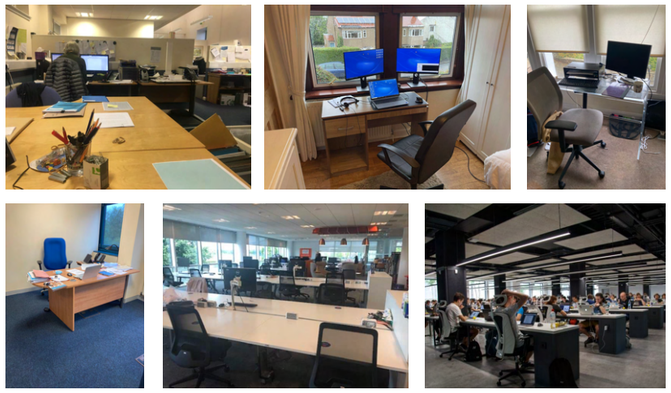
PDE 5 MEng

Project Overview

The Problem



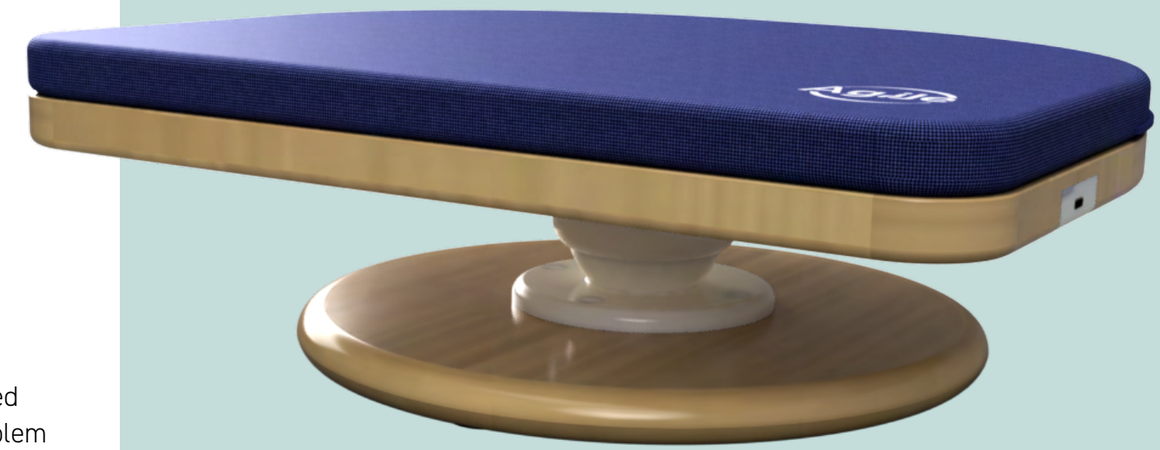
A working day and environment is one that can be extremely varied between users at home and in the office. However a common problem experienced is being tied to a desk for hours of a day. This results in a reduced level of mobility, which in turn creates lower back pain.

Current products on the market that try to combat this problem are unsuccessful as they introduce too large a jump in mobility, where the user is either drained or extremely uncomfortable. On top of this, many products rely on the user continuously using them solely for the health benefits with no added incentive or interaction.

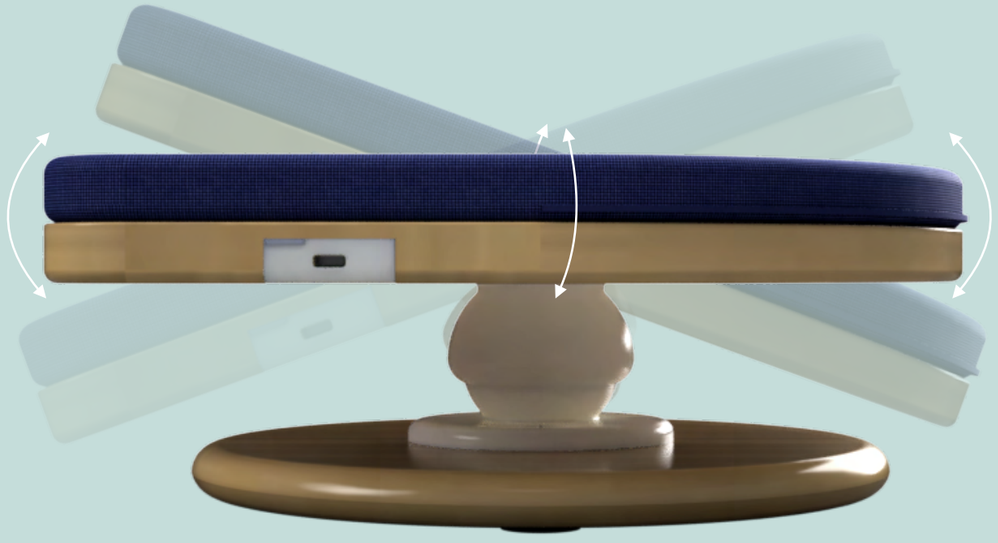
"A solution like this introduces mobility back into the office in an immersive and attainable way which would directly combat lower back pain. This idea shows a large amount of promise and is something I would be very interested in working further on with Aidan to take to market"
-Gavin Routledge, Head of Active X Backs

"The cure for lower back pain is simple - mobility and active exercises... It's clear from the stats that most people want the relief without having to change too much about their lifestyle. This idea I can see has taken this into account and therefore has a much greater chance of being adopted into a working life compared to other products I'd recommend to clients"
-Vicky, Chiropractor at Morningside Chiropractic

My Solution



2.5 kg, Height = 10cm + Cushion



Who:
15-65 year olds working from home and in the office in the UK that are bound stationary to a desk for hours of the day.

What:
A retrofit design placed easily on and off a user's office seat to allow for balancing as well as accommodating lower back movements for passive and active interaction that is tracked through an app.

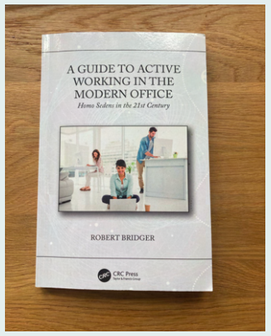
Where:
To be used at home and in the office, suitable for private or public workstations as well as hot desk scenarios.

When:
Can be used through the working day for the full time without the user feeling drained. It is recommended a lower back pain movement be achieved every 30 minutes.

Why:
The user can easily introduce active seating and mobility into their workspace in an accessible and interactive way to combat lower back pain through muscle engagement.

Research Insights

Active X Backs



The project was proposed to myself by the company Active X Backs, the only Edinburgh based osteopaths specialising in back pain and sciatica. The insights gathered from our meetings, the company's online course and journals on the problem were: lower back pain is the single biggest disability in the world and is not cured by a perfect posture but mobility; immobility causes a variety of health problem, but can't be cured by standing still as it is barely more physically demanding than sitting and produces varicose veins and load on back tissue; active seating is one of the best cures to engage muscle groups.

Day-in-the-life, Working Environments and Interviews

I found that many work from home or in the office, but in both environments many users cannot leave their desk due to nature of their work. However if they were to increase their level of mobility it would have to be conducive to their work i.e. not to point of sweating or exercise. Also the product must be space efficient as space is at a premium in workstation, but overall should tackle the biggest problem currently experienced which is lower back pain.

The Current Market

Many of the products on the market are unsuccessful as they are too big a jump in mobility. Almost none provide an aspect of awareness or achievement meaning the user is solely relying on the health benefits rather than enjoyment or social fitness. Also none are a complete fix, they either centre around posture, balance or movement but do not combine these aspects.

Experts and Literature

In reality there is not one key posture, it's all about movement. However many want the relief without having to change too much, meaning the movement must be accessible. An aspect of growth is also desired, as if it is too big a jump initially the user is prone to injury (acute to chronic ratio). NEAT was decided as a suitable level of energy expenditure for the workplace (anything that isn't sleeping, eating or sports-like exercise).

- **81% of UK workers spend 4-9 hours sat at a desk daily**
- **480,000 of UK workers suffer from work related musculoskeletal disorders in 2019/20**
- **Back pain accounts for 12 million work days lost every year**

Survey and Focus Groups

Through these methods I found majority of people need a workstation for their job. Standing desks also feel like too much work and can cause anxiety in public spaces, while for seating many get restless and desire movement. It was interesting to see that many businesses supply office based products to their employees for health and social fitness. However for most of these cases, a user will obtain a product for the health benefits but there's nothing else drawing them to continuously use it. Inevitably the product is thrown out or not used.

Design Opportunities

- **Incorporate growth to reduce jump for user and encourage them**
- **Use movement to combat lower back pain and it's impact**
- **Incentivise the user**
- **Create a balance between mobility, productivity and comfort**
- **Make mobility accessible**
- **Aspect of sustainability**
- **Should be convenient**
- **Could encourage sociability in the office**

The Brief

Design a solution that introduces mobility into the workstation in an accessible and incentivising way for the home and office. The solution should incorporate movement that is conducive to a working lifestyle and prevent lower back pain through muscle engagement.

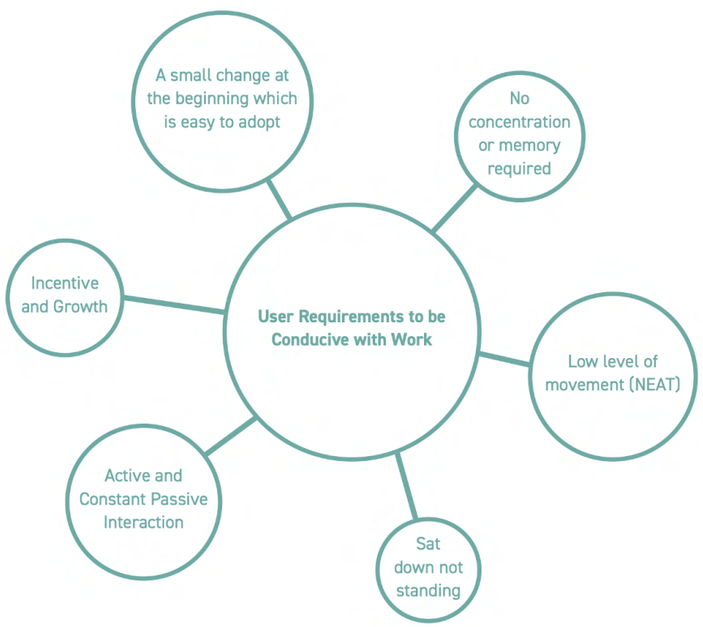
Concepts

Initial Ideas

Posted notes were used to quickly sketch down initial ideas. This allowed for groupings to be made for interesting overlaps, from which more convincing concepts could be constructed from these groups.

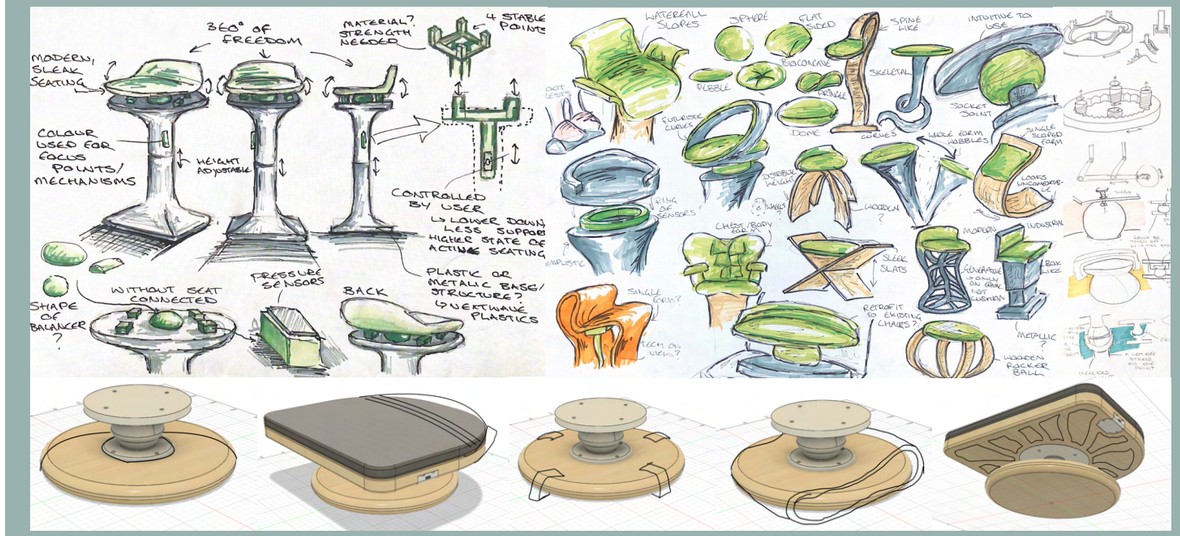
Focus Groups for Further Requirements

After initial ideas were constructed, they were analysed and shown to users and experts for feedback. The focus groups resulted in the following refined requirements:



2D Ideation

Sketching was useful for thinking of how the product could function and how various mechanisms of interest could be applied. Function was the main focus of the design with a great deal of time spent on how gamification could be integrated into the product. Aesthetics were considered throughout, with the simplistic final form taking inspiration from Scandinavian Design.



3D Ideation

Due to the product being centred around movement and seating, modelling in strong materials became vital for user testing. This allowed me to understand capabilities of different users when it came to balance and movements. Sizing was also of huge importance and creating models allowed for quick analysis of the product in its environment (on the chair).

Balancing and Movement Interaction

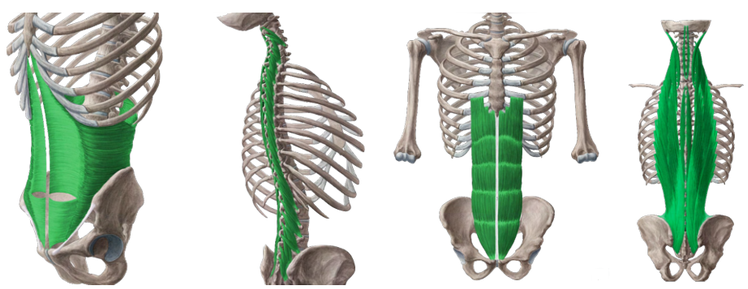
Balance Testing - Passive Interaction

Passive interaction that was accessible was a key aspect of the design. Testing was done for using a balancer on differing chairs to see how this effected muscle engagement and user opinion.

From this it was found that the user will naturally find their centre of gravity and therefore a balanced point, resulting in core engagement, without realising. However when the existing chair did not have a back rest or supports, the user did not feel safe and found the overall experience way too big a jump in mobility.

Specific Muscle Groups To Engage

Due to our bodies being different as well as our metabolic rates, the health benefits of the product can't be quantified. However it is known that movement increases the metabolic rate and engages the body's muscles. Through engagement of the four following muscle groups, the user greatly reduces their risk of experiencing lower back pain. These are from left to right: Transversus Abdominis, Multifidus, Anterior Abdominal Muscles and Erector Spinae.

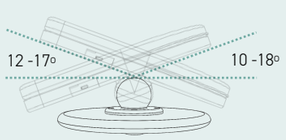


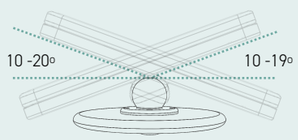
Lower Back Pain Exercises

Through contact with Osteopaths and Chiropractors, the following movements were chosen to be accommodated in the design which, if done, would engage the spinal and abdominal stabilising muscle groups. From left to right they are: right side wobble, left side wobble, back arching, back flexion (camel). A combination of all four is classed as a Hula Hoop motion. These can be done seated and come under the category of NEAT (Non-Exercise Activity Thermogenesis).

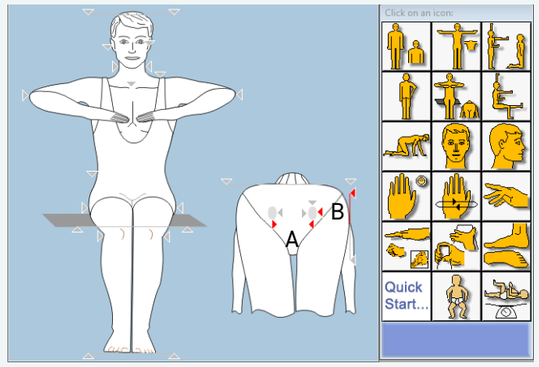
Movement Testing - Active Interaction

Contact with Experts and a Yoga Instructor found that range of movement will vary between users, but encouraging a large range is always desired. Testing found a user's range of movement varied for different exercises due to say weak left side muscles or intolerance to flexion or arching. Range of movement also varied between different users, but a minimum angle of 10º was achieved by all. The maximum angle achieved was 20º and this was a young flexible individual. User's will naturally only go to the maximum angle they feel comfortable at and then return back to stable point, but through multiple uses the user will improve their range.





Sizing, Stability and Form



Anthropometrics and Sizing

The product had to be large enough for the user to sit on, but also small enough to fit on the existing chair. From research and initial cardboard modelling I found that support of the full hip breadth is not needed but a distance slightly larger than the distance between the sitting bones is. Here anthropometric data was consulted for 95th percentile measurements and an acceptable width and depth was calculated and tested as seen below:

Width = A + (4/3) * B = 14.7 + (1.333 * 16.0)
= 36cm

Depth = 30cm (found from an initial sizing ratio and maximum trunk depth for 95th percentile women)

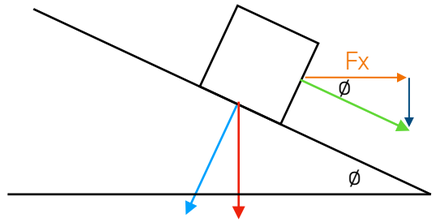
Ball and Socket Joint and Size

A ball and socket joint was found to provide the optimum stability and movement for 360º motion. The two pieces are moulded separately and joined through a force fit. Using a gap of 0.3 mm between the pieces and an 8 mm overhang, this joint is strong and was found not to fail when tested. The sizing was chosen as a 60 mm through trigonometric calculations to create a maximum angle of 25º. This diameter was then tested and found to be suitable for the balancing function.

The sphere also had to be made hollow so that the part was suitable for injection moulding (Melton Plastics), with a constant wall thickness of 8mm and a ribbed cross section for strength.

Frictional Force Calculations

Through testing it was realised that it was very important the product did not move when in use for safety reasons. From here frictional force calculations were carried out as seen below:



Nominal Force = Weight of Product + Weight of User
= 2.48 + 140 = 142.48

Max Frictional Force required would be equal to x component for the max load (140kg) at max angle (25º) to ensure product does not move

Weight at max angle = mgsinø = 140 * sin25
= 59.166kg

Fx = Weight at max angle x cosø
= 59.166 * cos25 = 53.623

μ = Friction Force / Normal Force
= 53.623 / 142. 48 = 0.376

From this, adhesive anti-slip silicone pads were added to the bottom base to ensure a static friction coefficient that was higher than 0.376

User Testing for Stability and Form

Testing ensured the product did not move when in use for a variety of chairs, as well as the chairs on wheels not moving themselves.

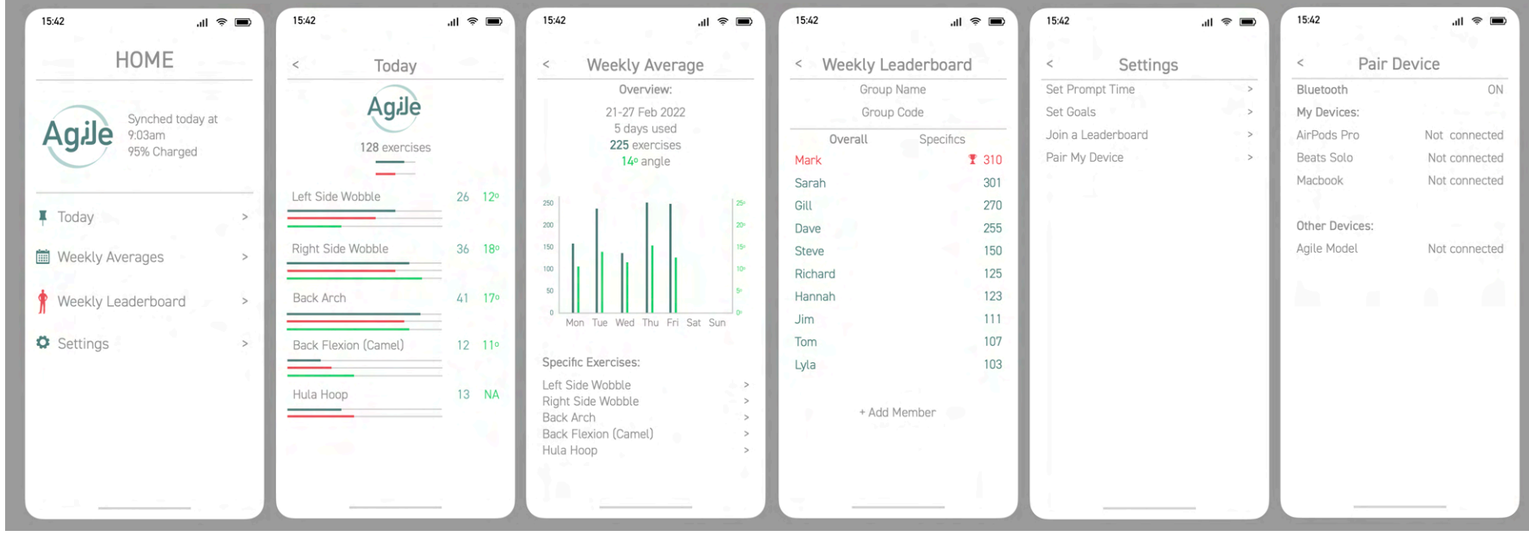
Form was explored and a curved back with a straight front was preferred for leg placement and also a useful weight distribution. The front section is 1.21x heavier than the back, so the product will naturally fall forward, pulling the user into a position where their feet are planted on the floor and their knees are slightly below the hips which is optimum for spinal health. This also means the product is at an angle that is easy to get onto, and allows programming of a switch off function when not in use. Simplistic design was key for a product of this nature.

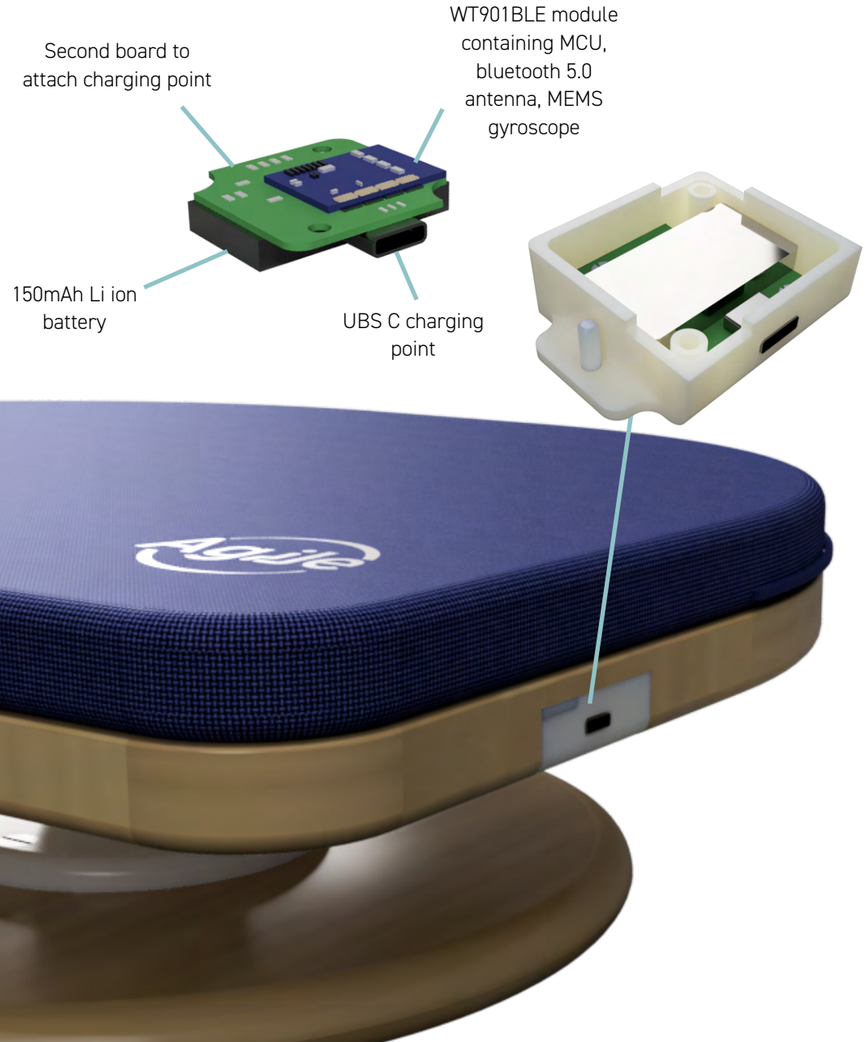
Data Software Control

The incentive and awareness were key requirements and important aspects of the product. To change human behaviour a prompt is successful if there is high motivation and the action is easy to do. The app will show the number of lower back pain movements and angles achieved (minimum=10º, maximum = 25º) in a competitive nature against the user's past weekly average. If chosen, a weekly leaderboard between colleagues or friends can be synched. A prompt time can be set and users would pair their device through bluetooth. This encourages movement while providing awareness for the user, where increasing their numbers increases their level of mobility and improves their range of movement. This could also be used with a chiropractor or osteopath for setting goals for specific client treatment.

App Design

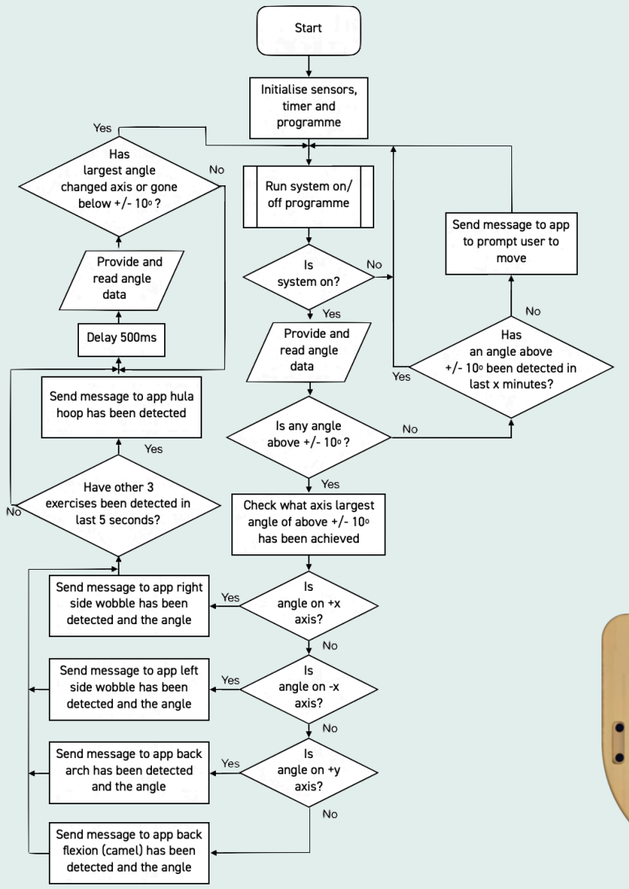
Comparing to user's most recent passed weekly average :
Comparing to the winner on the leaderboard :

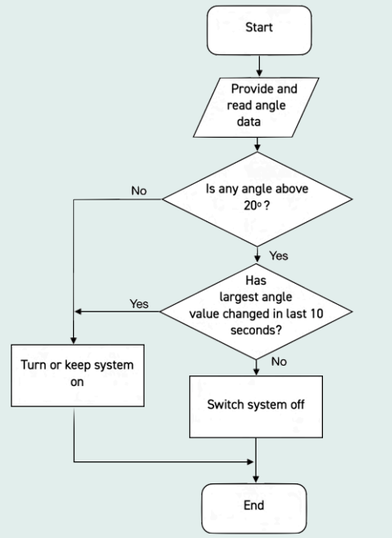


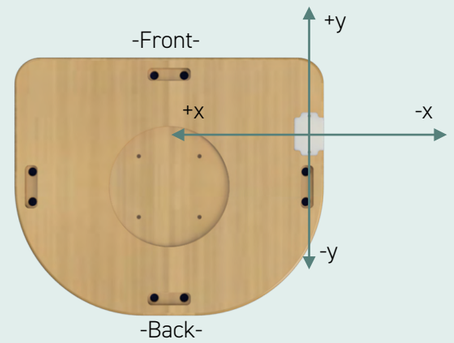


Programming Flowchart

The microcontroller would have to be programmed to correctly identify which lower back pain exercise has been achieved and at what angle, as well as automatically switching the system off when not in use. The system requires a minimum of a 10º angle achieved to mark an exercise being achieved. It would be based on an axis system, where the type of exercise achieved would be decided by the axis of the maximum angle above 10º.

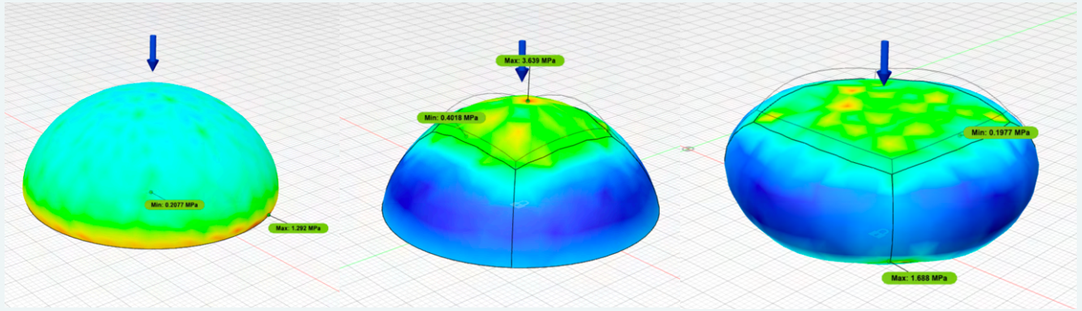




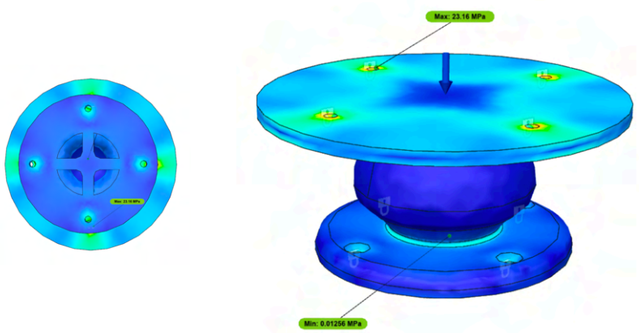


Strength Testing and Material Analysis

Balancer Form

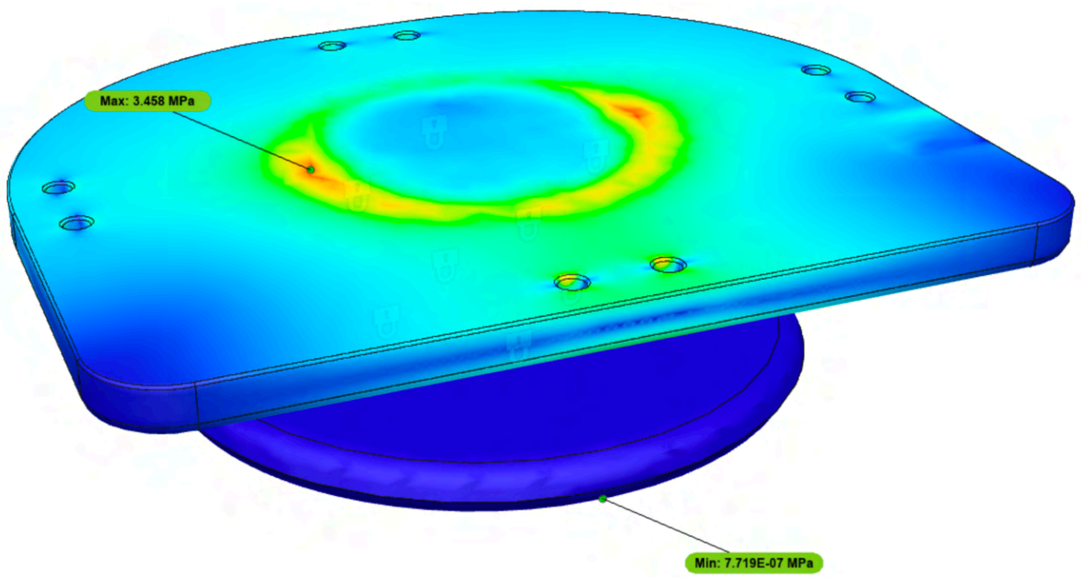


A spherical shape produced the smallest maximum stress value for a given load, as well as not exhibiting any stress concentration values at the top of its shape like that of a cone or pebble. This meant it was not susceptible to flex under load, as well as providing a space efficient, natural movement from its constant curve.



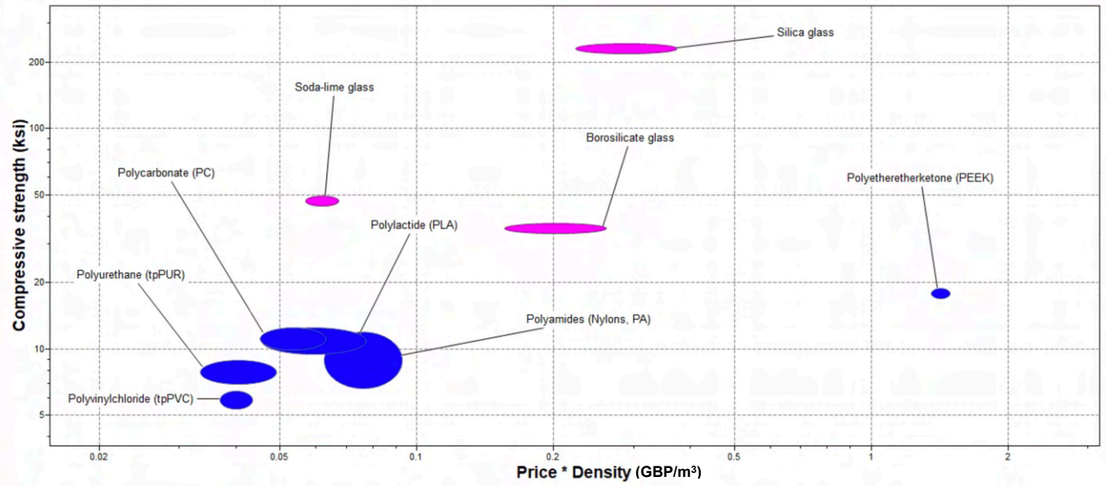
Structural Integrity

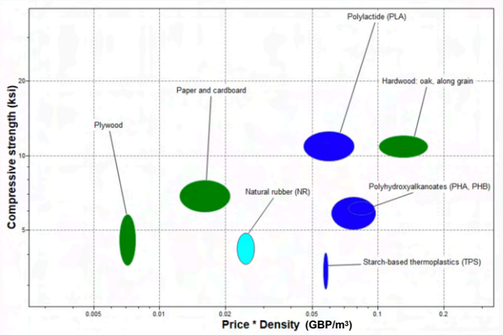
A load of 140 kg was chosen for a weight safety factor of 1.3 for 95th percentile male. This resulted in a factor of safety of 3.99 and 3.23 for yield stress of the birch plywood base and nylon 6 MoS2 5% balancer respectively. The cored out balancer has a cross-rib design for strength purposes. Overall, the design was deemed safe enough to be classed as structurally sound for its purpose.



Material Choices

Environment analysis, CES, conversations with industry professionals, user opinion and market trends were all used for choosing appropriate materials for the product.





Nylon 6 MoS2 5% Balancer: High strength to weight ratio as well as resistance to wear and tear. The 5% additives create a self lubrication property which is desired so movement is smooth and has no sound of squeaking. This was also chosen for the electronic casing to reduce variety of materials used in the product for cost reductions.

Birch Plywood Base: Natural aesthetic and high strength and durability, as well as being a fast growing UK and Northern European tree so has sustainability properties.

Polyurethane Foam Cushion: Most common type of material used for this function and through testing was found to be comfortable and suitable at 1 inch thickness for height reduction (in future could be developed/changed).

Silicone Anti-slip Adhesive Pads: High coefficient of friction.

Cotton Casement Fabric Cushion: Soft touch and durability to wear and tear; the casement provides fireproofing properties.

User Journey

Product on chair at arrival or..

... be placed there by the user at the start of the day

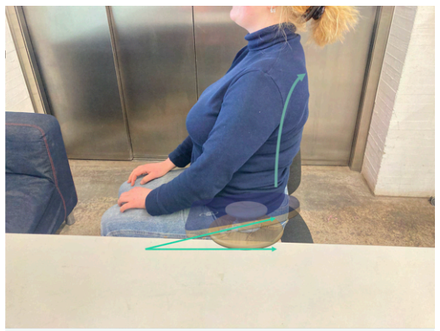
Product sits at an angle easy to get onto from weight distribution

Ensure feet are firmly planted on floor and knees are slightly below hips

Naturally find centre of gravity and therefore a balanced point, utilising core

Product accommodates lower back pain movements for differing ranges of movements - this is a left side wobble

This a right side wobble



This is a back arch or extension

This is a back flexion or camel pose - a combination of all four of these is a hula hoop motion

Check bluetooth linked app for awareness and incentive

App prompts if no movements detected after certain time (minimum 30 minutes recommended)

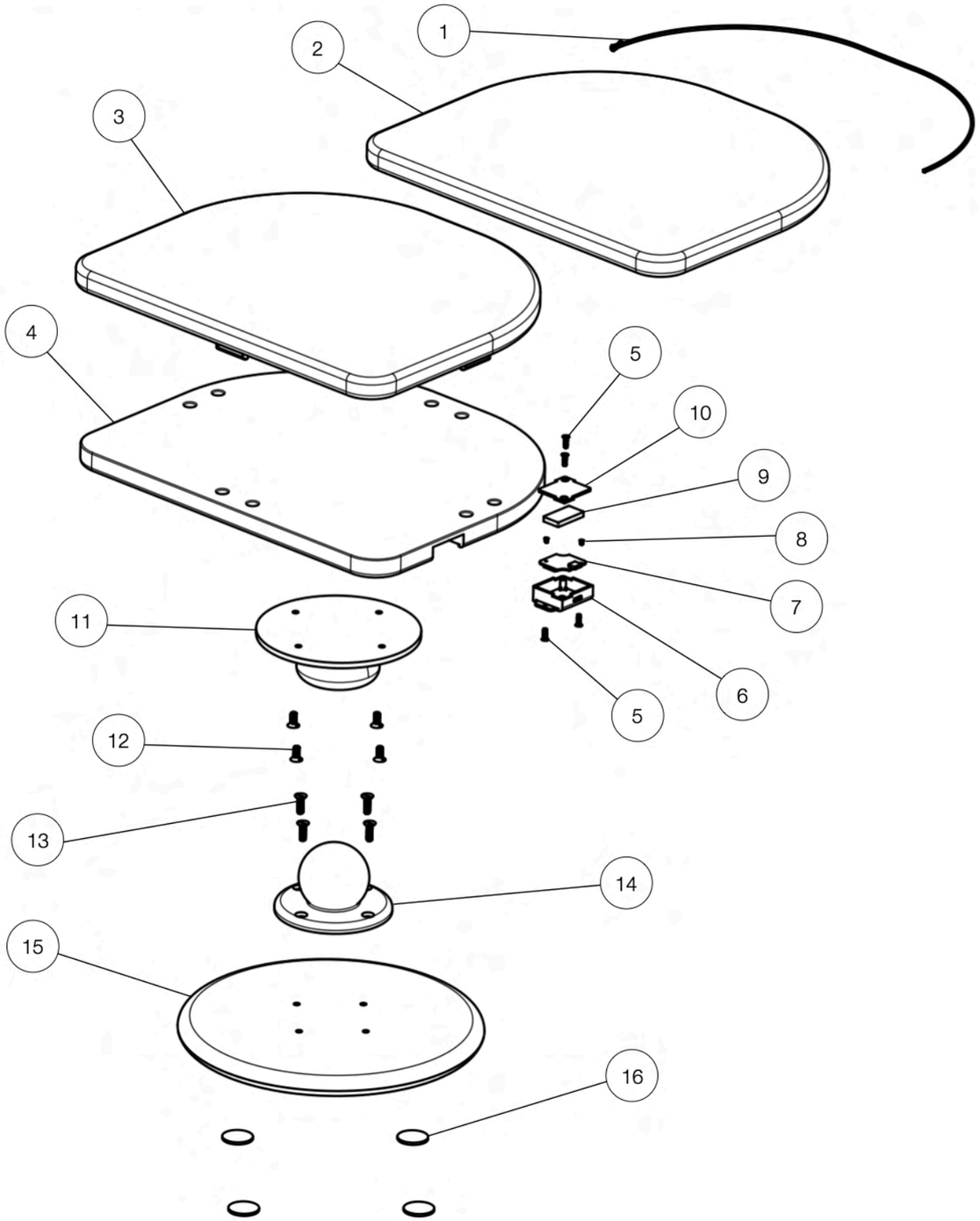
Product will fall back into angled position and switch itself off when not in use

Product ready for next use by same user, or another if in hot desk environment

Electronics powered through a USB C cable and take 9 minutes to charge, lasting 15 hours

Cushion and product easily detached for maintenance and improved sustainability

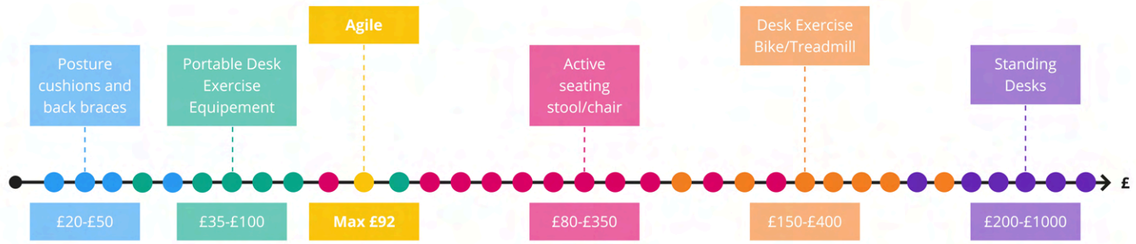
Assembly and Manufacture



Manufacture and Costing

Due to the market being so large it was decided a mass produced product was most suitable, utilising moulding and CNC machining. Semi-permanent joints allow easy disassembly for maintenance and recycling at the end of the product's life. A batch size of 5000 was used for costing estimates as it was large enough for the market but not too large that the product created a huge risk. The final costing was then compared to the existing market to ensure it was suitable.

Material Cost	£10.23
Manufacturing Cost	£30.70
Retail Price	£92



Parts List			
Item	Quantity	Part Name	Material
1	1	Cushion Zip	Nylon (Multiple Colour Options)
2	1	Cushion Foam	V38 Polyurethane Foam
3	1	Cushion Fabric	Cotton Casement (Multiple Colour Options)
4	1	Top Base	18mm Birch Plywood (Clear Water Based Polyurethane Finish)
5	4	M3 x 10mm Accu Flathead Screw	Nylon (White)
6	1	Electronics Case	Nylon 6 MoS2 5% (C-1 Finish, White)
7	1	Electronics (USB C, Microboard and WT901BLE Module)	N/A
8	2	M2 x 4mm Accu Flathead Screw	Nylon (White)
9	1	150 mAh Lithium Ion Battery	Lithium
10	1	Electronics Case Lid	Nylon 6 MoS2 5% (C-1 Finish, White)
11	1	Top Balancer	Nylon 6 MoS2 5% (C-1 Finish, White)
12	4	M5 x 12mm Accu Flathead Screw	Nylon (White)
13	4	M5 x 16mm Accu Flathead Screw	Nylon (White)
14	1	Bottom Balancer	Nylon 6 MoS2 5% (C-1 Finish, White)
15	1	Bottom Base	18mm Birch Plywood (Clear Water Based Polyurethane Finish)
16	4	Anti-Slip Adhesive Pads	Silicon

Final Concept Values

Benefits		
To Users	To Active X Backs and Morningside Chiropractors	To the NHS
Increasing level of mobility and range of movement in an accessible way without impacting their level of work	A product which they could recommend to their clients	Reduces cost for painkillers and other medications
Reducing number of health risks including lower back pain	Healthier and happier clients	Can recommend product to patients
One model can be used by multiple users and easily moved due to lightweight	Improves spine and back muscle health	Reduces number of lower back pain patients, improving productivity
Easily accessed, available 24/7 and provides a growth into a healthier more flexible state	Tailoring the product to their business (if choose to buy): custom branding and advertisement	Reducing use of injections for lower back pain
Increasing sociability and overall view of the workplace	Potential to evolve into not just a workstation option	Reducing unnecessary referrals for spinal surgery
Potential to evolve with new app aspects and functions		

Final Prototype Testing/Feedback

Testing the current prototype in its intended environment allowed feedback to be gathered on the intended interaction. The product was used for varying times and it was found that a full working day use is achievable without feeling fatigued. On top of this, many users (once they had their feet firmly planted on the floor) found the product a lot easier to use than expected. Further testing would be done in future for longer time periods (weeks or months) to allow the health benefits to come to pass.