Addressing Poor Back Posture

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Contents

1 Introduction

This report recommends a shoulder strap style solution to address poor seated back posture. As detailed in the background information, EngSci (Engineering Science) students have poor back posture, an issue they are of. However, on-the-market solutions, such as back braces, back pods, and many others, fail to meet requirements set by stakeholders, limiting their adoption (Appendix A). These stakeholder values formed the basis of our requirements framework, which require that a potential design actively fixes back posture, is safe, durable, portable, and concealed. This report will highlight our primary stakeholders as first-year Engscis, provide a requirements framework that incorporates stakeholder values into the design, and demonstrate the design process used to validate the efficacy of our recommended design, shoulder straps, and compare them to three other novel design concepts: a pokey belt, a pressure sensor, and an inclined pillow.

2 Why EngScis Have Poor Posture

In this design report, the concept of "poor posture" is defined by ISO 11226:2000 [1] and is visualized in Figure 1.

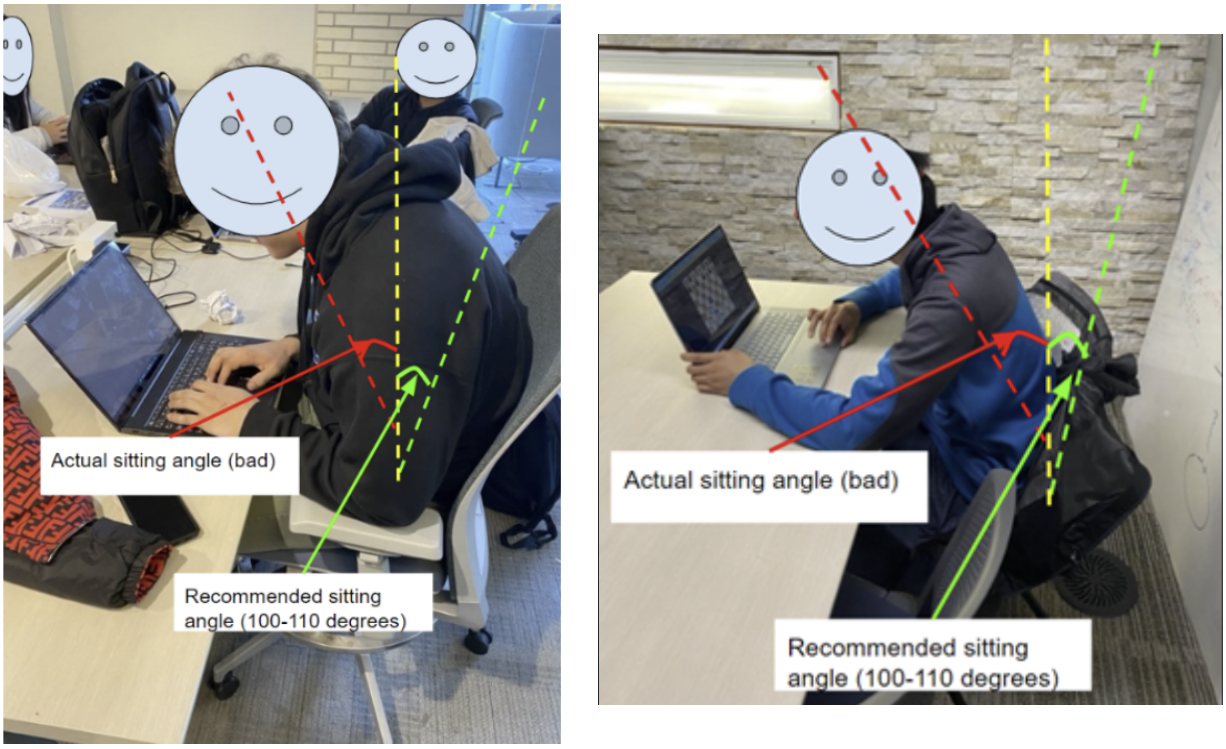


Figure 1: Examples of poor posture when sitting as defined by ISO 11226:2000 [1].

Existing designs that are poorly adopted by our primary stakeholders include the following: Back braces which EngSci students do not want to wear as they are concerned about the negatively attached social stigma; back pillows, which cannot be used while sitting down and studying; laptop stands, which are bulky and impractical to carry; and ergonomic chairs, which despite the well-intentioned design, are not properly used by EngScis, given that they continuously keep hunching.

Interviews with our stakeholders showed that most other existing products either (i) do not work, (ii) are annoying to carry, (iii) look "ugly" or (iv) are visible, leading to stigma and to the user being embarrassed to use them (Appendix A). Hence, a unique design concept that addresses the limitations of existing products is required.

3 Requirements Of A Design That EngScis Will Actually Use

Overall, there are 5 goals that need to be achieved by a usable design concept, listed in order of importance which will be explicitly justified in the requirements table:

1. The design fixes poor posture when sitting
2. The design is safe to operate
3. The design is durable
4. The design is portable
5. The design is aesthetically pleasing

These goals informed a set of objectives and corresponding requirements, outlined in Section 5 of Appendix B. For the purposes of evaluating different design concepts, the requirements are summarized in Table 1. The requirements are listed in order of decreasing importance. Relative importance flowed down from the perceived importance of our goals from stakeholders and relevant codes, standards, and DfXs.

Table 1: A summary of our requirements and their justification

Rank	Requirement	Justification and Choice of Rank
R1	Shall maintain user's trunk inclination between $100^\circ - 110^\circ$ [1]	ISO 11226:2000 provides the values for the optimal seating angle for good posture [1]. This requirement was deemed most important as it is the justification for a design's existence. If it does not fix back posture, then there is no point in using the design at all.
R2	Shall conform to California's Product AB-1817 Textile Safety on poly-fluoroalkyl substances (PFAS) and not contain flame retardant chemicals (FRC) more than 1000 ppm from California's AB 2998 prohibition [2][3].	Stakeholders will not use an unsafe product. The California Product Laws are a set of easily available, highly regulated, and widely used standards, ensuring proper user safety. While any design will be used in Canada, we decided to use the California regulations as they are generally easier to use and usually stricter.
R3	Peak voltage must be less than 15V.	15V is the smallest "safe" shock hazard, as described by [4].

R4	Should have the fewest possible mechanical parts (evaluation criteria only).	A Design for Manufacturability handbook [5] recommends having the fewest possible moving parts for ease of manufacturability as well as ease of use. In addition, as a team, we valued simplicity and ease of use in candidate designs.
R5	Shall not provide a shoulder load greater than 50% of the user's body weight.	Higher pressure creates greater discomfort, and users are unlikely to use a product that actively causes discomfort. The threshold value was determined from [6].
R6	Shall be operational when placed in conditions described by 3K21 conditions (temperature within from 15 - $32^{\circ}C$, with no humidity restriction), as specified in IEC 60721-3-3 [7]	This helps ensure product durability in typical indoor conditions, which is where EngSci students will primarily use any solution, as that is where they spend the majority of their time.
R7	Dimensions shall be no bigger than (27 cm x 11 cm x 20 cm) in it's smallest form.	From primary research (Appendix A), stakeholders want a portable object to carry during commutes alongside school essentials. Since a lunch bag is commonly placed in backpacks, it follows that a portable design should be of a similar size. We referenced a popular lunch bag for dimensions [8].
R8	Shall pass the Product Safety Laboratory Method M01.1 drop test procedure. [9]	The product must remain operational after incidental drops, a measure of durability. The drop test is originally designed for toy testing, and since toys are designed to remain safe even after repeated drops [10], it is fair to adapt this reference standard for our purposes.
R9	Shall weigh no more than 1.6 kg.	The design should be portable so it is easy to transport. The heaviest item most EngScis carry is their laptop, which makes that weight a reasonable upper bound. The MacBook Pro 14" (1.6 kg) [11] was chosen as a weight reference since it is one of the most popular EngSci laptops.

R10	Skin contacting material should be made of a material with a Thermal Evaporative Resistance Coefficient < 6	Products should be comfortable against skin. This means it should be sufficiently breathable and have a small R.E.T., the justification for which is specified in [12]. While not intended for back braces, the context of the standard makes it reasonably adaptable to our purpose.
R11	If the prototype is worn underneath clothes, it should not protrude more than 2 inches from any part of the users body.	Based on primary research, EngSci students prefer a concealed device. A 2-inch protrusion is considered small enough to be sufficiently concealed, since first-trimester pregnancies, which have baby bumps of 2-4 inches [13], are considered concealed.
R12	There shall not be sharp edges on any physical product	This is a common design for manufacturability requirement, and it is also applicable particularly, but not limited to, wearable designs to ensure safety, comfort, and concealment. [14].

4 Key Requirements And Verification That Designs Obey Them

Any potential design that met all the requirements in Table 1 was tested on their ability to fix posture, be safe, and be durable. The designs we came up can be categorized into designs that (i) force the user to sit with good posture or (ii) notify the user when their posture worsens.

4.1 Ensuring Designs Fix The User's Posture

To test how well posture was corrected, we wore each design for a lecture and observed changes in our posture. Designs that forced posture corrections maintained optimal posture throughout the lecture. Users wearing notification-style designs also sat with correct posture when notified to correct it. A limitation of this test is that *we* were the ones testing the devices, and we had some bias towards fixing our posture when notified since we wanted our concepts to work. A more effective test would be a fully flushed out blind independent study, which was not in the scope of this report. Secondary research with similar concepts with notable differences [15] show less than perfect effectiveness, but the devices worked for a majority of users nonetheless. For the notification-style designs to be effective, alerts when posture worsened had to be immediate; research shows that equipment to correct behaviour is inadequate without instant feedback.

4.2 Ensuring Designs Are Safe To Use

Designing for product safety was a continuously iterative process, balancing between materials that met the safety requirements and pushing the limit to maximize the other evaluation criterion score. All of our design specifications ended up meeting the safety requirements, as we specifically made design decisions to meet these requirements. No primary research was performed.

4.3 Ensuring Designs Are Durable

We tested durability by performing the Product Safety Laboratory Method M01.1 drop test for toys, as can be seen in the video (Appendix C). As well, all designs met requirement 6 (operating conditions) in prior proxy tests.

5 The Recommended Design: Shoulder Straps

Our recommended design was the shoulder strap-style design. The design works similarly to a four-point harness. The user attaches a fixed point to a chair and then puts on polyester straps from all four points. The design is intended to restrict forward/backward motion from the user while seated. The straps are padded with traditional memory foam, meeting the comfort and low-pressure requirements. Polyester is used for its flexibility and high breathability quality. [16]. The straps also meet the intended safety goals, as the materials used meet safety requirements and they also include a quick-release function in case of emergency. It is also designed to meet the compactness requirement, as the straps can be folded into a smaller size. Requirements concerning portability, trunk inclination, and durability can be seen in our video (Appendix C). Other requirements were tested through secondary research.

Figure 2: A basic prototype of our recommended design: A shoulder strap-style contraption.

5.1 Key Design Decision: Simplicity Ensures Ease Of Use

Our team highly valued simplicity and we considered it one of our defining decisions in choosing designs. The simpler a design is, the harder it is for it to fail. In addition, fewer electromechanical parts correlate with quicker and cheaper manufacturability, as well as a lower environmental cost.

Lastly, a simpler design is easier to use and understand. Shoulder straps incorporate simplicity the best, which is one of the reasons why it our preferred design for EngSci students.

5.2 Key Design Decision: Users Will Not Wear An Uncomfortable Design

We also valued comfort, as EngScis have to spend long hours working while sitting and would not want to wear something uncomfortable. To account for this aspect, we chose the straps to be padded with traditional memory foam. This design decision reduces the pressure of the device on the user, increasing comfort and achieving goals in other aspects, such as durability and meeting material safety requirements.

5.3 Key Design Decision: EngScis Carry Too Much Already

We decided to value portability as EngScis already carry many things in their backpacks, making it unlikely for them to want to carry anything else that is large and bulky. We chose a compact and foldable design for the shoulder straps in order to increase their portability. When they are worn, they are small and lightweight. When not in use, they can be folded into dimensions of 6 cm $\times$ 11 cm $\times$ 4 cm, as shown in the video (Appendix C).

6 Other Designs In Consideration

6.1 A Low-tech, Concealed Notification System: the Pokey Belt

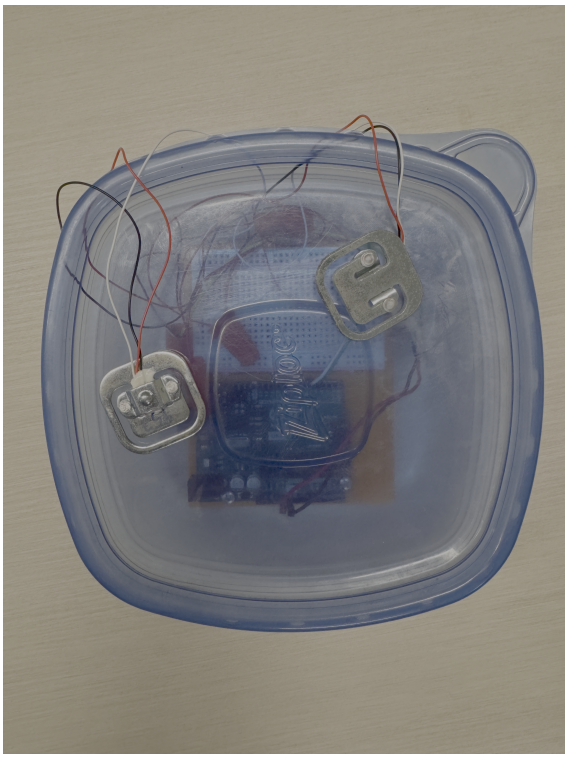
The first design that was not selected is a corset-styled design, worn in the lower back area around the entire body. If the user leans forward, they will experience a slight amount of discomfort within the limits stated by our requirements. It serves as a reminder for the user to lean backwards into good posture.

Figure 3: Elemental prototype of our pokey belt design concept

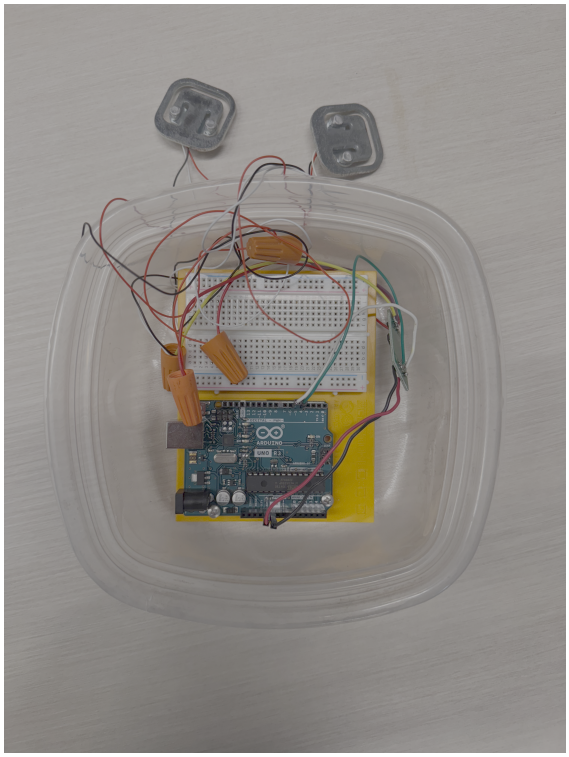
We did not choose this design as it performs worse in fixing back posture than other prototypes. Although it does meet our requirements, there is no guarantee that this design will perfectly correct all users' back posture. The biggest issue is that it still possible to have hunched shoulders while wearing the device, as the user is not forced to respond to notifications, thus not correcting posture as well as other designs. While secondary research does support the effectiveness of such concepts, as previously mentioned, further primary research is required to address the viability of this particular design.

6.2 A Higher-tech Notification And Tracking System: The Pressure Sensor

Research suggests that the pressure exerted from our backs into our chairs can be used to gauge correct posture [17]. Our second design leverages this concept. The design consists of a load cell with an HX711 amplifier wired with an Arduino and 12 V battery, which can detect up to 1000 N of force. The user first sits with correct posture, to get a preliminary pressure reading. If the pressure reading lowers from the preliminary reading, that suggests the user is in poor posture. The advantage to an electronics-based setup is that the sensor can be integrated with any personal electronic device and send alerts that remind the user to fix their posture when it worsens.



(a) The electronics can be concealed, satisfying the concealement requirement.



(b) The internals of the pressure sensor prototype

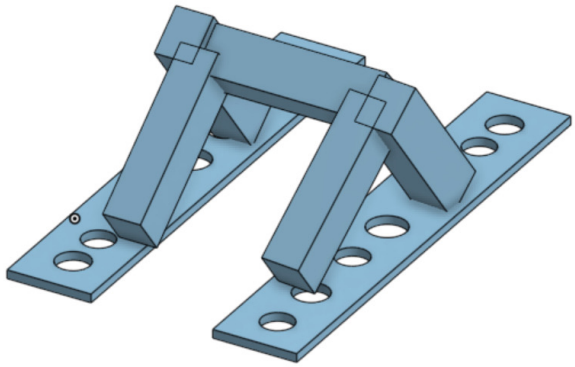
Figure 4: Minimally operational prototype of the pressure sensor design concept. The completed design connects the sensor to a notification device of the users choice.

We did not choose this design as it was also worse than others in the most important requirement: fixing back posture, for the same reason as the pokey belt. As well, the electronics in the design make it worse in the safety requirements, as mechanical designs of similar complexity are usually safer since they do not have voltage or frequency concerns.

6.3 Changing The Seating Angle To Make Good Posture Comfortable: The Inclined Pillow

Our final design for comparison is an inclined pillow. It is made of memory foam, which meets our safety requirements (requirements 2 and 10). The design is adjustable as it has a metal slider that changes the geometry of the pillow. This allows the user to modify the shape so that leaning backward and having good posture becomes the most comfortable position, which the user then adopts. The section that is in contact with the user is made out of memory foam and is designed to be wide enough to fit the 5th percentile EngSci female to the 95th percentile EngSci male, as per modified standard design practices.

(a) Wooden prototype of the inclined pillow.



(b) CAD model of the inclined pillow. This stripped-down model shows the mechanical part that allows the user to adjust their seating angle.

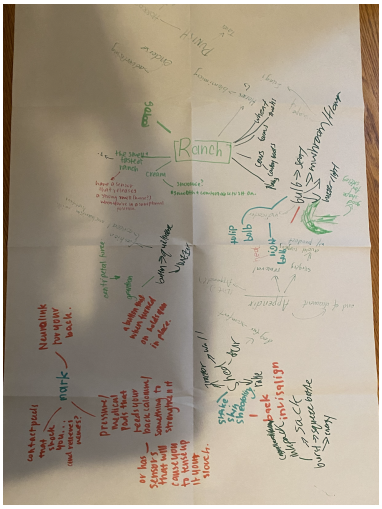
Figure 5: Basic operational prototype of the inclined pillow design concept. Memory foam and casing will be added to the actual design.

We did not choose this design as it is more complicated than the shoulder straps, and our team values simplicity. The increased mechanical complexity can lead to less durability and ease of use. Furthermore, the use of this design requires a backed chair, limiting the design's use. Lastly, this design is less portable than the other options, as it is bulkier and heavier than other designs.

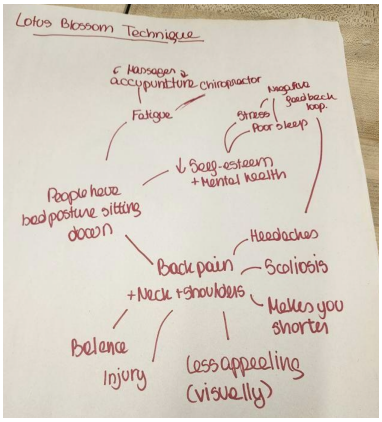
7 Process Used To Create And Rank Designs

7.1 Diverging

The diversity between the diverging tools we used, "Brainwriting 4-3-3", "Lotus-Blossom", "Biomimicry", and "Random Input", enabled us to explore the entire scope of the design space before converging (Figure 6). These specific tools were chosen as they had varying approaches to diverging, allowing us to explore the design space from different perspectives.



(a) Random words.



(b) Lotus Blossom Technique

Figure 6: Some of the diverging tools we used to come up with our designs.

7.2 Converging Onto And Comparing Prototypes

With the prototypes that aligned with our requirements, the converging process used our evaluation criteria to determine which design would work best for our primary stakeholder. Each tool used during the converging process. explained below, had some limitations, which needed to be addressed to equitably explore the design space.

7.2.1 A Pugh Chart With Some Bias

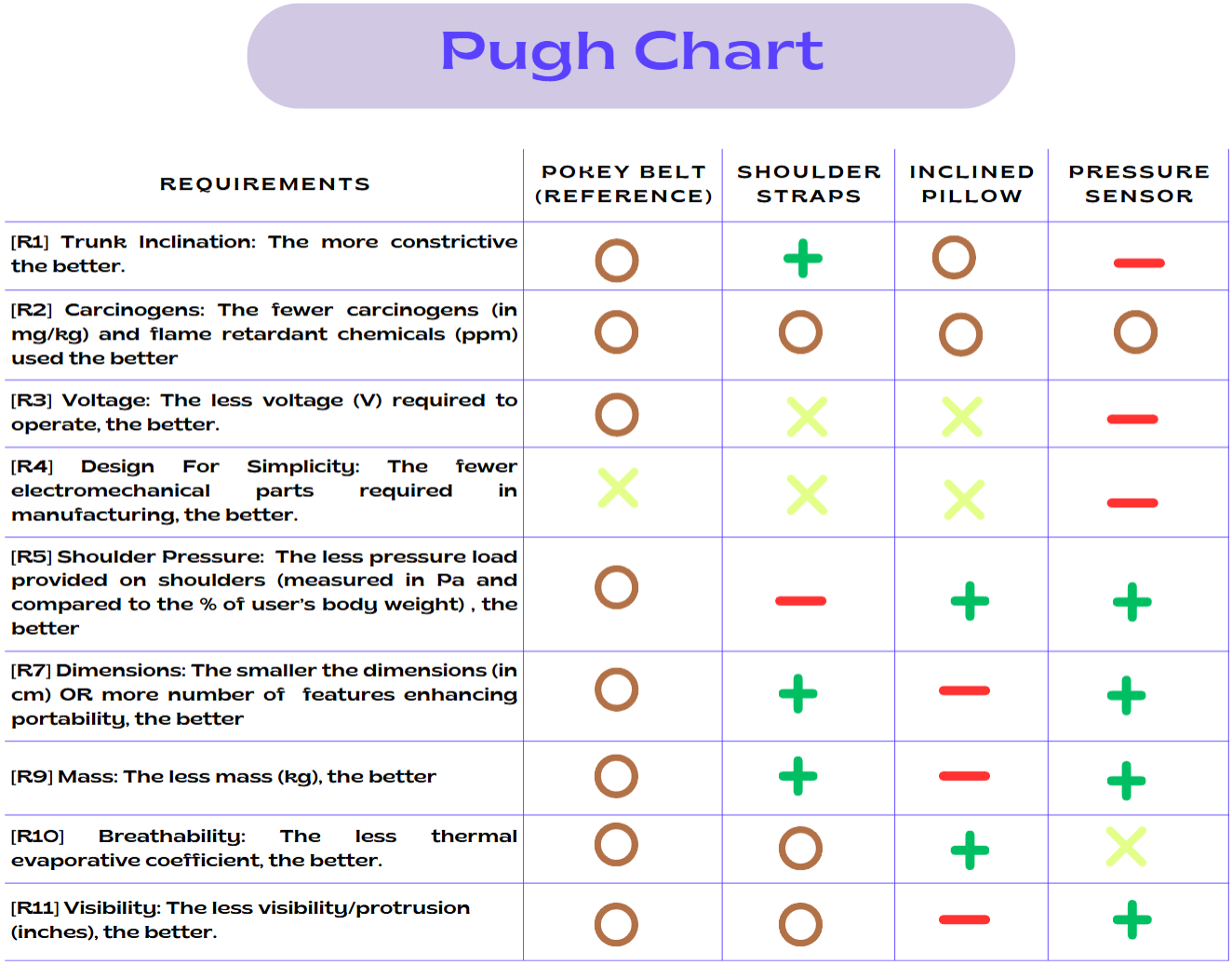


Figure 7: This Pugh chart shows our evaluation process for determining the best prototype. There are more requirements on electronics, suggesting a simpler physical prototype is more efficient.

The Pugh chart presents the shoulder straps as the most viable and fitting design. However, this model possesses limitations. Due to the diverse nature of our designs, the shoulder straps were evaluated the highest on most evaluation criteria as they emphasized simplicity. We purposefully included a slight bias in our requirements and evaluation criteria towards simpler, non-electronic citations since our group values ease of use and design simplicity.

However, there may be benefits to using technology that would be overlooked in our evaluation criteria framework, such as being able to track posture throughout the day and weeks, which would allow the user to see the trend line of improvement throughout an extended period of time. To acknowledge our biases and to avoid looking at a design space that is too narrow, we compared two different approaches of addressing the opportunity: The simpler shoulder straps and the more

complex electronic pressure sensor. During the initial diverging phase, we thought our strongest prototype was the pressure sensor, due to its innovation, instant feedback and relative ease of manufacturing for an electronic device. Thus, we performed a pairwise comparison between the pressure sensor and shoulder straps, helping us to arrive to the best solution from two separate design spaces.

7.2.2 Using Pairwise Comparison To Determine That Shoulder Straps Are Better

Figure 8: Pairwise comparison table comparing the shoulder strap and pressure sensor designs. The most important criteria include simplicity and ease of use, which is why the shoulder strap design outperforms the more complex pressure sensor, at least according to what our team values.

Shoulder Straps	Pressure Sensor
- No electromechanical parts	- Portable
- Constrictive and provides pressure feedback	- Provides instant feedback and notification based tracking throughout day
- Safer to use (no voltage)	- Positive reinforcement to train back muscles
- No protrusion since it's worn	- Less pressure on shoulder
- Durable	- Less volume

From psychological research studying the best method to maintain healthy posture[15] and the results of the pairwise comparison, the shoulder straps outperform the pressure sensor in actively correcting long-term back posture. They are worn, are more portable and have fewer mechanical parts, satisfying our biggest requirements. Consequently, the shoulder straps are chosen as the recommended design concept.

8 Final Recommendation Of Shoulder Straps To Fix Back Posture

We recommend the shoulder strap design because it is a viable and proven prototype that could gradually correct back posture amongst EngSci students when sitting on chairs with backs. This prototype includes quick-release straps, folds to fit inside a small lunch bag, has a polyester string to ensure breathability and flexibility, and incorporates traditional memory foam for comfort and low pressure. The design was inspired by suspenders and back braces, which did not adhere to the specific requirements frameworks of our stakeholders. Consequently, our goals targeted portability, safety, aesthetics, durability, and the ability to correct back posture, so they are more suitable to our stakeholders. Upon exploring the design space, we assessed our four different designs that best aligned with our requirements. The shoulder straps best fits the posed evaluation criteria. They performed better than most designs in our most important criteria, and avoid using materials that might pose a safety hazard altogether. Additionally, it is designed for manufacturability and simplicity, providing more benefits to stakeholders. Given that there was no preference for technological devices, it was deemed that shoulder straps were better since they do not have electromechanical components and voltage. This aligned with our teams values, and we believe it is the best option out of the proposed solutions to fix EngScis poor posture.

9 References

[1] *Iso 11226:2000 ergonomics – evaluation of static working postures.* [Online]. Available: https:
//subscriptions-techstreet-com.myaccess.library.utoronto.ca/products/70275.

ISO 11226:2000(E)

Table 1 — Trunk posture

Postural characteristic	Acceptable	Go to step 2	Not recommended
1) Symmetrical trunk posture [a]			
No			X
Yes	X		
2) Trunk inclination α [b]			
> 60°			X
20° to 60° without full trunk support		X	
20° to 60° with full trunk support	X		
0° to 20°	X		
< 0° without full trunk support			X
< 0° with full trunk support	X		
3) For sitting: convex lumbar spine posture [c]			
No	X		
Yes			X

[a] With a symmetrical trunk posture, there is neither axial rotation nor lateral flexion of the upper part of the trunk (thorax) with respect to the lower part of the trunk (pelvis) (see Figure 1).

[b] Posture during task execution (dark body segment, solid line) with respect to the reference posture (white body segment, broken line) when viewed from the side of the trunk (for α see Figure 2, where forward inclination is given a positive sign). Annex A describes the procedure for determining trunk inclination.

[c] Convex curvature of the lumbar part of the spine (see Figure 3). This posture is more likely to occur

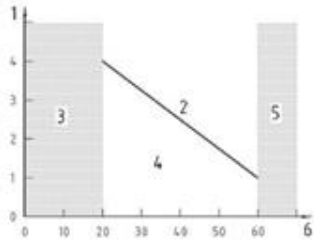
— when the lumbar spine is not supported by a backrest, and

— when a small hip angle is adopted (see 3.7).

Table 2 — Holding time for trunk inclination

Holding time	Acceptable	Not recommended
> maximum acceptable holding time [a]		X
⩽ maximum acceptable holding time [a]	X	

[a] Taken from Figure 4.



Key

1 Maximum acceptable holding time (minutes)
2 Not recommended
3 See 3.4.1, step 1
4 Acceptable
5 See 3.4.1, step 1
6 Trunk inclination α (degrees vs. reference posture)

Figure 4 — Maximum acceptable holding time vs. trunk inclination

[2] *Ab-1817 product safety: Textile articles: Perfluoroalkyl and polyfluoroalkyl substances (pfas).(2021- 2022).* [Online]. Available: https://leginfo.legislature.ca.gov/faces/billTextClient. ..

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

SECTION 1. (a) The Legislature finds and declares all of the following:

(1) Perfluoroalkyl and polyfluoroalkyl substances, or PFAS, are persistent, toxic, and bioaccumulative substances with multiple adverse effects on human health.

(2) PFAS are utilized in a broad range of products for their water- and stain-resistant properties, including clothing and textiles, despite the growing body of evidence that these materials may leach into food, water supplies, and even the human body through prolonged exposure. PFAS in apparel and textiles can contaminate sources of drinking water and our environment in multiple ways, including through washing and disposal in landfills and incinerators, in addition to impacts on workers and communities in manufacturing locations and global circulation of these persistent chemicals.

(3) Adverse health impacts associated with PFAS include kidney and liver damage, decreased immune system function, interference with vaccine uptake, developmental and reproductive harm, increased risk of asthma, and increased incidences of testicular and kidney cancer for those with high exposure.

(4) Multiple alternatives to PFAS have been identified for water resistance in clothing and textiles. For addressing stains, soap and water work well for most situations, and alternative materials and cleaning solutions offer additional options. This legislation, therefore, phases these uses of PFAS out.

(5) However, for some personal protective equipment (PPE), such as for firefighting gear, alternatives to PFAS are not currently in use. Firefighters face elevated levels of exposure to PFAS through a variety of means, including PPE that is treated with PFAS for its water-resistant properties, as well as through aqueous film-forming foams (AFFF) that contain highly fluorinated forms of fluorosurfactants.

(6) In 2020, the Legislature passed and the Governor signed into law Senate Bill 1044, phasing out the use of these fluorinated foams by prohibiting manufacturers from manufacturing, distributing, or selling any firefighting foams containing intentionally added PFAS beginning in 2022, with limited exemptions in place for facilities that require more time to transition their systems.

(7) This restriction on the sale and use of fluorinated foams, both in responding to emergencies as well as in training exercises, was in direct response to the health risks posed by repeated exposures, and in recognition of the environmental and other public health impacts of the discharge of these toxic foams.

(8) No such phaseouts were mandated for PPE in Senate Bill 1044, and unlike AFFF, currently there are no effective alternatives to PFAS in use for critically important, lifesaving PPE. Instead, the bill contained a provision mandating the notification by the seller of PPE to the purchaser if PFAS is present in the PPE, to be kept on file three years from the date of the transaction.

(9) Research and product development is currently ongoing to create PPE without PFAS that meets the stringent safety standards required for use by firefighters. Once these products are approved, it is of paramount importance that replacements are made as quickly as possible to ensure that California's firefighters are not forced to expose themselves to toxic substances while wearing their required safety equipment.

(10) While this act exempts PPE for the time being to ensure that first responders and other workers continue to have protection on the job, steps must be taken by all employers and manufacturers to ensure that PFAS are eliminated from PPE as quickly as possible, and to limit exposures as much as possible in the meantime.

(b) It is the intent of the Legislature that manufacturers of textile articles eliminate the use of PFAS from their materials, and that manufacturers of PPE, for which there are no current alternatives to PFAS, engage in product development and research in order to phase them out as quickly as possible.

[3] California enacts broad prohibitions on flame retardant use," [Online]. Available: https:/ / www . bdlaw . com / publications / california - enacts - broad - prohibitions - on -flame - retardant - use / # : ~ : text = 2998 % 20prohibits % 20any % 20person % 20from , for %20including%20in%20the%20list..

California Governor Jerry Brown has signed into law Assembly Bill (A.B.) 2998, restricting the sale of flame retardant-containing children products and furniture. Effective January 1, 2020, A.B. 2998 prohibits any person from selling or distributing new juvenile products (*i.e.*, products used by infants and children under the age of 12), mattresses, and upholstered furniture that contain a designated flame retardant chemical at levels above 1,000 parts per million. The law also prohibits, beginning on January 1, 2020, a custom upholsterer from repairing or reupholstering upholstered furniture using replacement components that contain more than 1,000 ppm of a designated flame retardant chemical.

An act to add Chapter 13.5 (commencing with Section 108970) to Part 3 of Division 104 of the Health and Safety Code, relating to public health.

[Approved by Governor September 29, 2022. Filed with Secretary of State September 29, 2022.]

LEGISLATIVE COUNSEL'S DIGEST

AB 1817, Ting. Product safety: textile articles: perfluoroalkyl and polyfluoroalkyl substances (PFAS).

Existing law prohibits, beginning January 1, 2023, any person from distributing, selling, or offering for sale in the state any food packaging that contains regulated perfluoroalkyl and polyfluoroalkyl substances or PFAS, as defined, and requires a manufacturer to use the least toxic alternative when replacing regulated perfluoroalkyl and polyfluoroalkyl substances or PFAS in food packaging to comply with this requirement. Existing law similarly prohibits, beginning July 1, 2023, a person from selling or distributing in commerce in this state any new, not previously owned, juvenile product, as defined, that contains regulated PFAS chemicals.

This bill would prohibit, beginning January 1, 2025, any person from manufacturing, distributing, selling, or offering for sale in the state any new, not previously owned, textile articles that contain regulated PFAS, except as specified, and requires a manufacturer to use the least toxic alternative when removing regulated PFAS in textile articles to comply with these provisions. The bill would require a manufacturer of a textile article to provide persons that offer the product for sale or distribution in the state with a certificate of compliance stating that the textile article is in compliance with these provisions and does not contain any regulated PFAS.

Vote: majority Appropriation: no Fiscal Committee: no Local Program: no

[4] *Determining voltage levels of concern for human and animal response to ac current.*

In terms of startle reaction levels, the UL leakage current limits [4] provide the basis where 0.5 milliamps has been selected as the level where more than 99 percent of the population will not have a startle reaction to that level of current. These values were determined by way of substantial testing and have some inherent factors of safety built in. It is difficult to translate this to a precise voltage, but the most conservative 15 volt level found in Table 1. provides a level that may be useful for initial discussion for a startle reaction threshold.

[5] J. G. Bralla, *Design for Manufacturability Handbook*, 2nd ed. McGraw-Hill, 1999, ISBN: ISBN: 978-0-07-007139-1. [Online]. Available: https://www.accessengineeringlibrary.com/binary/mheaeworks/03f486c4689e37d6/d9932f0a4f01b04de811b6587c2bfb5a538ed30b94f651b6a9c834 ..

TABLE 1.4.23 Major Principles of Design for Assembly

Minimize the number of parts in the assembly
Combine parts
Incorporate hinges, springs, bearings, guides, and other functions into the basic parts.
Eliminate fasteners by using snap fits to hold parts together.
Put electrical and electronic components in one location and consolidate components as much as possible.
Make an outright reduction For example, use fewer fasteners.
Make a full redesign of the assembly
Use a different technology For example, electronics instead of mechanical linkages.

[6] "Analysis of shoulder compressive and shear forces during functional activities of

daily life,"

This study analyses shoulder compression force components and shear force components during 26 functional activities of daily life utilizing a musculoskeletal shoulder model. The results demonstrate substantial loads through the shoulder with the contact force exceeding 50% of the body weight in 10/26 activities of daily living. The ratio of glenohumeral shear force component to compression force component exceeds 0.5 in 8/26 functional activities, with glenohumeral ratios for tasks involving for reaching across the body (1.09; SD 0.41) and picking and placing an everyday object (0.88; SD 0.36). The loading of the joint is considerable not only when high loads act at long lever arms but also at high angles of arm elevation. This improved understanding of glenohumeral joint loading will aid implant design, design of surgical procedures and rehabilitation planning.

[7] *Iec 60721-3-3 ed. 3.0 b:2019 classification of environmental conditions - part 3-3: Classification of groups of environmental parameters and their severities - stationary use at weather- protected locations.*

– 3K21 applies to continuously temperature-controlled enclosed locations. Humidity is not normally controlled.

  Heating, cooling or humidification is used where necessary to maintain the required conditions, especially where there is a large difference between them and the open-air climate. Installed products may be exposed to secondary effects of solar radiation due to increased ambient temperature and to heat radiation. They may also be exposed to movements of surrounding air due to draughts in buildings, for example through open windows, or due to special process conditions.

The conditions of this class may be found in continuously manned offices, workshops, data centres and other rooms for special applications.

[8] *Flowfly kids lunch box insulated soft bag mini cooler back to school thermal meal tote kit for girls, boys, black : Amazon.ca: Home.* [Online]. Available: https://www.amazon.ca/ Insulated- Cooler - School - Thermal - FlowFly /dp /B084JP8LQT /ref= sr_ 1 _ 31 ? dib= eyJ2IjoiMSJ9.5DB5Bvau2kAdv_LPYhgmSwdj03n5I7t0n5DtO9h99Ekre3_QvB3gzOV 2FH14bhgUB2LTVTBhU_ VT63oEYvMP0PlSYtKCLh3fapmqbRcat8KWyycPJ4V4mpAH5o2fqHVC06BqqJz62O Pu-T8wfodBmogPHLtHGDz_ YbMmx5FkgT2GhPzk4QWU4vRuU9kxEo76c- 99IZqqz3b92ZzOCQllEPf_-KoJvPNECGIal3aVt9b_ 38MLABeHz2JqaRUya71zpr906818osWEO0VVoSktuVBJsP1y4i7AxMZ_09SvXD4.Elz xUtzb_gaN2DMEaJCHqe- 3erLnscxhvu_c1SaZft8&dib_tag=se&hvadid=604748003003&hvdev=c&hvlocphy =9000934&

hvnetw = g & hvqmt = e & hvrand = 3905102597394909539 & hvtargid = kwd - 315460998209 & hydadcr=915_1015040235&keywords=lunch%2Bbag%2Bamazon&qid =1732720011&sr=8- 31&th=1.

- ✿ Spacious Design – Measures L: 27 x W: 11 x H: 20 CM You'll find it super spacious and will have no problem fitting your meat and milk inside,Go ahead, pack that extra treat! This FlowFly lunch pouch suit to children adult, men, women,work,office,beach.It is suitable for fitting into backpack .

[9] *Industry guide to health canada's safety requirements for children's toys and related products*, -08-31 2018. [Online]. Available: https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/industry-professionals/industry-guide- safety- requirements- children- toys- related- products- summary/guidance-document.html.

Drop test procedure

The Product Safety Laboratory Method M01.1 drop test procedure states that a toy be dropped four times onto a tile-covered concrete floor. Each drop is conducted with the toy in a different orientation. The orientations chosen are those considered as most likely to cause damage during the drop. A toy is dropped from a height of 1.37 metres (4.5 feet) if it is likely to be used by a child under three years of age. It is dropped from a height of 0.91 metres (3 feet) if it is likely to be used by a child of three years of age or older. Following each drop the toy is inspected for applicable safety hazards such as detached small components, sharp points and sharp edges.

[10] *A comprehensive guide to design and manufacture safe and durable toys* [Online]. Available: https : / / karkhana . io / a - comprehensive - guide - to - design - and - manufacture - safe - and - durable - toys / , % 20https : / / karkhana . io / a - comprehensive-guide-to-design-and-manufacture-safe-and-durable-toys/.

The safety and durability of toys heavily rely on the selection of materials. Manufacturers must carefully choose safe, non-toxic, and sturdy materials that comply with regulatory requirements and pose no harm to children's health. They must consider various factors such as the age range of the target audience, the type of toy, and the intended use. For instance, toys for young children must be easy to clean and made of safe materials since young children tend to put toys in their mouths. On the other hand, toys for older children can use more advanced materials and manufacturing processes.

Manufacturers should also prioritize the environmental impact of the materials they use. The materials should be sustainable and eco-friendly, and the manufacturing process should minimize waste and energy consumption. Compatibility is also crucial in material selection as the materials must not react with each other, which can lead to product defects or harm to children. Lastly, manufacturers must consider the availability and cost of the materials they select to ensure a steady supply chain and meet production demands.

[11] *Macbook pro*. [Online]. Available: https://www.apple.com/ca/macbook-pro/specs/.

[12] *How do you measure the breathability (r.e.t.) of a material?* [Online]. Available: https://www.quechua.com/how-do-you-measure-the-breathability-r-e-t-of-a-material

Breathability is measured using the Thermal Evaporative Resistance (RET) coefficient. It measures the capacity of a fabric to stop water vapour getting out. The lower this resistance (i.e. the lower the coefficient), the more breathable the fabric!
(The test method is defined by the ISO 11092 standard).

The RET score uses a numerical index:

- RET < 6: the fabric is extremely breathable, so you'll be comfortable while doing your most intense physical activity.

- RET between 6 & 12: the material is very breathable, making it suitable for moderate physical activity.

- RET between 12 & 20: the fabric is moderately breathable, and therefore not particularly pleasant to wear during physical activity

- RET > 20: the fabric isn't very breathable and therefore not suitable during even light physical activity.

- RET >40: the fabric is considered to be non-breathable.

[13] R. Rosenblum, Pregnant belly shape and size: A month-by-month guide. [Online]. Available:https://www.newtonbaby.com/blogs/pregnancy/pregnant-belly.

It makes sense that you don't show much (or at all) during the first trimester because your baby is very tiny! Your baby goes from a fertilized egg at conception to being around three inches long by week 12.

[14] J. B. G, "Design for manufacturability," in M. Handbooks, Ed., p. 1.64. [Online]. Available: https://www.accessengineeringlibrary.com/binary/mheaeworks/03f486c4689e37d6/d9932f0a4f01b04de811b6587c2bfb5a538ed30b94f651b6a9c83456b8ed6ca4/book-summary. ..

8. Avoid sharp corners; use generous fillets and radii. This is a universal rule applicable to castings and molded, formed, and machined parts. Generously rounded corners provide a number of advantages. There is less stress concentration on the part and on the tool; both will last longer. Material will flow better during manufacture. There may be fewer operational steps. Scrap rates will be reduced.

[15] R. Epstein, S. Colford, E. Epstein, B. Loye, and M. Walsh, "The effects of feedback on computer workstation posture habits," pp. 73–79, Jan. 2012. [Online]. Available: https://journals.sagepub.com/doi/epdf/10.3233/WOR-2012-1287.

Median values for percentage of time spent having proper posture with various ergonomic pads are as follows: with only the initial cue to sit properly (no pad), 0% (5^{th} percentile: 0%, 95^{th} percentile: 70%); use of the Blind Posture Pad, 40% (5^{th} percentile: 0%, 95^{th} percentile: 100%); use of the Feedback Posture Pad, 100% (5^{th} percentile: 83%, 95^{th} percentile: 100%). These findings are summarized in Fig. 3.

Statistical analyses between the conditions (all carried out using sign tests) showed that both prototypes resulted in significant improvements over baseline posture ($p < 0.001$ and $p < 0.0001$ for Blind and Feedback models respectively). Between the prototypes, the Feedback model significantly outperformed the Blind model ($p < 0.001$).

4. Discussion

The Qualcomm results (80% of employees sitting incorrectly) clearly demonstrated that equipment and training given to employees or frequent computer users will not automatically result in correct sitting posture. Even the best equipment will not ensure desired results without proper training. A source of continuous feedback should be provided in order for training or equipment to result in sitting correctly and the development of lasting good posture habits.

[16] K. Knapp, *How to pick the most breathable fabrics.* [Online]. Available: https://www.rei.com/learn/expert-advice/how-to-pick-the-most-breathable-fabrics.html.

2. Nylon and Polyester

Most activewear features one of these two synthetic materials.

- **Pros:** Wicks moisture and dries quickly; resists pilling and abrasion.
- **Cons:** Not as soft as cotton, retains odor, breathability varies based on yarn size and knit or weave.

[17] M.-C. Tsai, E. T. .-. Chu, and C.-R. Lee, "An automated sitting posture recognition system utilizing pressure sensors," *Sensors*, vol. 23, no. 13, p. 5894, /1 2023. DOI: 10.3390/s23135894. [Online]. Available: https://www.mdpi.com/1424-8220/23/13/5894.

Some researchers have utilized hybrid sensor systems to recognize sitting postures. Haeseok Jeong et al. [25] proposed a hybrid sensor system consisting of six pressure sensors and six distance sensors placed on a chair. The collected pressure and distance readings were used to train a K-nearest neighbors (KNN) model for posture classification. Their results showed an accuracy of up to 92%. However, this method required the placement of distance sensors on the seat back, and the accuracy could be affected by users' body size and height. Haeyoon Cho et al. [18] developed a system that combined two ultrasonic sensors and 16 pressure sensors. The collected signals were processed by an Arduino board and then transmitted to the Naver Cloud Platform, where Convolutional Neural Network (CNN) and Lower-Balanced Check Network (LBCNet) were used for posture classification. The recognition results were displayed on an Android phone. Although the system achieved an accuracy rate of up to 96%, it required 18 sensors, resulting in relatively high hardware costs. In contrast, our SPRS (Sitting Posture Recognition System) uses fewer pressure sensors while achieving similar performance. SPRS is capable of classifying ten different sitting postures, as shown in **Figure 1**. For ease of comparison, **Table 1** summarizes the existing methods and SPRS. The detailed methodology and evaluation of SPRS are provided in **Section 3** and **Section 4**.

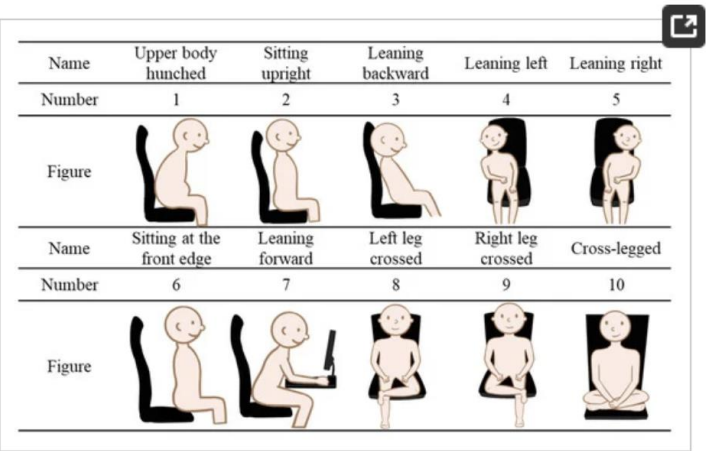


Figure 1. Illustrations of ten different sitting postures.

Table 1. Methods for recognizing sitting posture using pressure sensors.

[18] M. Jangi, C. Ferandez-de-las-Penas, M. Tara, F. Moghbeli, F. Ghaderi, and K. Javanshir, "A systematic review on reminder systems in physical therapy," *Caspian Journal of Internal Medicine*, vol. 9, no. 1, pp. 7–15, 2018. DOI: 10.22088/cjim.9.1.7. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5771354/.

Databases were searched until May 2017 and literatures were found from April 1992 until 2017. The literature recruitment strategy was based on applying several keywords and Medical Subject Heading (MeSH) combination running against title and abstract, including concepts such as reminder, physical therapy. The finally selected articles were categorized through reminder aspects such as how, who feedback. Data were extracted according to PRISMA guidelines.

Results:

In 47% of studies, the reminder was sent to the patients, 29% to the physical therapists and 12% to the caretaker team. In 24% of the studies, paper-based letters were main medium for reminders while the rest were various types of media like emails and SMS mobile text messages. 35% of the articles showed positive effects of the reminders.

Conclusions:

Many reminder methods consisted of SMS, phone calls, letters, emails and notices on the wall were used in physical therapy. Reminders may be used to improve patients' adherence to exercise programs.

[19] G. Calcagni, E. Caballero-Garrido, and R. Pell ón, "Behavior stability and individual dif- ferences in pavlovian extended conditioning," *Frontiers in Psychology*, vol. 11, Apr. 2020. DOI: 10.3389/fpsyg.2020.00612. [Online]. Available: https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2020.00612/full.

How stable and general is behavior once maximum learning is reached? To answer this question and understand post-acquisition behavior and its related individual differences, we propose a psychological principle that naturally extends associative models of Pavlovian conditioning to a *dynamical oscillatory model* where subjects have a greater memory capacity than usually postulated, but with greater forecast uncertainty. This results in a greater resistance to learning in the first few sessions followed by an over-optimal response peak and a sequence of progressively damped response oscillations. We detected the first peak and trough of the new learning curve in our data, but their dispersion was too large to also check the presence of oscillations with smaller amplitude. We ran an unusually long experiment with 32 rats over 3,960 trials, where we excluded habituation and other well-known phenomena as sources of variability in the subjects' performance. Using the data of this and another Pavlovian experiment by Harris et al. (2015), as an illustration of the principle we tested the theory against the basic associative single-cue Rescorla–Wagner (RW) model. We found evidence that the RW model is the best non-linear regression to data only for a minority of the subjects, while its dynamical extension can explain the almost totality of data with strong to very strong evidence. Finally, an analysis of short-scale fluctuations of individual responses showed that they are described by random white noise, in contrast with the colored-noise findings in human performance.

Appendices

A Stakeholder Interview Results

Responses from interviews conducted to a sample of 11 students show that even though they are conscious of their poor posture, they do not want to use any of the current designs due to the following factors:

1. Societal expectations: Students do not want to feel like outcasts in society or be seen as "nerds"
2. One of the current designs (lumbar pillow) continuously slips and is uncomfortable
3. Students found it annoying to have to put it on every time
4. Current designs can be annoying to carry around
5. Another design (back braces) is too obvious and visible

B Design Brief

Correcting Poor Seated Posture

A Critical Problem for First-Year Engineering Science Students

Word Count: 1794

Table of Contents

1. Introduction

We discovered that Engineering Science students (EngScis) have poor studying posture despite posture-correcting devices being widely available. We identified that existing products fail to simultaneously: (i) look inconspicuous, (ii) be portable, (iii) correct posture, and (iv) be safe. With these goals, we curated a list of objectives and requirements that a possible solution should meet to address this issue, especially while sitting and studying.

2. Background

According to the Hospital for Special Surgery, back posture correctors should be used to train an individual's "proprioceptive senses" to identify good posture, which later allows the user to replicate the behaviour without assistance [1].

Posture correction is important since it can alleviate health issues for EngScis. Through stakeholder interviews, we gathered that many EngScis do not correct their back posture because it is not a priority. However, long-term slouching causes a person's center of gravity to shift forward, which impairs balance and increases chance of injuries.

Furthermore, good posture improves confidence, energy, and peer interactions [2]. Considering the current mental health epidemic [3], we believe it is crucial to address stressors which may worsen mental health. Although on-the-market solutions exist (see reference designs in section 4), several constraints reduce their adoption by our community, including portability, convenience, and social stigmas. Our goal is to present a viable opportunity that can incorporate numerous features to create a better posture corrector.

3. Stakeholders

Those concerned by this opportunity include:

- First-year EngScis, who are directly impacted by this issue but do not fix it (for reasons mentioned in Introduction). This information was gathered through informal interviews with 11 participants in the EngSci common room (see Appendix A for transcript). Although our surveys were qualitative, the low participation does not disqualify the data. A strong majority of EngScis have sub-optimal posture, as illustrated in *Figures 1* and *2*, making extrapolation justifiable.
- Manufacturers of competing products. If a solution is found to the splartz, competitors will lose market share. Given that the splartz is addressable by a team of first-year EngScis, competitor firms can likely adapt their existing solutions to match any new entrants in the market.
- Other students. Poor posture is not limited to EngScis; by observation, most students have sub-optimal posture. Users of a solution to this problem are not limited to EngScis.
- As mentioned, many orthopedic solutions do not work as patients do not like to wear them. If a solution to the splartz is found that people wear, then orthopedic specialists and other professionals will have a new tool to help treat poor posture and its associated health issues.

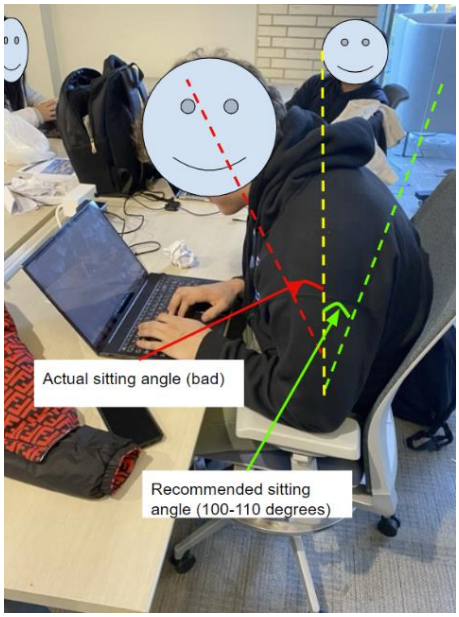


Figure 1 An EngSci student leaning forward in a chair with armrests, which deviates from recommended seating posture. The student is leaning forward to see the screen better.

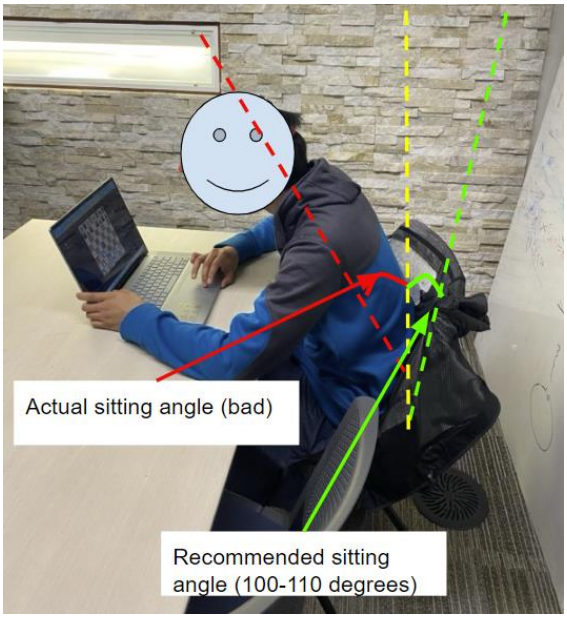


Figure 2 Another EngSci student leaning forward, this time in a chair without armrests. The student is still exhibiting poor posture, leaning forward to see the screen better.

4. Reference Designs

Pre-existing designs aim to correct posture by: (i) physically holding the user in a correct position, (ii) providing reminders to users to correct their posture when it is incorrect, or (iii) improving the ergonomics of a setup which naturally improves posture as a result.

4.1 Back Braces

Designs support posture consisting of braces, as shown in Figures 3 and 4, are known as scapular braces. A study done by Leung, Kan, Cheng, et al. on university students wearing scapular braces while typing showed less strain in back muscles, suggesting that back braces can help maintain proper posture for longer periods by reducing strain [4].

The disadvantage of scapular braces is that they look awkward and unnatural. First-year EngScis mentioned that braces are undesirable to wear because they look odd, or “nerdy” (see Appendix A). This suggests the solution to poor posture should be concealed, or at least discreet.

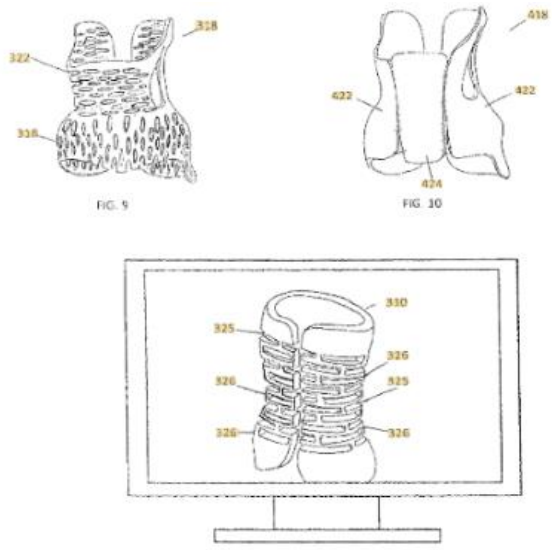


Figure 3: A scapular brace custom fit to someone's body [5]. It forces the user to maintain a straight posture and reduce muscle strain.

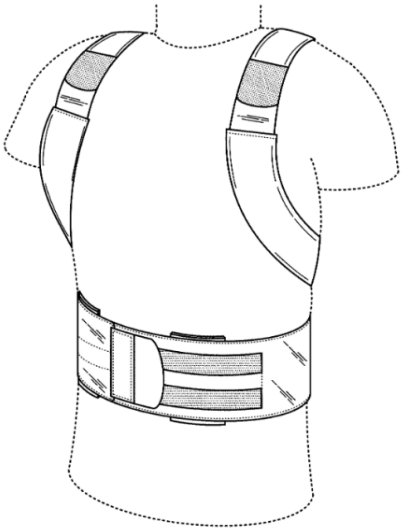


Figure 41: A scapular brace made adjustable using straps [6].

4.2 Sensor-Based Posture Correction

Sensor-based posture correction devices work by checking how much the user's angle differs from some reference initial angle. If it exceeds 15 degrees, it reminds the user to fix their posture [7]. This is advantageous because it is small and concealable, and it trains the user to improve their posture. However, we found little research to support its efficacy.

Figure 5: The Vibe Digital Sensor measures the angle user makes to a reference position, and prompts the user when the tracked angle is unergonomic [7].

4.3 Laptop Stands

Many effective designs improve workspace ergonomics to naturally promote better posture (Appendix B). These are mostly unsuitable for us as they are bulky and stationary, which is inadequate for

the chaotic lifestyle of EngScis. A more portable solution is a laptop stand *(Figure 6)*. They elevate the monitor screen, putting it 20-50 degrees from the horizontal, as specified by ISO standard 9241-392 [8]. This laptop position reduces hunching to encourage better posture, but only works for laptops. Posture corrections while working pen-to-paper remain unaddressed.

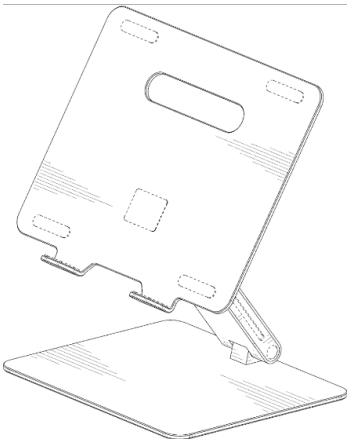


Figure 6. A 2laptop stand design from [9]

4.4 Back Pods

Back pods *(Figure 7)* are portable tools that aim to help improve lie-down back posture by reducing back tension. Due to its lightweight [10] and ergonomic design, the product has been well adopted. Unfortunately, the product is used in non-seated positions, which is not useful for EngScis when they study.

Figure 7: The Original Back pod made to improve back posture. The backpod is relatively small compared to the person, and is not too bright or distracting, deeming it portable and aesthetic (where the notion of "aesthetic" is determined through interviews with EngScis) [11].

5. Product Requirements

The reference designs suggest that the ideal design to correct back posture should be portable, discreet, and should be able to be used in diverse scenarios.

Table 1: Breakdown of the Needs, Goals and Objectives used to Establish the Requirements and Evaluation Criteria of our Opportunity.

Objectives	Requirements/*Evaluation Criteria*	Justification
Goal 1: The device is safe to use		
1. Materials used shall have the least amount possible of carcinogens and allergens	The number of carcinogens and allergens shall conform to the maximum carcinogens and allergens imposed by the OEKO-TEX Standard 100 [12]. *The fewer maximum carcinogens and allergens imposed the better.*	Research has been done to maximize potential users and be the least harmful possible.
2. Shall not be an electrical hazard for the user	The circuits in the materials shall conform to the maximum voltage dictated by UL 60601-1 [13]. *The less voltage required, the better.*	
Goal 2: The device is durable		
1. Shall not break during normal operation	Shall be operational when placed in 3K21 conditions (temperature controlled from 15°C-32°C, but not humidity controlled as specified by IEC 60721-3-3 [14] *The longer the product remains completely operational, the better.*	EngSci students study in many places so the product should withstand daily indoor wear and tear.
2. Shall not be damaged by household cleaning supplies	Shall maintain the same mass, dimensions, and appearance after drying from being immersed in household cleaning supplies (specified in Annex A of ISO 175. Examples include acetic acid, ethanol, and hydrogen peroxide). [15] *The longer the product remains immersed in the cleaning fluid without changing mass, size, or appearance, the better*	EngSci students will clean the product so it will not be damaged by cleaning supplies. We can also extrapolate these results to conclude that body oils and sweat will not damage the product because cleaning supplies are much more basic or alkaline than human sweat/oils [16].
Goal 3: The device is portable		
1. Shall have small dimensions.	Shall have dimensions no bigger than 7 x 7 x 7 inches Shall be able to hold with one hand.	The ideal phone size is 6.1 inches, as it is portable enough to fit anywhere you go but it is not too small to

	The smaller and more compact the product, the better.	function [17]. Based off this, to construct something that can be taken everywhere, almost like a phone, it is fair if it is in similar dimensions.
1. Shall be lightweight 2. Skin-contacting material should be breathable and should not impede the movement of the individual.	The product shall weigh no more than 600g (based of 500g from reference designs). *The lower the mass, the better.* Material should be made of soft silicone, memory foam, cotton/elastic blends, canvas, neoprene or anything with a Thermal Evaporative Resistance (RET) coefficient < 6 (tested using ISO 11092 standard) [18][19]. If fabric is used, it should be composed of nylon, elastic or materials sharing similar properties [20]. *A lower (RET) Coefficient is better*	The original back pod design (pg 7) has a mass of 500g [10], and the ideal phone has a mass of 130g [21] justifying this mass. Lower RET values mean more breathable materials that will keep users comfortable throughout the day. Cotton/elastic blends and similar materials are flexible, allowing for less pressure applied on the back, making it easier to wear the material.
Goal 4: The device is aesthetically pleasing		
1. Shall not be bulky or any weird shapes	The product shall not have sharp corners or radii [22]. *The larger the radii of curvature at corners, the better*	Sharp corners are both dangerous and uncomfortable to have in contact with skin.
2. Hardware shall not be visible or distracting	The colour of the product shall not be any neon colour. *The lower the visibility of the product while in use in public, the better.*	From [23], users of back braces did not wear them for the prescribed times as they thought the hardware being visible had an affect on their confidence.
Goal 5: The device corrects the users posture		
1. Shall encourage the user to sit without hunching or rounded shoulders.	The user shall sit with a symmetrical trunk posture, with a trunk inclination between 100-110 degrees [24], and spine posture as specified by ISO 11226:2000 [25]. *The more time we can comfortably sit in this position, the better.*	Posture research has informed ISO 11226:2000 [25] of optimal seating position for good posture. The user ideally follows this standard.
2. Shall only allow poor posture for some maximum recommended time	The user shall be allowed to sit with poor posture for a *maximum holding time* recommended by ISO 11226:2000, depending on the user's trunk inclination [25].	

6. Conclusion

We needed a solution to correct EngSci's poor postures. After researching reference designs, ergonomics, and interviewing EngScis, we identified that the ideal posture-correcting device should be safe, portable, durable, and be aesthetically pleasing. Existing products fail to meet at least one of these criteria, which is why we made requirements and objectives that the optimal solution should meet.

C Video Link

Testing Requirements - Praxis Design Report: https://youtu.be/jkqF1FlfK5o