

EXAMINING STIGMA AND USER COMFORT THROUGH THE REIMAGINATION OF CRUTCH DESIGN

by

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Abstract

Crutches are intended to support, restore independence, and aid social inclusion of individuals. However, crutch use may lead to undesirable mental and/or physical impacts. The dominant medical, functionalist aesthetic of crutches typically does not align with individual's self-identities, which may lead to reluctance of use, device abandonment, and/or negative social impacts that limit a person's societal participation. This study identifies postural risks associated with crutch use; presents the experiences and perceptions from current, past, and non-users; documents crutch concepts developed with SMEs; and evaluates people's perceptions of the concepts. These methods served to explore the concepts' anthropometric potential and whether they could move crutches toward personal aesthetic and social preferences, and the realm of fashion and wearables. The findings suggest that there is comfort in device familiarity and that new design developments should evaluate the whole-body impact of use to deliver devices that support all needs of users.

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Chapter 1: Introduction

1.1 Rationale for the Study

A literature review and anthropometric study (study of human bodily measurements relative to design) of current crutch designs indicate that there is a disconnect between users' personalities, identities, and physical 'fit' relative to the design and customization of current crutches.

According to researchers in this area, even the devices that receive design awards, appear to compromise form, colour, and style (Olander, 2011). Given their traditional alignment with 'medical design', the styling used in crutches serves as a reminder of a treatment or diagnosis for illness or impairment (Ibid.). This aesthetic sentiment is more akin to a medical model of disability that places aesthetics as a secondary consideration in favour of function. As these products have traditionally been seated within a medical model of design, people who use these products may feel stigmatized if they perceive the product to equate with 'impairment and treatment' (Chu & Vella, 2001). Reimagining crutches through a social model of disability reframes the focus on a person's impairment being the cause of disability, to rather, social factors which may be preventing people from feeling included and progressing in all areas of life. A social model seeks to minimize environmental, organizational, and attitudinal barriers that are imposed on persons with disabilities (PWDs), barriers which potentially hinder individual's inclusion and progress in daily

living. Looking at crutch design from a social model of disability also emphasizes the importance of people's identities and preferences in design.

Apart from reviewing the importance and potential of the social component in redeveloping these devices, an anthropometric analysis of images and video of crutch use reveals that current crutches (underarm and forearm) may result in poor postures, that is, postures that deviate from neutral positioning of joints and limbs. Furthermore, these devices may even exacerbate poor postures, creating opportunities for further physical harm. Neutral musculoskeletal postures are the most optimal positions to exert bodily forces and manage loads, but neutral postures may differ from person to person. The postural risks identified in this study include wrist extension, abduction, and supination; shoulder extension, elbow flexion, and other improper limb positioning. Based on these risk factors, this study aims to create crutch concepts that are better aligned with anthropometric principles to support more neutral postures and reduce the potential for pain or further injury.

1.2 Context

The researcher has a formal education in architectural design and drafting and industrial design. During their 4th year Industrial Design capstone project, the researcher designed a conceptual hands-free crutch intended for temporary usage due to lower limb injuries. During this project, questions emerged on how to examine and create a more comfortable, meaningful, and inclusive crutch design while

mitigating the pitfalls of designing without individuals who hold knowledge of this product category.

Design research is concerned with what ought to be, differentiating from scientific research that is concerned with what exists (Milton & Rodgers, 2013). As stated by Milton and Rogers (2013),

“Research in a design context breaks with the determinisms of the past; it continually challenges, provokes and disrupts the status quo. Whereas scientific research relies on and utilizes abstract mathematical explanations, design research uses representative images, physical models and 3D prototypes in the design and development of things that do not yet exist” (Ibid., p. 11).

The overarching intention of design research is to better understand and improve the processes, products, services, and systems being designed (Ibid). As an industrial designer the researcher acknowledges the role and importance of scientific research. An interdisciplinary approach that takes into account the importance of understanding ‘what exists’ is crucial in designing ‘what does not yet exist’ effectively.

1.3 Research Question

This research asks: *how might a user-centered and interdisciplinary design process reshape crutches to:*

1) improve our understanding of postural risk factors related to existing crutch use to mitigate these risks;

2) improve our understanding of people's perceptions of existing crutch designs in terms of use and aesthetics; and

3) reimagine the product's aesthetics to move this category towards people's personal aesthetic and social preferences, and the realm of fashion and wearables?

To answer these questions, three design research phases were conducted to facilitate the exploration and reimagining of this product category. The first phase asks, 'What is the intent of crutches and how are they used?' to define common postural risks, as well as users' and non-users' experiences and thoughts of existing crutches. The second phase asks 'How could they be?' to generate design concepts that may better align with people's personality, identity, as well as body dimensions and neutral positioning. The final phase asks, 'How are the new ideas perceived in terms of aesthetic and anthropometric potential?' These phases and questions were developed to explore the potential for progress in the field of walking aid design.

1.4 Study Contribution

This study does not seek to eliminate the potential for stigma surrounding crutches. Eliminating stigma related to products people use is a wicked or insurmountable problem and cannot be completed in one study; this is due to the nature of stigma as a by-product of societal categorization of persons and attributes (Goffman, 1986). A wicked problem may be any complex issue which defies complete definition and for which there can be no final solution (Brown, Harris, &

Russell, 2010). Instead, this study aims to examine the potential for stigma as inspiration to examine how stigma may be mitigated through the generation of new crutch concepts - designs that will mix anthropometric and aesthetic elements with the aim of aligning more closely with a person's identity, aesthetic preferences, and healthy body positioning.

The thesis also captures thoughts on crutch aesthetics, experiences of crutch use, and stigma from users and those who have never used them to gauge 'public opinion' of these devices. While the final outcome led to two crutch designs for consideration, this thesis contributes design recommendations and practices that may be applicable across a range of assistive devices. Lastly, this thesis highlights the value of designing assistive device concepts with people who use or have used these devices (subject matter experts) and people with additional expertise in anthropometrics/physiology. Notably, the responses and opinions collected within the study represent attitudes of persons within North America.

1.5 Overview of Thesis

In Chapter 1 – Introduction, we discuss the general subject matter, provide context and background that relates to the need for this study, outline the research questions to address this need, and the proposed methods to answer the research questions.

In Chapter 2 – Literature Review, the impact of crutch problems is identified by examining: the influence of the medical model on crutch design, definitions around

stigma and the relationship between stigma and assistive devices, reasons for crutch abandonment, the importance of device personalization as a means of reducing stigma, emotional considerations in design, and postural considerations. This review identifies the basis for exploring the research questions.

The data collection and analysis methods used to explore the research questions are discussed in Chapter 3 – Methods. The methods included an anthropometric analysis, existing crutch questionnaire, conceptual crutch development with a Design Advisory Group (DAG), and a new crutch concepts questionnaire that captured people’s perceptions of the concepts generated with the DAG.

The results of the methods are presented in Chapter 4 – Results. Findings emerged during each stage of data collection, including data on postural risks as well as crutch users’ experiences, pain points, perceptions and preferences related to these devices. This information was categorized to examine the perspectives and priorities of this participant group.

In Chapter 5 – Discussion, the key findings of the study are compared across methods and in relation to the literature review conducted in Chapter 3. The implications and contributions of the study to the field, study limitations and possible research improvements are also discussed here.

Chapter 6 – Conclusion, concludes the study by summarizing the findings, and providing recommendations.

Chapter 2: Literature Review

2.1 Defining The Impact of the 'Crutch Problem'

The World Health Organization (WHO) estimates that over one billion people require one or more assistive devices, with this figure expected to double to over two billion by 2050 (Vairis et al., 2021). Of these assistive devices, the two most popular are visual and walking aids (Ibid.). Within the United States of America approximately 6 million people use crutches; in Europe, 4.2% of women and 3.4% of men have a walking disability; and 2.8 million Canadians have a type of mobility disability (Rasouli & Reed, 2019). These authors highlight that the number of persons using assistive mobility devices is growing at a faster rate than the general population and that the figures provided above are conservative estimates as they “[d]o not include partially-impaired persons using a single or pair of crutches as a supplement to other assistive mobility devices such as wheelchairs, scooters, and lower limb prostheses” (Ibid., p. 2).

Walking aids may be in the form of a rollator, cane, knee scooter, walker, crutches, etc. These devices, particularly crutches, are recommended, prescribed, and used by persons for daily mobility because of: lower limb motor impairment, problems of pain, equilibrium, muscular weakness, joint instability, and fatigue (Rasouli & Reed, 2019; Sansom & Ulrich, 2013; Smidt & Mommens, 1980). The most commonly used types of crutches today are forearm and axillary (underarm) crutches, as shown in Figures 1 & 2.



FIGURE 1 (LEFT) UNDERARM CRUTCHES (MCKESSON, 2021)

FIGURE 2 (RIGHT) FOREARM CRUTCHES (DRIVE MEDICAL, 2021)

Crutches serve to allow and restore locomotion and independence (Rasouli & Reed, 2019; Sansom & Ulrich, 2013). To the unaware, none of these points lead one to believe there are any problems with crutches when in fact, persons may face the first problem with crutches prior to ever using one. Smidt and Mommens (1980) write,

“[t]he physical therapist may evaluate the patient for abnormalities and identify the form of assistive device to be used and type of assisted gait to be learned. The clinician may judge the quality of the patient’s walking performance using standards such as preconceived expectations of normality, information presented in scientific publications, or his clinical experience in dealing with manifestations of disorders” (Smidt & Mommens, 1980).

In this approach, practitioners aim to determine the extent of the person's abnormality, the level of deviation from what medicine has categorized as the 'norm'.

Individuals who use a crutch, be it short-term or long-term, will be affected by use. This does not apply solely to crutches, but assistive technology/devices as a whole. Disability has and continues to be experienced and perceived differently. The technology and devices that have been developed through a 'one size-fits-all approach' have shaped and constituted new forms of social relationships in our society (Ravneberg & Soderstrom, 2019). Crutches are double-edged in nature, a means of independence and an aid, but also a symbol of disability and dependence on the aid (Ibid.). To observers, an assistive device like crutches, may appear inseparable from the user and serve as a visual cue that the user has a disability (Brooks, 1991). Once perceived differently, the users may be marginalized and stigmatized. Crutches as a physical object are stigmatized. Their stigmatization may result in a person's outright refusal to use the device (if given the option), abandonment of the product, or psychological problems for users. However, those that use crutches, and do so by choice, also face physiological impacts resulting from altered gait and postural risk factors (Olander, 2011; Weerasinghe et al., 2015; Ravneberg & Soderstrom, 2019).

2.1.1 Stigma

It is key to first discuss definitions around stigma, its significance within daily life, and pertinence to crutches. Firstly, a stigma is not a stereotype. A stereotype

may be advantageous or disadvantageous to a person, whereas stigma is always negative (Olander, 2011). In recent years, the concept of stigma has seen increased interest throughout social sciences and design research (Vaes et al., 2012). Stigma “[b]ridges many disciplines, including sociology, clinical psychology, social psychology, and public health” (Ibid., p. 11). The definitions of stigma reviewed for this thesis overlap.

The term stigma, as per *Stigma: Notes on the Management of Spoiled Identity*, originated with the Greeks to “[r]efer to bodily ... signs [that were] cut or burnt into the body and advertised that the bearer was a ...blemished person, ritually polluted, to be avoided, especially in public places” (Goffman, 1986, p. 11). The term *Stigma*, defined in the Cambridge Dictionary is “[a] strong feeling of disapproval that most people in a society have about something, especially when this is unfair” and the act of ‘stigmatizing’ someone as “[t]o treat someone or something unfairly by disapproving of him, her, or it” (Cambridge Dictionary, 2021). Goffman (1986) states that “[s]ociety establishes the means of categorizing persons and the complement of attributes felt to be ordinary and natural” (Ibid.). Any person who falls outside of the socially crafted categories of “ordinary” and “natural” is perceived differently or stigmatized. Goffman doesn’t give a definition of ‘ordinary’ or ‘natural’. These terms, much like ‘norm’ or ‘normal’ transcend precise definition of what it means to be ‘normal’ or ‘other than normal’. Their interpretation differs from person to person, nation to nation, and society to society. What may be construed as out of place in one society may be common in another. As such, stigma and the intricacies that

determine who or what is stigmatized cannot be neatly packaged or presented. Stigma is a malleable entity, directly correlated to societal values. As a malleable entity, these means of categorizing persons and attributes can be shifted, diminished, or cease to exist.

Goffman (1986), other fellow sociologists, and psychologists have expanded the definition of product-related stigma, adding the importance of understanding formative factors (Vaes et al., 2012). Jones et al. (1984), for example, identified six factors that may influence the act of stigmatizing an 'other': (1) the concealment or apparentness of the trait(s) to others; (2) course of the mark, which means whether the stigmatizing trait is reversible over time, with irreversible traits eliciting more negative attitudes from others; (3) disruptiveness, or how a trait that is stigmatized can strain, tension or obstruct social relationships; (4) aesthetic qualities, and the extent to which the trait is displeasing to others; (5) origin, which refers to the perceived responsibility of the individual in acquiring or creating the trait; and (6) peril, or the perceived danger to others attributable to the trait (Hilbert et al., 1985).

Goffman (1986) introduces and emphasizes 'visibility' as an important factor of stigma. The author continues that within 'visibility' there are either "discredited" or "discreditable" individuals. The "discredited" individual's 'differentness' is either previously known or immediately evident. The "discreditable" individual's 'differentness' is invisible, not immediately apparent, or known by those around them (Goffman, 1986). The use of a crutch, a highly visible device, can be potentially stigmatizing, which in turn may cause the individual using the crutch to lose legitimacy

(be discredited), whereas the user may be discreditable if the stigmatizing device is concealed or less visible. The existence of an attribute or device, such as a crutch, that stigmatizes the individual using it also simultaneously confirms the 'usualness' of the non-crutch user.

In looking at the potential 'cause' of the stigmatizing condition, Falk (2001) differentiated between two types of stigma: "existential stigma" (e.g. race/ethnicity, mental condition) where an individual is not responsible for or has little control over the stigma and "achieved stigma" (e.g., prisoners and panhandlers) where an individual's conduct contributes/d to them attaining the stigma and is perceived as responsible for their condition (Falk, 2001). Although more recent research on social determinants of health questions the real extent of an individual's ability to make choices about their conduct versus "the wider set of forces and systems shaping the conditions" that form their daily life (World Health Organization, 2021), this distinction between existential and achieved stigma is worth noting here. Some individuals purposely wear or use items such as piercings, extreme fashion, and political symbols as a source of personal enjoyment gained by provoking societal norms and purposeful, achieved stigma (Vaes et al., 2012). These products and symbols represent decisions to achieve stigma. However, for those experiencing existential stigma due to products they require and are not within their control, the outcomes may differ. According to Vaes et al. (2012), some "[p]roducts that can be linked to an existential stigma include wheelchairs, crutches, or obliged protective devices" (ibid.,

p. 12). These existentially stigmatizing and highly visible products are attributes that may result in the person being discredited by others.

2.1.2 Stigma and Assistive Devices

People may label individuals using assistive devices based on the factors outlined above which have been related to stigmatization. Fraser et al. (2016) state that while “[l]abeling is efficient as it minimizes the use of cognitive resources, it can be problematic as we tend to resort to categorizing a person by a particular trait which is not representative of the person” (Fraser et al., 2016). Once labeled, they are stereotyped and their social identity recast, regardless of self-identity. This may be an unfortunate reality for some users of assistive devices, depending on their context.

Assistive devices may be classified by several terms. Sometimes called devices, products, or technology; this thesis shall use the term ‘devices’. The WHO (World Health Organization) (2018), defines assistive technology as

“[a]n umbrella term covering the systems and services related to the delivery of assistive products and services. Assistive products maintain or improve an individual’s functioning and independence, thereby promoting their well-being. Hearing aids, wheelchairs, communication aids, spectacles, prostheses, pill organizers, and memory aids are all examples of assistive products” (World Health Organization, 2018).

Assistive technology/devices, therefore, should enable persons to live healthy, productive, dignified, and independent lives to participate in school, the workplace,

and daily life. The WHO also states that “[w]ithout assistive technology, people are often excluded, isolated, and locked into poverty, thereby increasing the impact of disease and disability on a person, their family, and society” (Ibid.). A profound positive impact of an essential assistive device for people who require devices, such as those described by the WHO, is the ideal outcome.

When individuals use devices that are essential to personal functions such as communicating, eating, and mobility, these devices act as cues to social roles because they are typically observable to others (Brooks, 1991). The use of an assistive device may invoke stereotypes around an individual’s limited range of bodily movement, appearance, and increased spatial requirements as an abnormality (Ibid.). Olander (2011), states that an assistive device, be it a plaster cast, intravenous (IV) drip, or crutches, are all items that were manufactured to substitute a missing human function, as seen from a view of how the typical human body should function (Olander, 2011). The cast serves as a temporary substitute of the broken limb; the IV drip provides hydration, blood, or medicine to allow one to heal; crutches provide support for the injured lower limb and balance. Olander continues that assistive devices have,

“[a]ll been developed with ergonomic, medical, and technical requirements in mind: to fix or mend that which is broken, or to supply that which is missing. This means that the human body, by artificial means, again comes as close to normal as possible, so that an injured person can participate in the social and cultural context offered by our society” (Ibid., p. XXV).

The use of an assistive device should mitigate the user's missing human function and in an ideal situation normalize that which is labelled as 'sick' or 'impaired' in a physical context. The imagery of an assistive device is so synonymous with correction of a missing human function, that a stylized image of an assistive device, the wheelchair, serves as the international symbol of disability.

The original intention of assistive devices may be, as defined by the WHO, to allow people to participate in society. However, their use often leads persons to experience "...marginalisation and stigmatization, especially if the use is not temporary, but permanent" (Ibid.). This long-term need for an assistive device to facilitate a 'regular, normal life', as perpetuated by our society, reinforces that those who lack these bodily functions are different from others. As Olander (2011) states, "[t]he functions, prejudices, and values of society turn you into a disabled person" (Ibid.). Shinohara & Wobbrock (2011), title these environmental and attitudinal factors as "barriers of discrimination", suggesting that disability is a socially constructed phenomena, much like stigma (Shinohara & Wobbrock, 2011). As disability is not necessarily a by-product of crutch use, but rather social values, there "[i]s a social responsibility to provide for accessibility in the creation of environments and artifacts" (Ibid., p. 706). Crutches as an assistive device should, by intention, allow users to break down and overcome social barriers rather than be the reason for the social barriers. What happens then if the user's self-identity and identity invoked by the device oppose one another or are mismatched?

Crutches are not 'static or dead' assistive devices or objects, but actors and identity markers in people's lives (Ravneberg & Soderstrom, 2019). We associate personal meaning to objects used in our daily lives, be it a baseball cap, pair of shoes, t-shirt, eyewear, and so on. Whatever the object may be, we may feel these objects aid in defining part of our identity in some form (Shinohara & Wobbrock, 2011). As a product, crutches may be viewed by users as not just part of their identity but also important body parts, an extension of the body, as a leg or their legs. In doing so, it's supposed to be a part of them. This assimilation of body and device may only occur if the device is a good match to the user's identity. Ravneberg and Soderstrom (2019) link this to Haraway's (2017) fiction of the human being, or cyborg image and define a cyborg as "[a]n organism that adds to, or enhances its abilities using technology" (Ravneberg & Soderstrom, 2019, p. 58). By this definition, the majority of humans are cyborgs in one form or another. Haraway describes machines such as computers, hearing instruments, mobile phones, wheelchairs, glasses, and even pencils as "prosthetic devices", "intimate components", or "friendly selves" (Haraway, 2017, p. 164). However, a device like crutches may not be viewed or categorized as "friendly selves" if the person does not want to use them.

Assistive devices like crutches could, and are intended to, make a major positive impact in the lives of those for whom they are prescribed, but the device will only be adopted if they, the user, really think that it is useful (Weerasinghe et al., 2015). The mismatch between the person and the assistive device is a major barrier to using assistive technology. Weerasinghe et al. (2015) state, "[p]ersons with lower

limb disabilities have to adjust psychologically at the point of their first instance of using assistive devices” (Weerasinghe et al., 2015, p. 81). The crutch creates a psychological barrier to adoption. To quote a participant from Weerasinghe et al.’s (2015) study,

“I thought initially that if I started to use crutches I would become a disabled person in the society. I did not want to be looked at by others as disabled. Therefore, I was not in a position to accept the crutches even after the doctor prescribed them to me” (ibid., p. 89).

This participant’s remarks were not an outlier but rather the common sentiment of the participants in that study. It also identifies a feeling that persons do not consider themselves as discredited or outliers or disabled until they begin using crutches. If a person does not consider themselves as discredited or identify themselves as disabled, they may reject the device’s implications in forming their social identity and may outrightly reject using or abandon their crutches following a period of use.

2.1.3 Crutch Abandonment

Technically speaking, assistive devices like crutches, are all devices that ‘work’, but there is evidence of high levels of abandonment (Pullin, 2010). Device abandonment can be defined as non-use of a device type following prescription of the device (Chu & Vella, 2001). Chu (2001) cites Phillips and Zhao’s 1993 study that evaluated which assistive devices were frequently abandoned, including: lower extremity braces, walkers, canes, wheelchairs, electric scooters, splints, and crutches (Zhao & Phillips, 1993; as cited in Chu & Vella, 2001). These devices had a

total average abandonment rate of 29.3% (Ibid.). In an earlier study, Phillips and Zhao noted that mobility aids were abandoned at a rate between 10.4% and 49% (Chu & Vella, 2001). As for why persons abandon their devices, the reasoning is very complex (Olander, 2011). Federici et al. (2016) state that device abandonment is the by-product of a complicated interaction of four main factors; 1) personal factors such as age, gender, maturity level, or acceptance of disability; 2) device factors such as quality and appearance; 3) environmental factors such as physical and social barriers and support; and 4) delivery factors, which includes receiving a device, taking users' opinions into consideration, device instruction and training, as well as follow-up services (Federici et al., 2016). All of these factors must be carefully managed, observed, and assessed by the professionals involved in the process of matching the individual to their device in order to minimize the possibility of device abandonment (Federici et al., 2016). The complexity of device abandonment provides some insight into why the abandonment rate has such a large percentage range. However, these studies on device abandonment rate do not note the age range, median age, or average age of respondents. Assistive devices are typically used by elderly persons, but young persons are more dissatisfied with their devices than elderly users (Olander, 2011).

Matching a device to a person is a delicate and difficult process. Every individual has different interpretations of their ideal device and priorities (Ravneberg & Soderstrom, 2019). Some users may select device function as their main priority, while others prioritize aesthetics. Matching a device to a person is more difficult than

matching them to clothes or footwear. Ravneberg and Soderstorm (2019) state “[p]eople do not necessarily use devices they ‘clinically’ need. People abandon devices and do take risks” (Ibid., p. 57).

2.1.4 Personalization and Destigmatization

Olander found that there were three strategies employed by users who felt disconnected or that their device did not align with their identity; 1) putting up with the device, accepting the situation; 2) device abandonment, as discussed above; or 3) customizing the product or creating something new rather than using an existing product (Olander, 2011). Individuals seek a larger choice of options to allow for individuality and personality when selecting a device that is new to them. Traditionally, aesthetics have not been a priority, particularly in the welfare state (Ravneberg & Soderstrom, 2019). Ravneberg and Soderstorm quote an e-mail from a civil servant in the British Health Department that explicitly stated “[i]n the UK the priority for each patient clearly is the clinical need rather than the aesthetic appearance” (Ibid., p. 57).

The aesthetic identity of a device is important to use; the product may be abandoned if the user does not ‘want’ or show an interest in their device. Some occupational therapists suggest it may be best to put up and cope with the device by providing users personal strategies when faced with other people’s adverse reactions (Olander, 2011). Rather than providing users with personal social strategies to be applied to other’s reactions, Olander (2011) suggests the possibility of changing the product’s identity; “[i]n doing this, the product is allowed to be a part of the

person's extended self and the person can continue to be who he or she is without applying a new strategy" (Ibid., p. 10). The interviewees from Olander's (2011) study expressed their preference of hiding or camouflaging the product rather than acting differently in relation to others (Ibid.). Camouflaging the device has been a priority in designing for disability; enabling independence while attracting as little attention as possible (Pullin, 2010). In doing so, the approach has been less about projecting a positive image of disability but rather to not project an image at all. Pullin (2010) asks "[i]s there a danger that this might send out a signal that disability is after all something to be ashamed of? If discretion were to be challenged as a priority, what would take its place?" (Ibid., p. 15). Fashion may be perceived as largely concerned with the creation and projection of an image; making those who wear it feel and look good (Ibid.). Fashion and discretion are not opposites, fashion can be understated.

Eyewear typically serves as the exemplar when disability and design are mentioned. Eyewear is an assistive device, yet it carries little to no stigma; a positive image of disability achieved without invisibility. Eyeglasses, even among wearers, no longer elicit categorization as medical devices, rather as a fashion accessory (DeLong & Daly, 2013; Montalto, Graziosi, Bordegoni, & Di Landro, 2018). The very fact that mild visual impairment is no longer considered to be a disability speaks for the success of the design of eyeglasses (Pullin, 2010). However, this has not always been the case for eyeglasses. In the 1930s, the British National Health Service classified spectacles as medical appliances, their wearers as patients, and dictated that medical products should not be styled (Ibid.). These days, eyeglasses have become

invisible, an aspiration rather than humiliation. Pullin (2010) states that for some brands, up to 20 percent of eyeglass sales feature clear, non-prescription lenses (Ibid.). For these persons, eyeglasses are solely fashion and styling. The acceptance of eyeglasses is not due, in part, to their invisibility, but visibility. Eyeglasses have become eyewear. One wears eyeglasses rather than uses them. Portrayal of the user as a 'wearer' sets up a different relationship between the designer and those being designed for. Aesthetic design and styling are highly subjective, differing from person to person. The traditional development of assistive devices differs from fashion and designed goods in that it "[r]eflects traditional ways of thinking about medical cure, treatment, and rehabilitation" (Ravneberg & Soderstrom, 2019, p. 60).

2.2 Problems with the Current Approach to Crutch Design

There are a variety of terms used within the field of crutch design, each requiring a definition to properly define the elements of a crutch. In medical terminology a crutch is a type of ambulatory assistive device. Those who use assistive devices to walk are unstable and at greater risk of falling and further injury (Vairis et al., 2021). Sansom (2013) states "[a]ssistive devices are prescribed for patients with motor disabilities to increase safety and stability...[and]...[d]ecisions regarding which AD [assistive device] to prescribe are often based upon safety with functional mobility a secondary consideration" (Sansom & Ulrich, 2013, p. 3). The most common types of crutches are the forearm and axillary, also known as the underarm crutch. Crutches, particularly axillary or underarm crutches, have existed for 5 millennia

(Hernigou, 2014). Underarm crutches generally include an underarm pad and allow for more trunk support than other crutch types and were first used during the Greek era in Egypt in 32nd century BC (Rasouli & Reed, 2019). Many early manuscript illustrations within the middle-ages depicted persons using crutches, but the earliest manuscript illustrations depicting crutch use are from ancient Egypt within 1580-1350 BC.

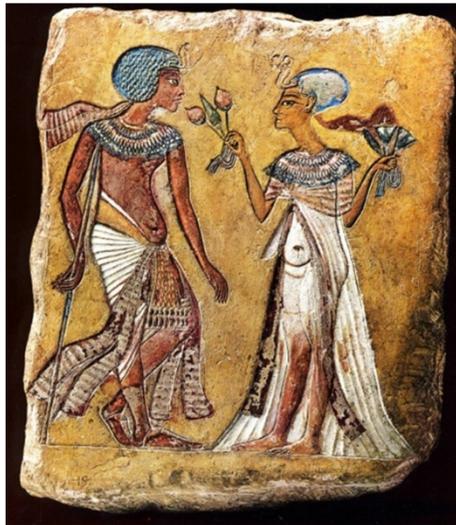


FIGURE 3 EGYPTIAN USING AXILLARY TRAVERSE CRUTCH (HERNIGOU, 2014, P. 1330).

The correct use of underarm crutches places weight only on the handle. The axilla/underarm pad exists, and should only be used, to aid a person's stability (Rasouli & Reed, 2019). Underarm crutch users may use their device incorrectly, splitting their weight between the handle and underarm pad or primarily upon the underarm pad, especially when stationary. Forearm crutches replace the underarm pad with an armband placed around the user's forearm to support the upper arm and transfer body weight and minimize or eliminate pressure from the underarm, "[w]hen [forearm crutches] fit correctly, an individual's elbow is slightly flexed (10-15

degrees) and the arms typically rotated during use” (Ibid.; Sansom & Ulrich, 2013, p. 64). User posture and limb positioning during use is a key consideration in crutch design.

2.2.1 Postural Considerations and Physical Design

Crutches serve to aid and support the musculoskeletal system, of which body posture is an important function. Lee et al. (2021) state “[p]osture is an important health indicator, and postural abnormalities are associated with a large number of disorders, including pain syndromes, generalized or regional musculoskeletal disorders, and respiratory dysfunctions” (Lee et al., 2013, p. 453). The use of crutches bears postural risks. When used, the user’s posture changes during gait to accommodate the crutches, causing the individual to tilt forward. Tilting forward during crutch use changes the body posture and joint positions of the hand, elbow, shoulder, and trunk (Ibid.).

The use of crutches causes a significant change in the locations of forces applied to the body. Walking with crutches creates forces that are applied to the upper extremities whereas without a crutch, ambulation only includes forces applied at the feet. Underarm crutches particularly impact the hand and axilla, while forearm crutches create forces in the hands and forearms (Rasouli & Reed, 2019). The affected joints are also subject to increased impact. The movement of load away from the lower limbs, with the crutch tips contacting the ground prior to the feet, transfers this load to the handle and increases the forces experienced on various areas of the

body. Rasouli and Reed (2019) note that a total average of 1.8 times of bodyweight is applied to the hands through the crutch handles during the initial stance phase (Ibid.). It is not only the hands that are impacted, the impact of crutch use affects the body as a whole. Smidt and Mommens (1980) state that the “use of assistive devices tends to increase the vertical loading on structures of the body as a whole even though use of an assistive device can reduce forces at one lower extremity” (Smidt & Mommens, 1980, p. 558). The transfer of bodily weight to the upper limbs often results in upper extremity injuries. This is especially common in long-term users, who experience high pressures in the shoulders, underarm (axilla), forearm, palms, and wrists (Rasouli & Reed, 2019). To counteract and address injury/ies Smidt and Mommens (1980) recommend that the movement of all body parts should be monitored when assistive devices, like crutches, are used (Smidt & Mommens, 1980). These devices need further modifications to increase comfort, reduce the risk of injury, and evolve aesthetics. To place these as priorities, a broader approach is required. In 2006 the National Health Service (NHS) in England recognized that not all of clients’ needs were not taken into consideration, stating “[a] whole-systems approach is needed that encompasses not only posture and basic mobility but also the well-being, lifestyle choices, and emotional and mental needs of individuals” (Ravneberg & Soderstrom, 2019, p. 78).

2.2.2 Medical Model of Design

A whole-systems approach differs from the current medical model of assistive device design. Assistive devices serve to increase, maintain, or improve functional capabilities of persons with disabilities (Shinohara & Wobbrock, 2011). Anyone may acquire an impairment or be labeled as ‘disabled’ at any time as a result of life events; disability is not something one has, it is applied to individuals with impairments, through the creation of inaccessible spaces or unwelcoming attitudes. However, if assistive devices like crutches are built to be functional, usable, and assistive as their name implies, but are subsequently abandoned by the user for any of the multitude of reasons discussed earlier, then the proposed functional benefits are undermined by other factors, factors worthy of consideration.

Assistive devices may aim to promote inclusion through mobility but also inherently impede social participation (Ravneberg & Soderstrom, 2019). People who advocate for a medical model of care have traditionally focused on ‘abnormality’ categorizing disabling conditions as something wrong that should be fixed, with devices viewed as cures rather than components of the (re)habilitation process (Brooks, 1991). Addressing impairment in this manner may overlook the individual and their context. Before focusing on the final design outcome of an assistive device, it is important to identify all human needs and motivations (Thomas & McDonagh, 2013). Ravneberg and Soderstrom (2019) state that devices have “...been dominated by the medical model applying a ‘clinical’ touch or a ‘one size-fits-all’ approach... [but] it is not a person’s impairment that governs their use, but rather the

social practices in which this use takes place” (Ravneberg & Soderstrom, 2019, p. 2).

‘One size-fits-all’ or ‘design for all’ approaches are, as a concept, very similar to ‘Universal Design’. Universal Design, as a term, stems from the United States, while in Europe the term ‘design for all’ is more commonly used (Ibid.). Universal Design (UD) takes an all-encompassing approach, asking ‘What can everyone do?’ (Wobbrock et al., 2011). The starting point for UD requires that products, buildings, and environments should be accessible to as many people as possible (Olander, 2011). One major challenge of UD is that there is no ‘standard’ individual. Instead there are a multitude of individuals with differing anthropometrics, abilities, wishes, and personal standards (Ravneberg & Soderstrom, 2019). To properly address the needs of everyone, we can’t rely solely on designing for demographic generalities, but rather look at what we can learn from individual characteristics and outliers. Instead, personalized design approaches that ask ‘What can you do?’ will support the knowledge of physical and cognitive differences required to deliver a product that is tailor made to fit the individual (Olander, 2011; Ravneberg & Soderstrom, 2019; Wobbrock et al., 2011). Product developers and designers need to ensure that the products they create, especially with assistive devices, resonate with ‘individuals’.

2.2.3 Value of Emotions in Design

Every product we see, use, or remember elicits an emotional response, even if it is subconscious. The abandonment of crutches by users discussed earlier may

be the by-product of a negative emotional response associated to their device(s) as a whole or some aspect of the device (Olander, 2011). A designer has many factors to consider in creating a product: materials, manufacturing methods, marketing, cost, practicality, and how easy the product is to use or understand (Norman, 2004). There is also a strong emotional component to how products are designed and used. Thomas and McDonagh (2013) state: “[p]roducts can also evoke strong emotional responses in humans that can lead to purchase desire, retention of old and/or unused products, or even product abandonment” (Thomas & McDonagh, 2013, p. 2). The products we choose to place within our lives are more than mere material possessions, we take pride in them because of the meanings they bring to our lives.

Norman (2004) states there are three different emotional dimensions/levels embodied in designs; the visceral, behavioral, and reflective, stating that “[i]t is not possible to have design without all three” (Norman, 2004, p. 6). The visceral level is pre-consciousness, pre-thought, the initial impact of a product; its appearance, touch, feel, and how first impressions are formed. The behavioural level is about use and experiences with a product, how it functions, performs, and the usability. The reflective level is about long-term relations, self-image, memories, and feelings of satisfaction produced by owning, showing, and using a product (Ibid.).

The medical model places the function of the device as its primary objective. Impairment or abnormality must be ‘fixed’. Devices developed with this more singular mindset may lack two of the three emotional levels of design Norman states are necessary to have *design*. Herein lies the opportunity and challenge for the designer:

exploring what may be the two underserved levels of design in crutch development to see if experimentation in this product category can elicit positive visceral responses from individuals while also connecting with or reflecting their self-image.

2.3 Rationale for Research and Methods

With the rate of assistive device use growing faster than the population growth rate (Vairis et al., 2021), more individuals will need to use crutches either short or long term. Crutches aim to create a positive impact to individual's lives by allowing independence and the opportunity for social interaction. However, the current focus of assistive device prescription for treatment of 'abnormality' coupled with the current clinical focus of this product category, risks stigmatizing users. Further, there is evidence to suggest that crutch use holds postural risks to individuals which may further exacerbate musculoskeletal issues, and in turn, contribute to the formation of chronic injuries (Rasouli & Reed, 2019). Previous research on crutches indicates a need to better support mental health and minimize the negative impacts of use on physical health. This review of the literature:

1. defined the importance and malleable nature of stigma in relation to assistive devices and psychological risks;
2. established the rate and potential causes of device abandonment, as well as the importance of device alignment with users' self-identities;

3. defined the importance of aesthetic identity and methods of assistive device personalization and destigmatization through fashion design, as exemplified by eyewear;
4. discussed correct crutch usage, postural considerations and risks;
5. highlighted the drawbacks of the current medical model's use of a one size-fits-all approach in respect to assistive device design; and
6. highlights the value of emotion in design, and specifically, the need for visceral, behavioural, and reflective emotional levels to have *design*.

The literature indicates a need *to investigate the experience(s) of individuals using crutches*, but also question *how might a user-centered and interdisciplinary design process reshape crutches to:*

- 1) *improve our understanding of postural risk factors related to existing crutch use to mitigate these risks;*
- 2) *improve our understanding of people's perceptions of existing crutch designs in terms of use and aesthetics; and*
- 3) *reimagine the product's aesthetics to move towards people's personal aesthetic and social preferences, and the realm of fashion and wearables?*

To answer these questions, this study uses four methods. The first method is comprised of an anthropometric analysis of crutch users to determine postural risks of underarm and forearm crutch use. The second method uses a questionnaire to gather responses from current, past, and non-users of crutches about their

perceptions of existing crutches, and, if applicable, experiences and pain points during use to gather baseline data and participant device preferences. The third method involved the development of conceptual crutch designs with subject matter experts in a *Design Advisory Group* (DAG) to reimagine crutches. The fourth method used a questionnaire to gather and analyze general public perception of the conceptual crutch designs formed with the DAG to assess how perceptions towards these new concepts compare to people's perceptions of existing devices.

Chapter 3: Research Methods

A qualitative and quantitative, mixed-method approach was used to gain insight on users' experiences with and perspectives on crutch design, but also perspectives on crutch design from people who had not used crutches. This study involved four methods which helped define design requirements. Each method begins by defining the combined procedure and materials. The participants are described prior to the introduction of the methods.

The first method involved an *Anthropometric Analysis* (study of human bodily measurements and posture), specifically a postural risk analysis, of existing crutches through images and videos of people using underarm and forearm crutches. This in turn led to the creation of the second method; a questionnaire gauging people's perception of existing crutch designs and feedback on their experience and pain points during past or current use, if applicable. Building on these methods, a *Design Advisory Group* (DAG) was formed to develop new concepts. The DAG members in this third method included people who use or have used crutches, with one participant having additional expertise in physiology and anthropometrics. The fourth method was a questionnaire showing the new designs developed by the DAG where the general public (users and non-users of crutches) could evaluate and reflect on the concepts.

3.1 Ethical Considerations, Recruitment and Participants

This study received clearance from the Carleton University Research Ethics Board (see Appendix A). Participants for the questionnaires (Methods 2 and 4) were recruited through posts on social media, primarily Facebook and Instagram, as well as a recruitment poster shared on the lead researcher's personal social media account and those of the Abilities Centre in Whitby, Ontario and the Steadward Centre in Edmonton, Alberta, as well as personal and professional contacts. The posts were shared widely by the lead researcher, his family, friends, and colleagues. This approach was undertaken with the aim of accessing various channels to collect responses from a wide breadth regardless of whether individuals currently use, have, or have not used crutches. There was only one inclusion or exclusion criteria, stating that participants must be over the age of 18.

Participants for this study belong to one of two groups depending on methodology, those of known identity and those of unknown identity. The identities of participants within Method 3, the DAG, were known to each other as they participated in meetings together. DAG members were given the option to use an alias during the meetings and only use their cameras if comfortable. All meetings with the DAG were conducted through a password protected video conference (Zoom) call. DAG members were informed that the meetings would not be video recorded and their comments during the design process would be noted by the lead researcher. However, for methods 1, 2, and 4 anonymity was maintained by not asking participants for any personal or demographical data.

In total 95 participants were recruited, which included individuals who are current users, past users, and non-users of assistive devices. Due to the anonymity of the *Existing Crutch* and *New Crutch Concepts* Questionnaires demographic information, such as gender, age, and nationality of the participants are unknown. Of these participants, 60 completed the *Existing Crutch Questionnaire* (Method 2), six subject matter experts (SMEs) participated in the *DAG* (Method 3), and 34 completed the *New Crutch Concepts Questionnaire* (Method 4).

Method Type	Number of Participants
Existing Crutch Questionnaire	60
Design Advisory Group	6
New Crutch Concepts Questionnaire	34

TABLE 1: OVERVIEW OF PARTICIPANTS BY METHOD

Some participants, such as DAG members, participated in more than one method within the study. Of the DAG members, five of the six participated in the *Existing Crutch Questionnaire*. This is reflected in the differing total number of participants, where the numbers by method total 100 and actual study total of 95. Participants for questionnaires were recruited until the lead researcher determined an acceptable level of saturation had been met to accurately identify themes, insights, and common social sentiment regarding the existing and new concept crutches.

3.2 Method 1 - Anthropometric Analysis

The first phase of the study began with an *Anthropometric Analysis* of underarm and forearm crutches using existing images and videos publicly available on the internet. This was performed by the lead researcher and involved the collection

of visual data on hand and limb postures during use of underarm/axillary and forearm crutches. Images were found online using search engines and royalty-free image sharing websites. The analysis comprised of a total of 20 images and videos (18 images and 2 videos for each crutch type, underarm and forearm crutches, totaling 36 images and 4 videos).

3.2.1 Participants

This first method focused on evaluating publicly available images and videos of persons using crutches on the internet. Demographic information of the respective crutch users shown in the media are not known.

3.2.2 Materials and Procedure

The limb and hand positions, and postures of persons in the photos and videos were compared relative to joint ranges of movement and neutral positions described in *Bodyspace: Anthropometry, Ergonomics and the Design of Work* (Pheasant & Haslegrave, 2006). Each photo or video was analyzed for wrist flexion, wrist extension, wrist abduction, wrist adduction, shoulder abduction, shoulder adduction, wrist supination, wrist pronation, shoulder flexion, shoulder extension, hip flexion, elbow flexion, elbow extension, and trunk flexion.

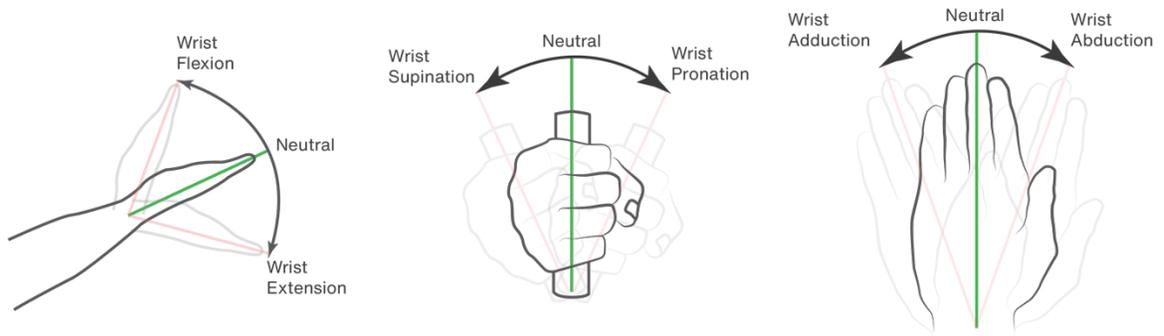


FIGURE 4 DIAGRAMS OF WRIST AND HAND POSITIONING

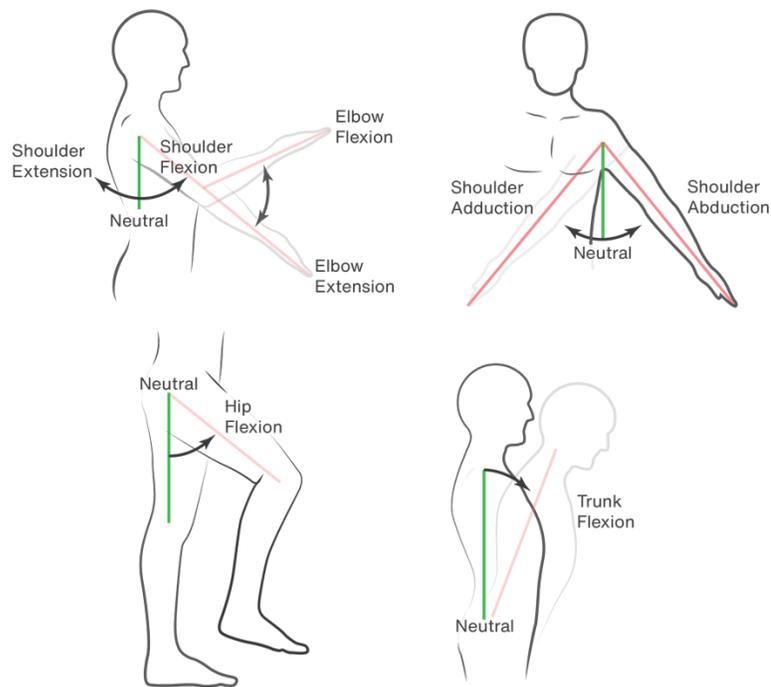


FIGURE 5 DIAGRAMS OF UPPER BODY, LIMB, AND HIP POSITIONING

The data gathered from this method was combined into a diagram in Miro (Figure 12) and spreadsheet to cluster similar elements, differences, and compare instances of improper positioning across axillary and forearm crutches. This analysis helped identify potential areas that may lead to pain with prolonged use or frequency of use due to deviations from neutral postures. The analysis also identified areas of

interest to compare with user feedback garnered in Method 2, *Existing Crutch Questionnaire*, and Method 3, *DAG Meetings*, and informed the sketches of new crutch concepts to support neutral postures. This provided a preliminary understanding of upper body, limb, and hand positioning during use of existing crutches. Lower body, limb, and foot positioning were not evaluated during this method as the primary pain points, areas of increased load, and subsequent areas of interest impacted through existing device usage were located on the upper body (Lee et al., 2013).

3.3 Method 2 - Existing Crutch Questionnaire

In this second method, a questionnaire with visuals of current crutch designs was developed to gather feedback on existing products (Appendix B). The questionnaire asked current, past users, and non-users of crutches about their: experiences with crutches and physical pain points as a result of use (if applicable), perceptions of these designs; and questions around stigma.

3.3.1 Participants

Participants were recruited whether current users, past users, or non-users of these devices. As this method sought to compile a summary of experiences and perceptions of current crutch designs, participant demographics were not collected. Sixty participants were recruited, of which six of these individuals participated in the *DAG Meetings* (Method 3).

3.3.2 Materials and Procedure

The *Existing Crutch Questionnaire* was designed to better understand first-hand experiences and/or perceptions of these devices. Questionnaires are a common method of collecting self-reported information from people in a short time-frame from large samples of respondents about their “[t]houghts, feelings, perceptions, behaviours, or attitudes” (Martin & Hanington, 2012, p. 172). The questionnaire was conducted online, remotely, through Qualtrics to increase the response rate and decrease in-person research risks to the participants and lead researcher due to the ongoing COVID-19 pandemic. This method was chosen and designed to suit participant’s preferences and allow them to answer at their leisure, with their choice of internet connected device. The data collection tool was intended to be simple and effective but leave space for participants to expand on their answers where they felt this was necessary. Participants were asked to respond through a series of yes/no questions, ‘please explain’, and Likert scales. The Likert scale designed for this study is a revised version of the 32-item Discrimination and Stigma Scale or (DISC 12). DISC 12 is an “[i]nterview-based instrument which measures the extent to which participants had, as a result of their physical disability, experienced stigma and discrimination in key areas of everyday life and social participation” (Milačić-Vidojević et al., 2020, p. 292). Scale terms were lightly revised for reasons of clarity (from not at all, a little, moderate, and a lot) to; *Not At All*, *Very Little*, *A Little*, *Occasionally*, and *Often*. These were used for questions pertaining to how they are/were treated during device use and whether they feel/felt stigmatized.

Participants were also asked to rate the aesthetic appeal of underarm and forearm crutches on a five-point Likert scale ranging from *Very Unattractive* to *Very Attractive* and later which device they would rather use. These responses were gathered to understand which of the three levels of design appealed to users. According to Don Norman (2004), there are three levels within design, the *Visceral*, *Behavioral*, and *Reflective* (Norman, 2004). The *Visceral* response is “pre-consciousness, pre-thought... [it’s] where appearance matters and first impressions are formed. *Visceral* design is about the initial impact of a product, about its appearance, touch, and feel” (Ibid., p. 37). Refer to Appendix B for the *Existing Crutch Questionnaire*. Data collection was done until enough responses were received and distinguishable themes and patterns emerged from crutch users and non-users.

The questionnaire was designed to have two primary paths depending on if the participant had used/is using crutches or had never used crutches. The approximate time expected for participants to complete the questionnaire differed from 1-3 minutes for non-users to 5-10 minutes for users. Those that had experience with crutches were asked to expand on pain points and perceptions on open ended questions and device aesthetics. Non-users were only asked to rate aesthetics of current crutches on a Likert scale and expand on the reasoning for their score.

The data gathered from the *Existing Crutch Questionnaire* was put into a digital affinity diagram using Miro to highlight key themes and focus areas that emerged from participant comments and visualize the Likert scale ratings.

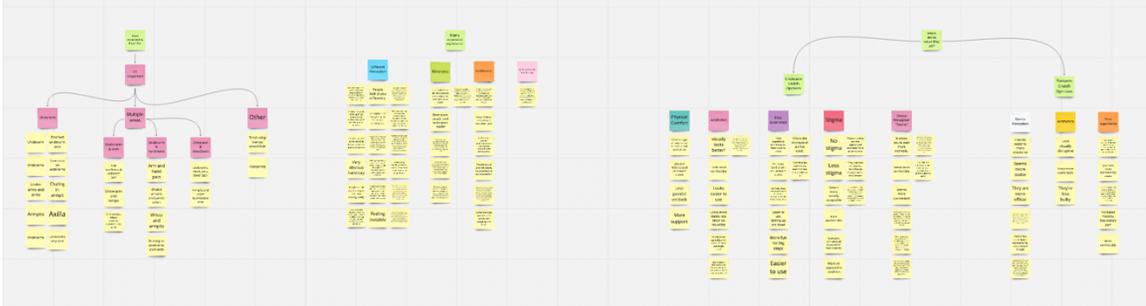


FIGURE 6 AFFINITY DIAGRAMS OF 'EXISTING CRUTCH QUESTIONNAIRE' RESPONSES

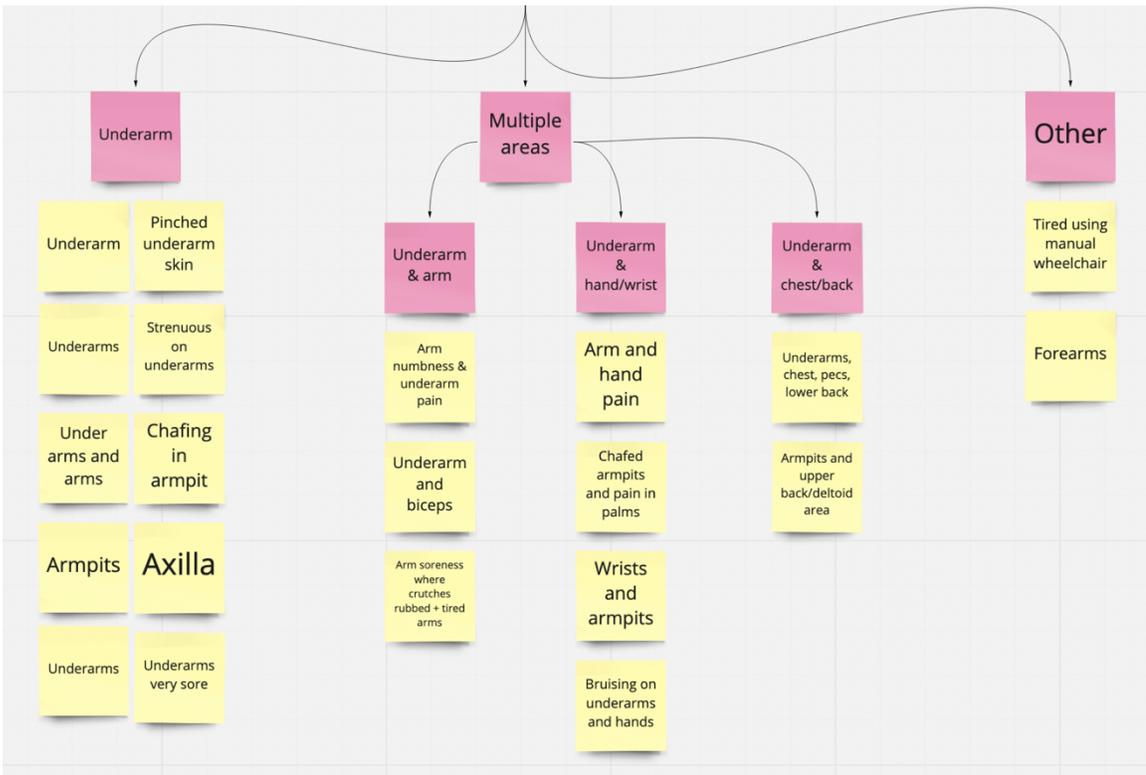


FIGURE 7 DETAIL VIEW OF AFFINITY DIAGRAM

3.4 Method 3 - Design Advisory Group (DAG)

The *Design Advisory Group (DAG)*, was developed for the lead researcher and selected group members to further develop crutch concepts together using their ideas and expertise. Members of the DAG also completed the *Existing Crutch*

Questionnaire. Consideration was given to the period of time available for this method but also to use the participant's time as efficiently as possible. Consideration was also given to ensure participant comfort and pleasure during the design process.

3.4.1 Participants

A total of six members, not including the lead researcher, were involved in the ideation and development of crutch concepts which included three current crutch users, two non-users with past experience, and one currently using another type of walking aid (cane), with one of the SMEs having expertise in neuromusculoskeletal considerations (a chiropractor). Participants for the DAG consisted of four females and two males. Due to scheduling difficulties, one participant was unable to attend group meetings but shared their thoughts with the lead researcher at their earliest convenient time through email. The sixth and final member of the DAG joined late and was therefore only able to participate in the final meeting. Participants were invited to participate based on their current or past device use and related expertise.

3.4.2 Materials and Procedure

The DAG was designed to enable the SMEs to aid development of crutch concepts through user-centred design. Collectively, members of the group brought expertise in use, experience, design, and anthropometric considerations. Rather than forcing users to change their behaviour to accommodate a product, user-centred design tries to optimize the fit of products to how users can, want, and need to use them (Chun, Harty, & Schweber, 2015). Each end-user brings with them “their own

experiences, expertise, and expectations about the products, services, and systems they use in their everyday lives” (Wilson & Sharples, 2015, p. 255). This method was chosen because it would help surface unconscious bias on the part of the lead researcher, build on earlier collected data, but also leverage SME expertise pertaining to crutches. To begin, the lead researcher developed a number of concepts or sketch prototypes inspired by the data and feedback collected in prior methods. These sketches were then uploaded to a digital workspace in Miro.

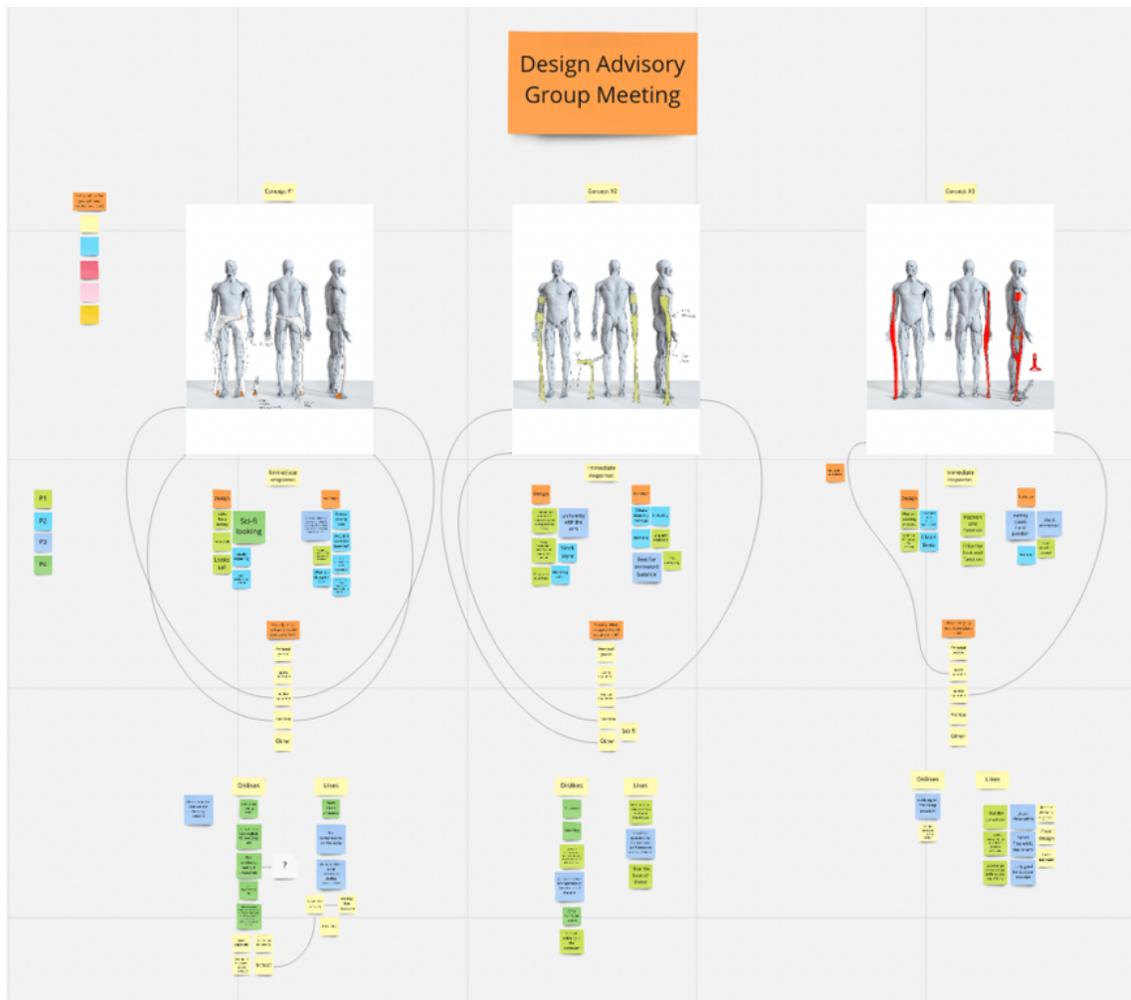


FIGURE 8 DIGITAL MIRO WORKSPACE WITH CONCEPTS 1-3

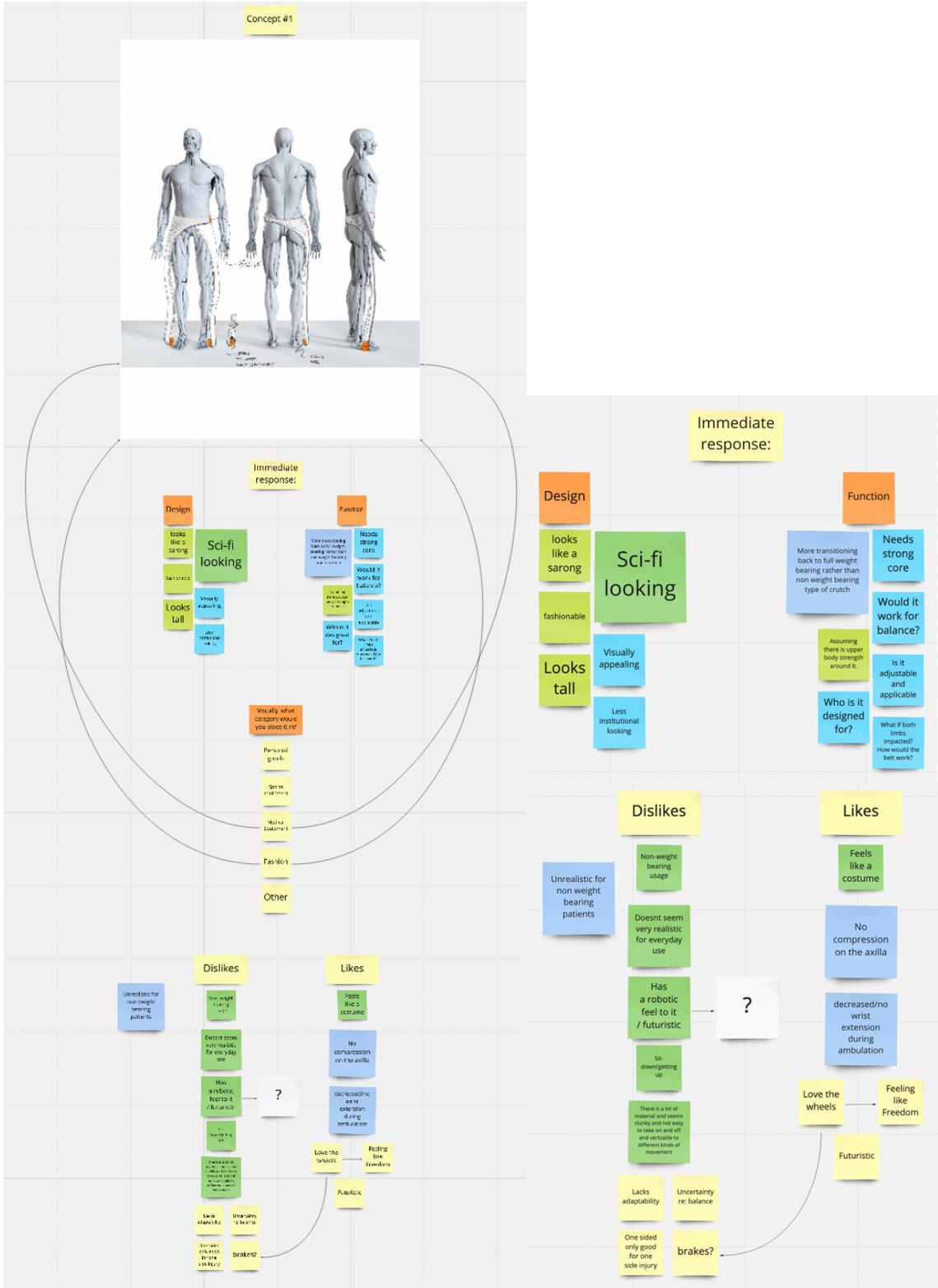


FIGURE 9 CONCEPT AND DAG MEMBERS' RESPONSES

The DAG met virtually through video conferencing (Zoom), and this digital workspace allowed DAG members to comment, discuss, and develop concepts together simultaneously. Three one-hour long meetings were held in total, with 2-4 members joining (not including the lead researcher) each meeting. The first two meetings were attended by different group members due to scheduling difficulties. An overview of meetings and attendees is shown in Figure 10.

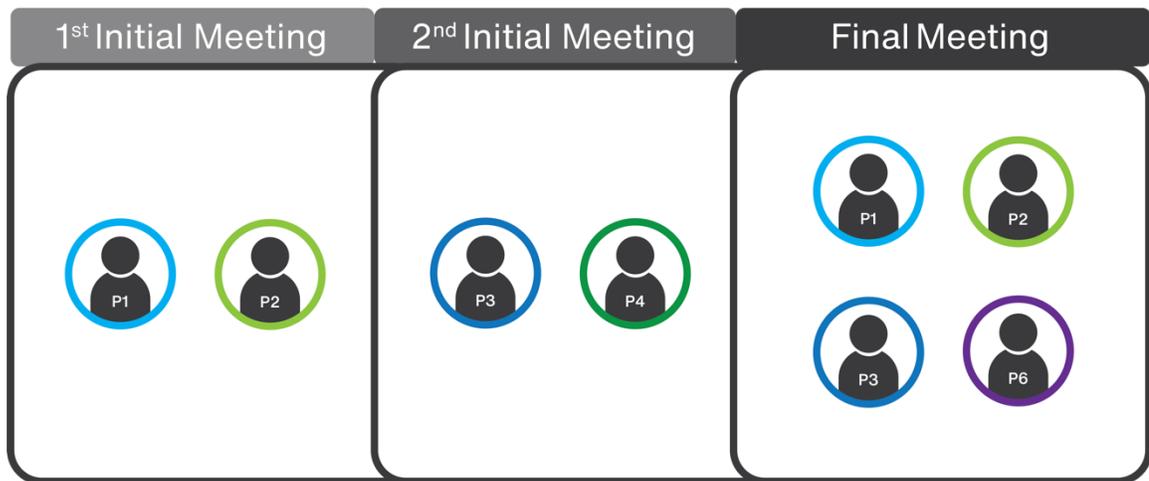


FIGURE 10 DAG MEETING ATTENDEE OVERVIEW

All three meetings were conducted within 14 days during September, 2021. Meeting #2 took place six days after Meeting #1 and the third and final DAG meeting was eight days after Meeting #2. The design of the meetings was developed by the lead researcher without participant consultation prior to conducting Method 3 *Design Advisory Group*. Meetings were semi-structured in nature. During the first two Initial Meetings members were given a brief synopsis of the lead researcher's study thus far, including a summary of the literature review findings and results of Method 1 *Anthropometric Analysis* and Method 2 *Existing Crutch Questionnaire*, then shown

preliminary concepts based on information collected in the literature review, Method 1 *Anthropometric Analysis*, and Method 2 *Existing Crutch Questionnaire*. Members were asked to comment on the overall form, features, and which category they perceived the device to belong to aesthetically. Once this was done, the group generated keywords and phrases, ideated, and shared points of inspiration or stories of their experiences to further develop or form concepts. During the third and final meeting, members were shown sketches of the developed concepts, based upon their comments in the earlier meetings, and asked to share their thoughts regarding perceived usability and device aesthetics. This tool was intended to be intuitive, simple, light-hearted, and enjoyable for participants, with space to place virtual post-it notes, sketch, or share images to develop concepts. The goal of this method was for the DAG to share their comments and ideas to further develop a range of concepts prior to converging on one or two concepts that the group believed had merit and offered a step forward from current devices.

3.5 Method 4 - New Crutch Concepts Questionnaire

A second questionnaire was conducted to gauge people's perspectives on the two new crutch concepts created with the DAG. The *New Crutch Concepts Questionnaire* was made available to the general public, regardless of current or past use of crutches, and also to those who had never used crutches.

3.5.1 Participants

Similar to the *Existing Crutch Questionnaire*, participants were recruited irrespective of whether they were current users, past users, or non-users of devices. As this method sought to evaluate perceptions of the developed crutch designs, participant demographics were not collected. A total of 34 participants participated in the *New Crutch Concepts Questionnaire*.

3.5.2 Materials and Procedure

Like the first questionnaire, this was conducted online, remotely through Qualtrics to increase the response rate and decrease in-person research risks to the participants and lead researcher due to the ongoing COVID-19 pandemic. This method was chosen to suit participant's preferences and allow them to answer at their leisure, using their preferred internet connected device. The tool was intended to be simple and effective but leave space for participants to expand on their answers where required. The questionnaire contained visuals and was designed to be completed quickly, in less than five minutes, to capture participants immediate responses to / impressions of the design concepts. This questionnaire followed the same procedure for gathering responses as the *Existing Crutch Questionnaire*. The goal of the questionnaire was to answer the second research question, *Could these devices be moved into the realm of fashion and wearables?* Participants' *Visceral* responses to the concepts and perceptions would indicate how the new crutch

concepts were received and whether they had potential to align with or support respondents' sense of identity, and in the process, perhaps mitigate stigma.

The questionnaire began by showing participants an image of the first concept and asking them to share their immediate reaction to the device on a five-point Likert scale between *Very Unattractive*, *Unattractive*, *Neutral*, *Somewhat Attractive*, and *Very Attractive*. Participants were then asked to place the concept in one of five product categories and note any changes they would make. These steps were repeated for the second concept prior to answering which concept they would select, or neither, with a written explanation.

3.6 Summary of Methods

This mixed-methods study encompassed 4 methods to answer the following questions.

- *Method 1: What is the hand and limb positioning of current crutch users?*
- *Method 2: What are the experiences of current and past crutch users? What are the opinions of crutches from non-users?*
- *Method 3: How can we reimagine the design of crutches anthropometrically and aesthetically?*
- *Method 4: What are the immediate responses to the reimagined crutch concepts?*

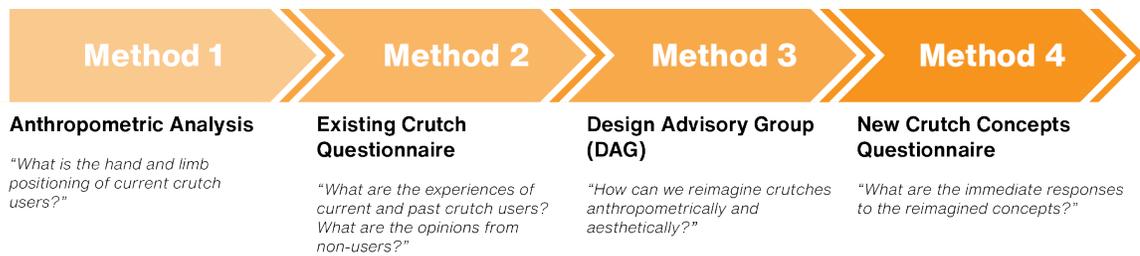


FIGURE 11 MULTI-METHOD STUDY OVERVIEW

The process of gathering the experiences and opinions of users, past users, and non-users through each method and respective focus is illustrated in Figure 11. This research aimed to answer the following question: *How might a user-centered and interdisciplinary design process reshape crutches to:*

1) *improve our understanding of postural risk factors related to existing crutch use to mitigate these risks;*

2) *improve our understanding of people's perceptions of existing crutch designs in terms of use and aesthetics; and*

3) *reimagine the product's aesthetics to move this category towards people's personal aesthetic and social preferences, and the realm of fashion and wearables?*

The researcher designed and implemented the approaches listed below to explore and address these questions:

1. Conducted an *Anthropometric Analysis* of people using underarm and forearm crutches through photo and video-based analysis.
2. Asked users and non-users of crutches about their perceptions, and where applicable, their experiences in using crutches through a

Questionnaire. Analyzed and categorizing the existing crutch questionnaire data to inform concept designs.

3. Created conceptual crutch designs based on what was discovered in the first three methods with insight from subject matter experts in a *Design Advisory Group*.
4. Created a *New Concept Crutch Questionnaire* to gauge users and non-users perceptions of the designs.
5. Analyzed the *New Crutch Concept Questionnaire* responses to compare perception of existing crutches versus new concepts generated with the DAG.

The findings generated from these methods are reported in the next chapter, *Results*. As discussed in the literature review, the design of existing crutches may result in poor postures and limb disorders associated with prolonged use. The existing literature also showed that the aesthetic characteristics of existing crutch designs are clinical in nature, and for this reason may convey that the person using the crutches is impaired.

The clinical nature of these devices may also not reflect a person's identity. The purpose of this study was to provide insight on what people think about these devices, and where applicable, their experiences using these devices to explore both anthropometric and perceptual considerations that could inform the design of future crutches. The approach also included design meetings with subject matter experts,

who have and/or continue to use crutches, to gather feedback and develop sketch concepts that align better with anthropometric principles while also exploring aesthetics that better align with people's identities to potentially move this product category into the realm of fashion and wearables.

Chapter 4: Results

The following chapter outlines the results of each method – anthropometric analysis, existing crutch questionnaire, design advisory group (DAG), and new crutch concepts questionnaire. The data that was collected from each method was synthesized into categories to provide insight on people’s perceptions of, and if applicable, experiences of using existing crutches and perspectives on new crutch designs.

4.1 Anthropometric Analysis

The first method answers the first question *How might a user-centered and interdisciplinary design process reshape crutches to improve our understanding of postural risk factors related to existing crutch use?* The lead researcher collected and analyzed a total of 40 images and videos collected from the Internet of individuals using existing underarm and forearm crutches. The 40 images and videos comprised of 18 photographs and 2 videos, per crutch type. This analysis led to the identification of: risk factors associated with primarily upper limb flexion/extension (non-neutral postures) or abduction/adduction in use; differences and similarities of hand and limb positioning per crutch type, with additional analysis specific to hip posture; and opportunities for development in subsequent methods.

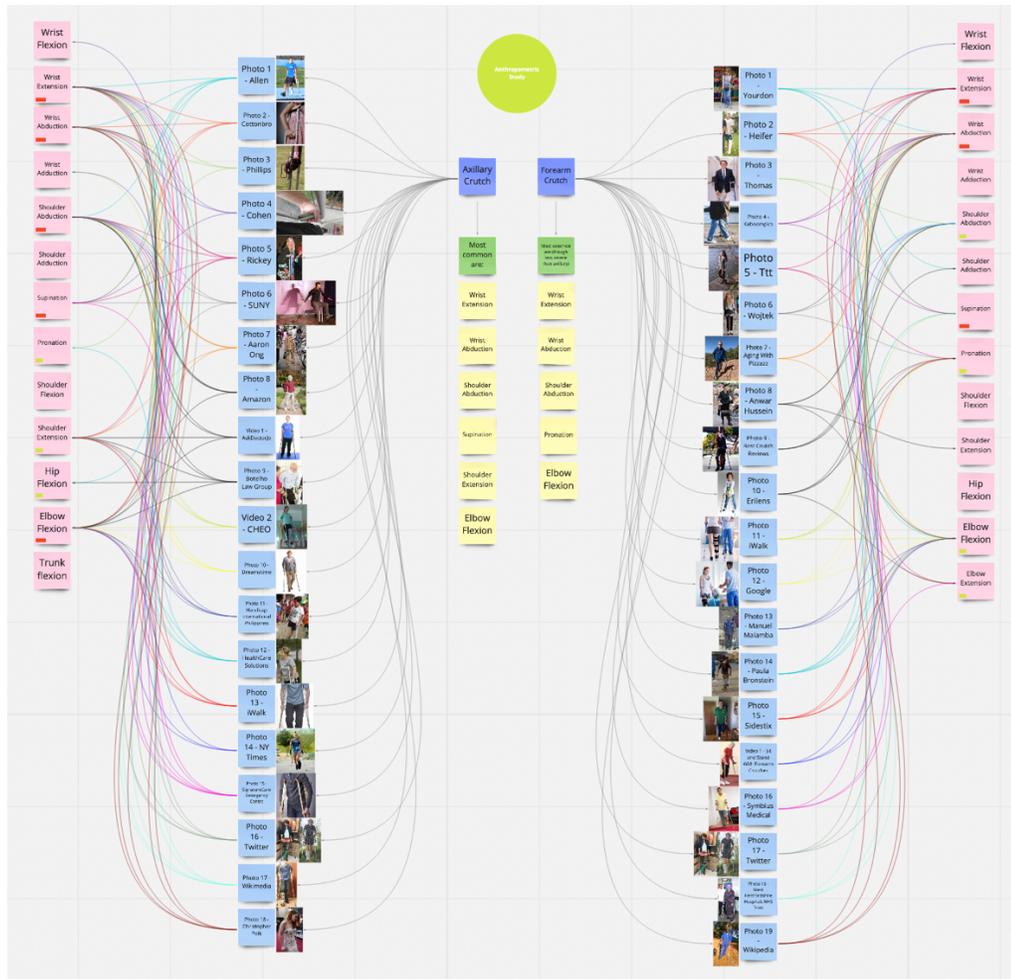


FIGURE 12 CRUTCH ANTHROPOMETRIC ANALYSIS DIAGRAM

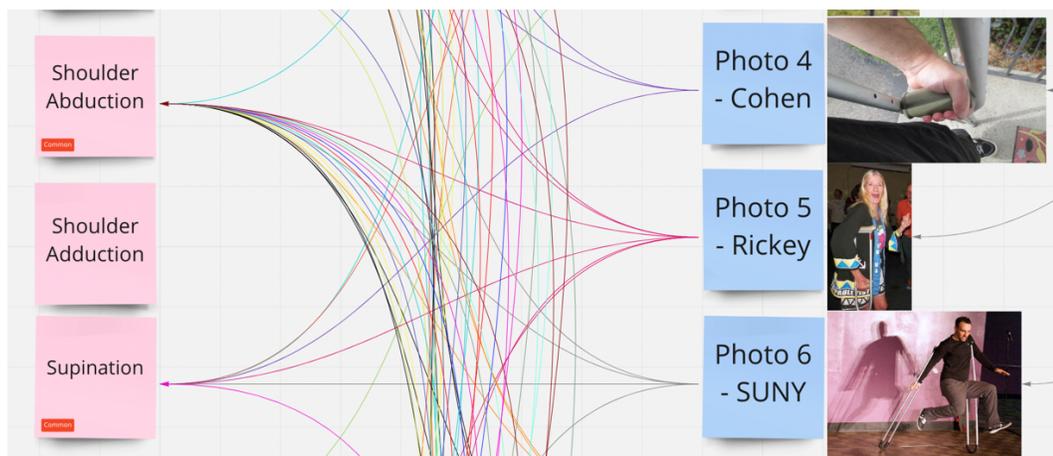


FIGURE 13 CLOSE-UP OF ANTHROPOMETRIC ANALYSIS DIAGRAM

Diagrams of the 14 common improper positions can be seen in Figure 4 and Figure 5, within Chapter 3 *Research Methods*. The analysis shows 12 of 14 common postural risk factors related to underarm and forearm crutch use (Fig. 14). These include but are not limited to: wrist extension and abduction, shoulder extension and abduction, and elbow flexion.

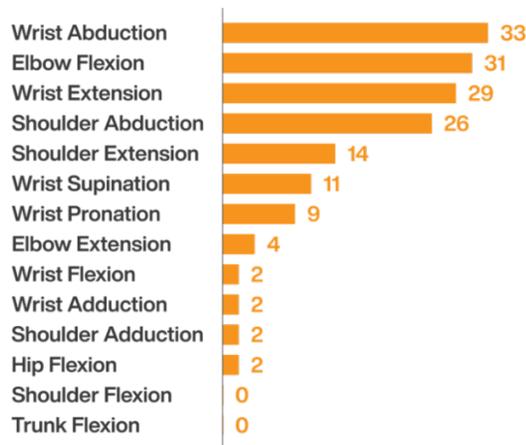


FIGURE 14 INSTANCES OF POSTURAL RISKS FOR UNDERARM AND FOREARM CRUTCHES

Of the 12 postural risk factors identified, 8 or 75% were related to underarm and forearm crutch use. The postural risk factors shared across underarm and forearm crutches are highlighted in Table 2. The most frequently noted postural risks for both underarm and forearm crutches, in no particular order, included wrist extension, wrist abduction, shoulder abduction, and elbow flexion.

Postural Risk Factor <i>*identified in 18 photos and 2 videos</i>	Instances for Underarm Crutch*	Instances for Forearm Crutch*
Wrist Flexion	1	1
Wrist Extension	18	11
Wrist Abduction	15	18
Wrist Adduction	2	0
Wrist Supination	6	5
Wrist Pronation	2	7
Shoulder Abduction	17	9
Shoulder Adduction	0	2
Shoulder Extension	13	1
Hip Flexion	2	0
Elbow Flexion	18	13
Elbow Extension	0	4

TABLE 2: POSTURAL RISK FACTORS FOR UNDERARM AND FOREARM CRUTCHES

The most commonly identified postural risks for underarm crutches were wrist extension (18), elbow flexion (18), shoulder abduction (17), wrist abduction (15), and shoulder extension (13). For the purposes of this thesis, a common occurrence is defined as instances above 50%, or occurring in at least 10 of the 20 media examined.

The most commonly identified postural risks for forearm crutches were wrist abduction (18), elbow flexion (13), and wrist extension (11).

A major difference that was noted between crutch types was related to the positioning of the wrist in extension, as well as shoulder abduction and extension. In this analysis, postural risk factors for underarm crutches were noted 1.63 to 13 times more often than forearm crutches. For example, the presence of shoulder extension was 13 times more evident in underarm crutch use than forearm crutch use. Shoulder abduction was 1.89 times more evident in underarm crutch use than forearm crutches, and wrist extension was 1.6 times more evident in underarm crutch use

than forearm crutches. Figure 15 provides a summary of the key differences and similarities that resulted based on the type of crutch used.

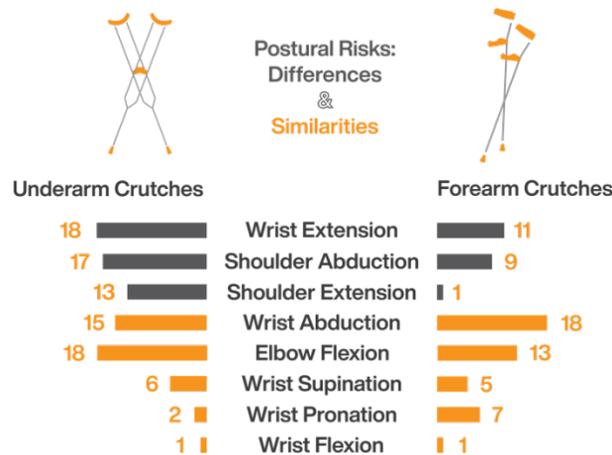


FIGURE 15 POSTURAL RISK DIFFERENCES AND SIMILARITIES BETWEEN CRUTCHES.

4.2 Existing Crutch Questionnaire

The second method serves to answer the question *How might a user-centered and interdisciplinary design process reshape crutches to improve our understanding of people's perceptions of existing crutch designs in terms of use and aesthetics?* Participants identified whether they are current users, past users, or non-users of crutches. If they were current or past users, participants were asked: how the device had been received; the length of time the device was used if it was temporary; if bodily pain had been experienced, and if so, where, and how; whether they felt as if they were treated differently, or stigmatized as a result of crutch use; among other questions.

4.2.1 Information on Crutch Use

The *Existing Crutch Questionnaire* was completed by 60 participants. The data was analyzed to gauge people's experiences with the device (if applicable), their perceptions of the existing devices, and emerging themes of interest. Of the 60 participants, 11 were current users of crutches (18%) and 49 were non-users at the time of response (82%). Of the 49 non-users at the time of response, 28 had used a device in the past (57%) and 21 had never used crutches (43%). Of the individuals who had used or were currently using crutches, 30 used/use underarm crutches (62%), followed by seven who have used or use forearm crutches (15%), seven used/use walking canes (15%), and four used/use other devices (8%). Participants were allowed to select however many devices applied to themselves as some changed devices during their current or past usage. Of the participants who had used/use crutches, 23 had been prescribed a device by a healthcare professional to best match their needs (61%) and 15 participants chose the device themselves without the consultation of a healthcare professional (39%). Only one participant of the 23, or 3% of those who were prescribed devices by a healthcare professional were given options by their healthcare professional to choose their device. Figure 16 outlines the percentage of participants currently using a device, the percentage who have used a device in the past, the percentage who have not used a device, and the types of devices that are currently in use or were used.

The typical period of crutch use was short-term (0-2 months), with 25 participants or 66% of past and current users within that range. Of short-term

respondents, two were currently using a device (8%). Correspondingly, 13 participants or 34% had or have been using a device long-term, a period of three months or more. Of these long-term respondents, nine currently used a device (69%). When asked if they felt that the crutches they use or have used align/ed with their identity, 18 responded *No* (47%), 14 had *No Opinion* (37%), and six stated that they *did align with their identity* (16%).

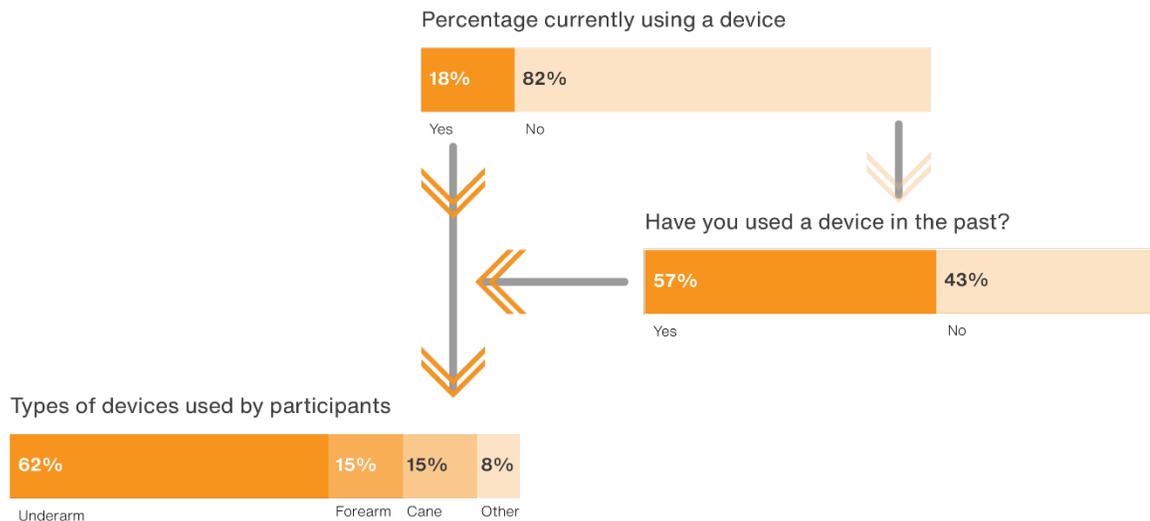


FIGURE 16 CURRENT, PAST & NON-USERS OF DEVICES AND DEVICES USED.

4.2.2 Crutch Use and Pain/Discomfort

The majority, 22 participants or 81% of past and current users of crutches and walking aids stated that they felt pain or discomfort during or as a result of their use. Participants who had experienced pain or discomfort were subsequently asked to describe where it had occurred. The bodily areas identified by participants were categorized under three main titles; *Underarm*, *Underarm and Other*, and *Other*. The most commonly noted pain point was the *underarm*, by 10 participants. The category

of *Underarm and Other* was further subdivided into *Underarm and Arm*, *Underarm and Hand/Wrist*, and *Underarm and Chest/Back* based on additional information provided by participants. Of the participant's responses categorized beneath *Underarm and Other*, three noted pain in the *Underarm and Arm*, four noted pain in the *Underarm and Hand/Wrist*, and two noted pain in their *Underarm and Chest/Back*. The final two participants who experienced discomfort noted *Other* pain points, highlighting pain in the *Forearm and Fatigue* from using a manual wheelchair. A complete Table of crutch use pain points can be found in Appendix C.

4.2.3 Crutch Use and Perception

The majority, or 30 of current and past crutch users (86%) reported that they felt as if they were treated differently to some extent as a result of their crutch use, while five reported that they were treated differently (14%). Of the 30 participants, or 86% who stated they felt they were treated differently, 12 participants, or 35%, stated they felt this *A little*, 13 participants felt this *Moderately* (37%), and five participants, or 14%, felt that they were treated *A lot* differently than prior to crutch usage.

When asked if current and past users feel/felt stigmatized using a crutch or walking aid, 32 reported that they felt stigmatized to some degree (84%) while six reported no discernable stigma (16%). Of these respondents, six felt *Very Little* stigma (16%), nine felt *A Little* stigmatized (23%), 11 *Occasionally* stigmatized (29%), and six reported feeling *Often* stigmatized (16%). The explanations for their responses were mapped under four themes. These are *Perceived Differently*, *Kindness*, *Indifference*,

and *Environmental Limitations*. Table 3 provides an overview of participants' comments related to stigma and crutch use. A more explicit analysis is provided in Appendix D.

Reflections on Stigma
<p>Perceived Differently [...] look at you differently. [...] too young to be using a mobility aid. Feeling invisible. [...] judged by my crutches before someone gets to know me. [...] look at me and see the crutches and make a "pity" face – they underestimate me. Other times, people assume because I have them that I can do anything including stairs.</p>
<p>Kindness [...] helped me without asking them. Given space, people tend to be more helpful. [...] people hold doors more often or offer assistance. Everyone always is good with helping out for various things but when being helped it does feel like you are a burden to most people. [...] offer help if I'm carrying items such as groceries or school supplies.</p>
<p>Indifference Most people understand when you are using the standard underarm crutches. [...] give me space, no attention or extra attention. Sometimes I get questions and sometimes people ignore them [my crutches]. [...] friends and classmates didn't treat me any differently while using crutches to recover. Never noticed much as it was short term.</p>
<p>Environment Limitations Hard to find elevators and some places don't even have them and just have stairs.</p>

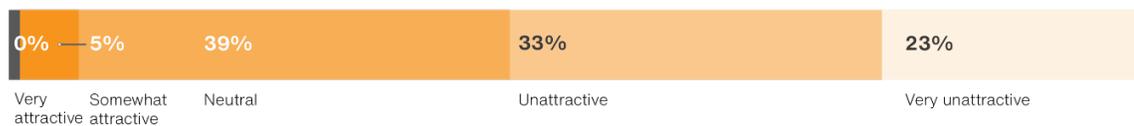
TABLE 3: PARTICIPANTS' REFLECTIONS ON STIGMA

To further explore people's perceptions of existing crutches, participants were asked to share their immediate and emotional (*Viscera*) response to an image of an underarm crutch by rating the device's attractiveness on a Likert scale. The ratings were as follows: 32 participants considered the device *Very Unattractive* or *Unattractive* (56%), with 13 participants selecting *Very Unattractive* (23%) and 19 selecting *Unattractive* (33%) respectively, 22 reported a *Neutral* rating (39%), three

found the device *Attractive* (5%), and no participants rated the underarm crutches as *Very Attractive* (0%).

Participants were asked the same question but this time using an image of a typical forearm crutch. Responses to the forearm crutch were critical of the aesthetics; 41 participants considered the device *Very Unattractive* or *Unattractive* (72%), with 22 participants selecting *Very Unattractive* (39%) and 19 participants selecting *Unattractive* (33%), respectively. Of the remaining participants, 14 rated it as *Neutral* (24%), two found the device *Very Attractive* (4%), and no participants/0% rated the forearm crutch as *Attractive*.

Underarm crutch aesthetic rating



Forearm crutch aesthetic rating



FIGURE 17 PARTICIPANTS’ AESTHETIC RATINGS OF UNDERARM AND FOREARM CRUTCHES

When participants were asked if they would rather use an underarm or forearm crutch, 39 selected the underarm crutch (71%) and 16 selected the forearm crutch (29%). When asked ‘why?’, participants responses varied and fell under one of five possible themes: *Physical Comfort*, *Aesthetics*, *Prior Experience*, *Stigma*, and *Device Perception (Seems Statements)*. The reasons for preference towards underarm crutches included that they are more comfortable and less painful; visually appealing;

noted prior experience(s) of use; lack of stigma; that they seem more comfortable (placing their weight on the underarm pad), and supportive. Reasons participants gave for selecting forearm crutches fell within three of the five above themes: *Device Perception, Aesthetics, and Prior Experience*. Regarding forearm crutches, participants stated that they are less visually disruptive and bulky relative to underarm crutches, noted neutral prior experience(s), and that forearm crutches seem more stable and comfortable. A more explicit analysis is provided in Appendix E.

The second method, which captured information from past and present users, revealed that the most commonly used walking aid was the underarm crutch, which was typically used short-term and prescribed to the user by a healthcare professional or selected by the user without prior consultation. Participants reported that the devices typically did not align with their identity and the use of these devices resulted in pain to the underarm, arm, forearm, hand, wrist, chest/back, general fatigue, or combinations of these areas. The data suggests that most crutch users feel as if they are treated differently due to their crutches and stigmatized due to a perceived difference in their physical abilities and environmental limitations when navigating buildings. However, the data also suggests that, to a lesser degree, some individuals felt as if they were treated indifferently and sometimes the use of crutches evoked increased kindness and offers of assistance.

This method also revealed a common aesthetic ratings of *Neutral* and *Very Unattractive* for underarm crutches and forearm crutches, respectively. Neither device was ranked highly in terms of aesthetic design. However, the underarm

crutch was generally preferred by respondents over forearm crutches based on device *Aesthetics*, perceived lack of *Stigma*, and *Prior Experiences*.

4.3 Design Advisory Group (DAG)

The third and fourth methods built on another to answer the question *How might a user-centered and interdisciplinary design process reshape crutches to reimagine the product's aesthetics to move this category towards people's personal aesthetic and social preferences, and the realm of fashion and wearables?* Members of the DAG noted that the first concept was visually appealing, less institutional in aesthetics, with a science fiction feel, but perceived that it would not function for persons who were non-weight bearing or had both lower limbs impacted. The DAG participants' comments for *Concept 1* are shown, as written by them, in Table 4.

When asked to place the concept in one of the five product categories of: *Personal Goods*, *Sports Equipment*, *Medical Equipment*, *Fashion*, or *Other*, two DAG members selected *Medical Equipment* and two selected *Fashion*. Participants' comments included that the concept was perceived to have "no compression on the axilla or wrist extension during ambulation", that it visually "feels like a costume", was "futuristic", and one participant loved the wheels, stating that "they feel like freedom". However, the wheels were also disliked because they gave the impression that they "may require brakes" and provide a feeling of "uncertainty regarding balance", that the device would be unusable for individuals who are non-weight bearing on one or both lower limbs and that the design had a futuristic feel, among other comments.

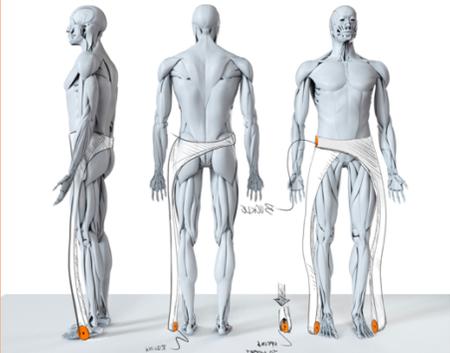
<p>Concept 1 Assigned to the following categories by participants: Medical Equipment (3) Fashion (3)</p>	
<p>Function</p>	<p>Aesthetics</p>
<p>P2: (User) needs strong core. P4: Would it work for balance? P3: Is it adjustable and applicable? P2: What if both limbs impacted? How would the belt work? P1: Who is it designed for? P2: Assuming there is upper body strength around it. P3: More transitioning back to full weight bearing rather than non-weight bearing type of crutch.</p>	<p>P2: Looks like a sarong. P2: Sci-fi looking. P1: Fashionable. P4: Less institutional looking. P3: Visually appealing. P2: Looks tall.</p>
<p>Dislikes</p>	<p>Likes</p>
<p>P1: Non-weight bearing usage not possible. P3: Unrealistic for non-weight bearing patients. P2: Doesn't seem very realistic for everyday use. P2: Has a robotic feel to it/futuristic. P2: Sit-down/getting up? P2: There is a lot of material and seems clunky and not easy to take on and off or versatile to different kinds of movement. P1: Lacks adaptability. P1: Uncertainty re: balance. P1: One sided only good for one injured side. P1: Brakes for the wheels?</p>	<p>P2: Feels like a costume. P3: No compression on the axilla. P3: Decreased/no wrist extension during ambulation. P1: Love the wheels -> feeling like freedom. P1: Futuristic.</p>

TABLE 4: DAG PARTICIPANTS' RESPONSES TO CONCEPT #1

When shown the second concept, DAG members' immediate responses regarding the *Aesthetics* noted sleek style, organic form, and superhero similarity. Other comments centered around impressions of the design feeling restrictive, pinching the arm, and that the device would not be for everyday use. The DAG

participants' comments for *Concept 2* are shown, as written by them, in Table 5. When asked to place the concept in a category, two participants selected *Medical Equipment*, one selected *Fashion*, and one selected *Other*, stating that it felt "science fiction" in nature. For *Concept 2*, members liked the look, the presence of a tripod foot for balance, the impression that they would be confident in use, and that the concept had a hands-free nature. Participants disliked the mounting and anticipated discomfort during use.

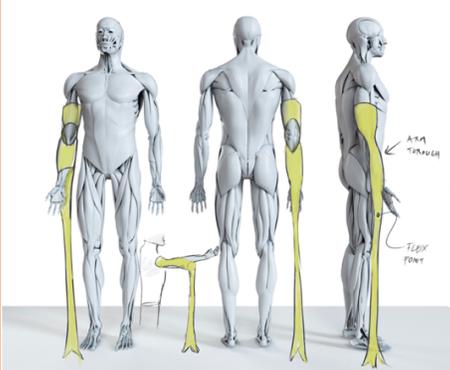
<p>Concept 2 Assigned to the following categories by participants: Medical Equipment (2) Fashion (1) Other (1)</p>	
<p>Function</p>	<p>Aesthetics</p>
<p>P1: Where does my hand go? P1: PINCHING. Restrictive. P4: Long arm extension. P3: Feet for increased balance. P4: Not for everyday use.</p>	<p>P1: I like the look and that it seems to curve along with the body. P3: Uniformity with the arm. P2: More fashionable and look of part of the person. P1: Sleek style. P2: Mega-man superhero P1: Marching robot.</p>
<p>Dislikes</p>	<p>Likes</p>
<p>P1: Mounting. P1: Pinching. P4: Without somewhere to hold onto it's a lot of pressure on the arm and bicep. P3: Possible nerve entrapment on the interior of the arm. P2: Only hands or crutch. P4: Lots of rubbing in the underarm.</p>	<p>P2: Great idea on trying to keep the hands free for use. P4: Tripod feet excellent for balance and confidence on uneven terrain. P2: I like the look of these.</p>

TABLE 5: DAG PARTICIPANTS' RESPONSES TO CONCEPT #2

The third concept shown to DAG participants elicited immediate responses comparing this concept to existing crutches, as if a “forearm and underarm crutch had a child”, “clean lines”, and affinity for the conceptual shock absorbing crutch foot, and concept’s mixture of fashion and function. The DAG participants’ comments for *Concept 3* are shown in Table 6.

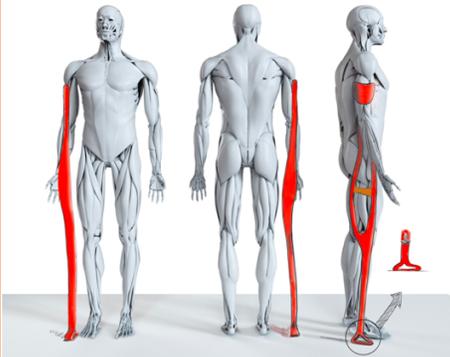
<p>Concept 3 Assigned to the following categories by participants: Medical Equipment (2) Sports Equipment (2)</p>	
<p>Function</p>	<p>Aesthetics</p>
<p>P3: Axillary classic hand position. P3: Shock absorption. P4: Pinching during use? P1: Can stand on its own. P2: I like the look and function.</p>	<p>P2: Play on existing product. P1: Underarm and forearm had a child. P1 & P2: Like the bottom (foot design). P1: Clean lines. P3: Fashion and function.</p>
<p>Dislikes</p>	<p>Likes</p>
<p>P3: Rubbing on the bicep possibly. P1: Cannot separate from the device.</p>	<p>P2: I like the curvature. P4: I like the absorption but mostly for outdoor activities. P4: Love the use of the hands. Definitely my top priority. P3: Shock absorption. P3: Hands free while stationary. P3: Really good for outdoor activities. P1: Blends devices together. P4: Foot design. P2: Clean Aesthetic.</p>

TABLE 6: DAG’S PARTICIPANTS’ RESPONSES TO CONCEPT #3

When asked in what category the concept would be placed, two participants selected *Sports Equipment* and two selected *Medical Equipment*. The DAG participants liked the form, clean aesthetic, and perceived function of the device for

outdoor activities. Participants disliked the possibility of the device rubbing on the bicep and that they felt as if they could not separate from the device.

Following the review of three concepts previously created by the lead researcher, the members were given time to share and collaborate on keywords/phrases for forthcoming designs, design inspiration, and sketches. Keyword and phrase generation resulted in seven words/phrases that served as design goals and areas of focus: movement, following the user when angling/moving, stability, foot/base, two-sided, functional, and sexy. When discussing inspiration, one participant shared their own custom underarm crutch (Fig. 18).



FIGURE 18 DAG PARTICIPANT'S CUSTOM UNDERARM CRUTCH

Their crutch is handmade out of lightweight wood, with a flowing body that they reported aligns with their identity. It also features a replaceable foot and, never previously seen to any DAG members, a bicycle grip in place of the typical hand grip. The bicycle grip uses a low durometer rubber to aid cushioning and user comfort.

This led to a discussion among DAG members and the lead researcher (an avid cyclist) about the use of a winged bicycle grip to further increase comfort. Winged bicycle grips are used to alleviate and spread the point of high pressure at the base of the palm when the rider's hands are placed upon the handlebar. Furthermore, the winged design also prevents the wrist from sitting in extension, maintaining a neutral posture. This participant reported they had used the crutch on multi-day hikes and adventures without complaints. Other discussions centered around the inability of some individuals to use crutches due to physical limitations, instead preferring rollators. However, even with rollators, few options were available that align with their identity. Additionally, members experienced mistreatment during travel, particularly flights, where airport staff took their devices away from them. They also found an inability to place devices conveniently nearby when at restaurants or other establishments. Participants suggested the possibility of a device that can be worn while seated or removed and tucked under the seat, has replaceable feet, and includes a choice of colour. Though the lead researcher encouraged the sharing of sketches, none were developed by members.

The third and final DAG meeting was attended by four participants. Participants were shown two concepts whose forms were an evolution of the most liked and welcomed of the prior three with additional inspiration based on the ideas and preferences generated by DAG members, these being *Concept 1* and *Concept 3*. The final two concepts included modifications to the function and design of the devices based on the knowledge and feedback from DAG members.

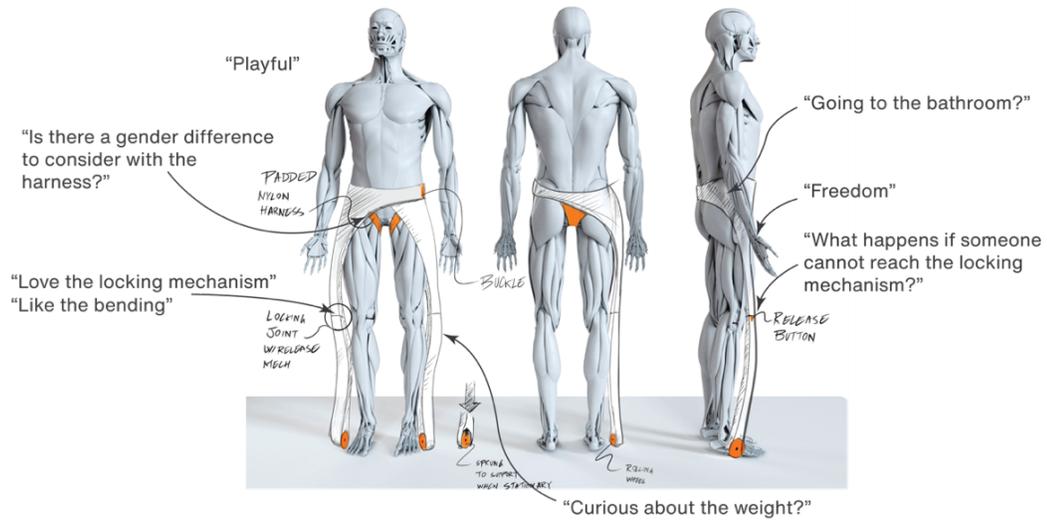


FIGURE 19 FINAL CONCEPT A, ANNOTATED WITH DAG MEMBERS' COMMENTS

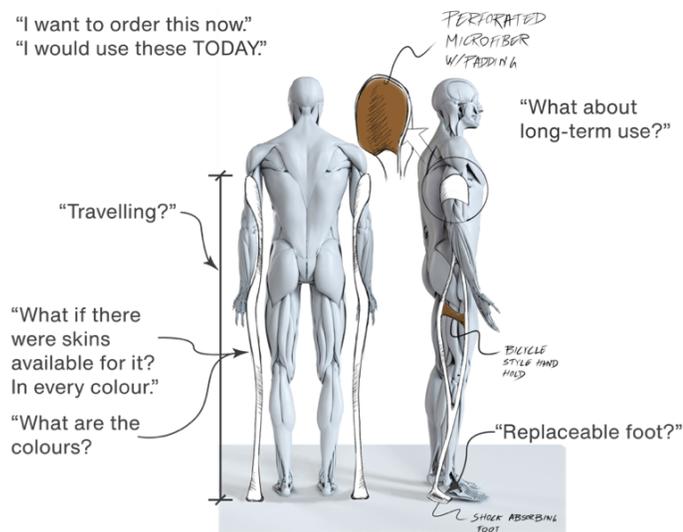


FIGURE 20 FINAL CONCEPT B, ANNOTATED WITH DAG MEMBERS' COMMENTS

The members from the DAG had 13 immediate responses to *Concept A* which included: appreciation of the locking mechanisms on the legs of the device, the device's hands-free nature felt like freedom, the crutch's ability to bend, and the playful design. However, participants questioned whether the individual could reach

the locking mechanism, the perceived high device weight based on the drawing, gender differences with harnesses, and use scenarios. The DAG participants' comments for *Concept A* are shown in Table 7. When asked to categorize the device two participants selected *Medical Equipment*, one selected *Fashion*, and one selected *Personal Goods*. Members liked that the use of a harness made it more stable around the waist, but disliked the integration of a sprung wheel, usability in everyday scenarios, and lack of options for non-weight bearing usage.

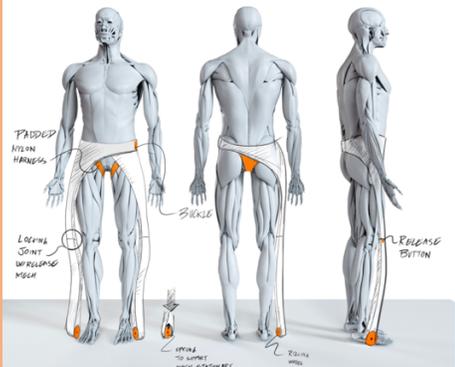
<p>Concept A Assigned to the following categories by participants: Medical Equipment (2) Personal Goods (1) Fashion (1)</p>	
<p>Function</p>	<p>Aesthetics</p>
<p>P3: Love the locking mechanism. P3: Cannot reach the locking mechanism? P1: Curious about the weight? P1: Like the bending. P1: Freedom. P2: Gender difference with the harness? P1: Still not sure about braking/stopping (would prefer something I could tell actually locked it). P2: Can you take the lowest part off? P2: Wearing while driving? P2: Take apart? P3: Replacement wheels needed.</p>	<p>P1: I like the balance. P2: Playful.</p>
<p>Dislikes</p>	<p>Likes</p>
<p>P1: Spring doesn't feel solid enough. P3: Wheels not very conducive to stationary or unstable positions. P2: No option for non-weight bearing use. P5: How would driving work? P1: Going to the bathroom?</p>	<p>P3: More stable around the waist.</p>

TABLE 7: DAG PARTICIPANTS' RESPONSES TO CONCEPT A

Members from the DAG had 23 immediate responses to the second final crutch concept – *Concept B*. These responses included questioning: long-term use, whether the device feet were replaceable, and if an individual could travel easily by plane with the device.

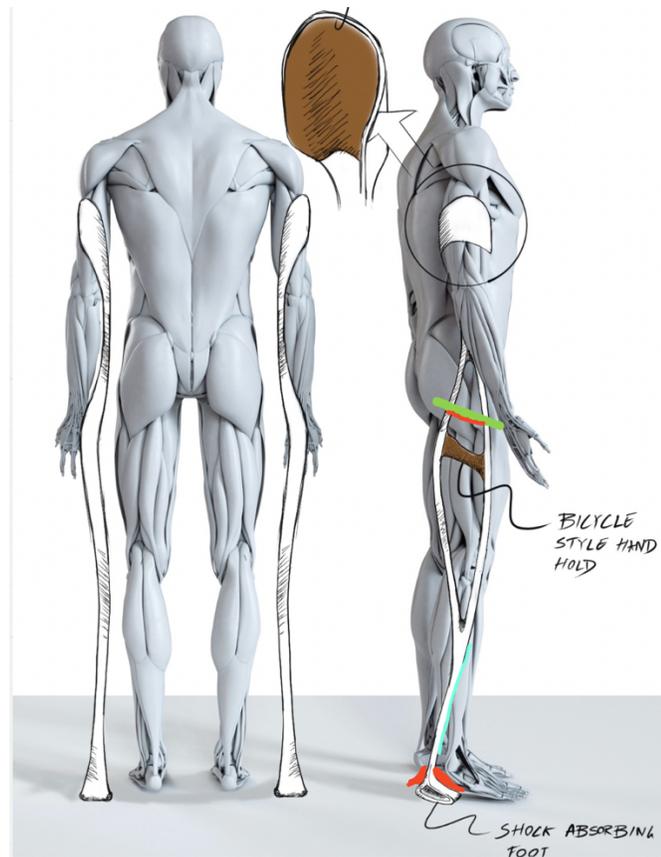


FIGURE 21 CONCEPT B LIGHTING POSITION SKETCH

Participants questioned customization possibilities such as lighting for night visibility, colours, and P1 wanted to order and use the device “today”. Their complete comments are presented as written by participants in Table 8. When discussing lighting, DAG members used the sketching ability of the digital workspace to share ideas on lighting positions by sketching atop *Concept B*. Locations discussed

included on the foot of the device (seen in red), device 'leg' (seen in light blue), and above the hand (shown in red and green). This sketch can be seen in Figure 21.

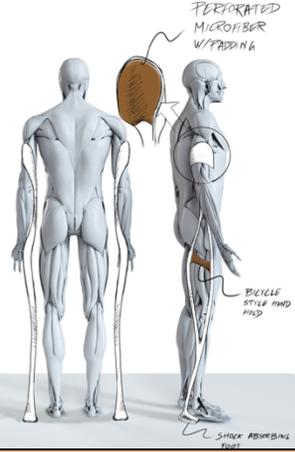
<p>Concept B Assigned to the following categories by participants: Sports Equipment (2) Medical Equipment (2)</p>	
<p>Function</p>	<p>Aesthetics</p>
<p>P2: What about long-term use? P2: Requires high grip and arm strength P1: I would use these TODAY P2: Replaceable foot? P2: Hanging hook? – When seated at a restaurant. P3: Lightweight with shock absorption P1: Unobtrusive P3: Hands free standing option without axillary compression. P2: Free hands. P6: Traveling?</p>	<p>P2: Accessories? P2: Customization possibilities P2: Instinctively I really like the look P1: What if there were skins available for it? In every colour. P1: Love how it flows with the body P3: Favorite design for sure P1: Feels like replacement legs (of mine) P6: What are the colours? P6: I love this concept. P1: I want to order this now.</p>
<p>Dislikes</p>	<p>Likes</p>
<p>P3: Would it need to be fitted more specifically due to the lack of a strap around the bicep? P3: Level of function limitation</p>	<p>P3: Shock absorption P2: Hands free P3: Outdoor activity friendly P1: Could have opportunities to change out the crutch head (foot)</p>

TABLE 8: DAG PARTICIPANTS' RESPONSES TO CONCEPT B

When asked to categorize the concept, two selected *Medical Equipment* and two selected *Sports Equipment*. The DAG dislikes included noting that the extent of an individual's abilities may hinder use and the device would therefore require proper physical fitting of the device to the user. The members liked that the individual could

take their hands off the device. They perceived the device to have an activity friendly design based on the possibility for shock absorption from the foot design.

The third method allowed the lead researcher and SMEs from the DAG to be placed at the same table, virtually, to discuss, inspire, develop, and refine the crutch concepts. The DAG participants' experiences and expertise provided insight on crutch foot design, pinching and/or other mounting hazards, form, use considerations, detailing, and device customization. Categorizing the participants' comments revealed a preference for two types of crutches, a hands-free device, *Concept A*, and an amalgamation of an underarm and forearm crutch, *Concept B*. Of the commentary of the two preferred devices, the amalgamated forearm and crutch concept, *Concept B*, elicited the highest level of interest, with P2 stating they would use it, want to "[o]rder this now", and use the concept today. Furthermore, members began imagining levels of customization with accessories, lighting, storage, colours, and activities they would do with the device. The data suggests that SMEs prefer a device that blends together the existing devices, a more organic form, and a form that has improved positioning to support the posture of upper limbs.

4.4 New Crutch Concepts Questionnaire

In the fourth and final method, members of the general public were shown *Concept A* and *B* developed by the DAG through a *New Concepts Questionnaire* and asked to give their immediate reaction toward each concept regarding aesthetics, concept categorization, and if there were any changes they would

suggest, and if so, why? Upon viewing both concepts, participants were asked which of the two concepts they would select to use themselves, or neither, and to explain their selection. The *New Crutch Concepts Questionnaire* was completed by 34 participants. The data was analyzed to assess their immediate perception with the intention of analyzing immediate responses, to assess the nature of changes being suggested, and the reasoning behind their final selected concept.

Participants were asked to share their immediate responses to an image of *Concept A* and rate the device on a Likert scale. When shown *Concept A*, 14 participants rated the design *Neutral* (41%), 12 *Somewhat Attractive* (35%), five *Unattractive* (15%), two *Very Attractive* (6%), and one *Very Unattractive* (3%). When asked to categorize *Concept A*, 25 selected *Medical Equipment* (73%), four selected *Fashion* (12%), two *Personal Goods* (6%), two *Sports Equipment* (6%), and one *Other* (3%).

Changes to the concept were suggested by 18 of the participants (53%). The remaining 16 participants felt no changes were required (47%). Participants who selected they would change some aspect(s) of the device were asked to explain what that change would be. Their responses were organized by theme, under *Functionality*, *Aesthetic*, or *Other*. Of those who noted a change to the concept's perceived *Functionality*, six noted increasing the amount of support given by the device (67%), and the remaining three mentioned a perceived lack of stability (33%). Participants suggested *Aesthetic* changes that may make the device narrower and less bulky to reduce visibility, as well as a less organic form, Two participants'

comments contrast one another, with one stating the design is very masculine and the other that the device has a feminine form, akin to a dress, that may limit men's willingness to use it. The comment categorized under *Other* was that they wished they could change people's mindsets regarding device usage. A complete overview of suggested changes, as written by participants, is included in Table 9.

Suggested Changes to Concept:
<p>Function Support through the lower back too. Seems that it needs more support. It doesn't look very supportive. It looks a little stiff. It looks like it will need to flex near the waist/hip. It looks a bit flimsy. Seems unstable? In normal crutches, arms provide support and mobility. Consider increasing the size of the area that contacts the ground to help with stability. Not sure about the little rolling wheel. Not sure how it works yet, does it just roll? Or is it like a crutch/new leg? Might need a bit more support into the torso to carry the weight of a human. Not sure, functionality is critical- this does not appear to be a fashion statement, it's a functionality device.</p>
<p>Aesthetic Make it as narrow as possible to avoid environmental barriers. The design is very masculine, and might not suit everyone's tastes. At first glance I see a dress, which might put off some men's willingness to use. I would like the leg supports to be more form fitting so they are less bulky. That would make them less noticeable. Make it look less awkward. Less organic form (alien-like)</p>
<p>Other I wish I could change those people's minds who pity me all the time. It's really stressful.</p>

TABLE 9: PUBLIC'S SUGGESTED CHANGES TO CONCEPT A

When shown *Concept B* and asked to share their immediate response, 15 participants rated the device somewhat attractive (44%), 11 very attractive (32%), five neutral (15%), and three unattractive (9%). No participants rated the device very unattractive. When asked to categorize *Concept B*, 27 selected *Medical Equipment* (79%), five *Personal Goods* (15%), and two *Sports Equipment* (6%). When given the

option to change anything about the device, 22 said they did not have any suggestions for changes (65%) and 12 said they had suggestions for changes (35%). Recommended changes to *Concept B* are shown, as written by participants, in Table 10.

Suggested Changes to Concept:
<p>Function I prefer the first model, but this one may be more functional and similar to current crutches (user may learn to use it faster, but it is traditional). The first model blends into the environment better. The arm wrap thing looks annoying. Should the arm part wrap around that much? It looks more comfortable than “crutches”. Especially the underarm discomfort. I would be concerned about the needed arm strength for proper functionality. Looking at the image it looks rather restrictive for your hands/arms. With a standard crutch you could stick it in your armpit and still use your arms, this looks as it would not give the same result.</p>
<p>Aesthetic Where it wraps around the arm, it would be nice to have a leather pouch with a zipper for credit cards or something. Even something to put your favourite hockey team logo on to share your pride. The band around the arm should be breathable & flexible/stretchy if possible. Looking good. Angle of the grip?</p>
<p>Other People’s mindset. Very nice</p>

TABLE 10: PUBLIC’S SUGGESTED CHANGES TO CONCEPT B

Issues that were identified included: the device looked restrictive for the hand/arm, concern for arm strength for proper device functionality, and annoyance regarding the upper device band that contacts the bicep area. Others suggested changes that included breathable and flexible materials/properties for the bicep band region, on-device storage, and customization options, and angling the hand hold/grip area.

The last question asked participants to state if they would select one of the two concepts or neither, and explain their selection. These responses were then

analyzed and grouped into one of three categories referencing Don Norman's (2004) *Three Levels of Design*. These levels include the *Visceral* level, which centres on people's immediate perceptions of a design's appearance; the *Behavioural* level which focuses more on the practical and functional aspects of a product, and the *Reflective* level which focuses on a product's meaning, personal memories, or appeal to one's self-image or personal narrative. *Concept B* was selected by 22 participants (65%), *Concept A* by 10 participants (29%), and two did not like either concept (6%).

In reviewing the reasons for selecting *Concept A*, nine participants provided reasons that fell under the *Behavioural* level of design (90%). Their comments centered around functional aspects such as the hands-free form of the device and its inherent lack of upper body requirements during use, as well as perceived ease of use. The remaining participant who selected this device was categorized beneath the *Reflective* level of design, stating they wished others would understand what it's like using a device (10%). Reasons for selection of *Concept A* are shown, as written by participants, in Table 11.

Emotional Reasoning for Selection:
<p>Behavioral</p> <p>If this truly supports and is an easy “grab/go” I would choose this due to the freedom of the arm concept.</p> <p>Hands free.</p> <p>Seems less restrictive to upper body movement.</p> <p>Less upper body requirements.</p> <p>Appears to offer less disruptive fit/adjustment to various body forms. Lesser impact to clothing.</p> <p>I would prefer Concept A if it took the same load off as the second model and provided the same level of comfort. I prefer the curves on Concept B better.</p> <p>I like this one. I feel like it will take the pressure off of your arms.</p> <p>Wheels seem more stable for someone struggling to ambulate. They both seem like good ideas but this one seems more user-friendly.</p> <p>Looks easier.</p>
<p>Reflective</p> <p>This, I wish they understand.</p>

TABLE 11: PUBLIC’S REASONING FOR SELECTION OF CONCEPT A

In reviewing the reasons for selecting *Concept B*, nine participant’s comments were grouped under the *Behavioral* level of design (43%), seven participant’s comments fell under the *Visceral* level of design (33%), five participant’s reasons were grouped under the *Reflective* level of design (24%), and one never gave a reason. *Behavioral* comments centred around the perceptions of the product’s stability and support. These were mentioned by seven participants (78%), with the remaining two noting it looked more practical, efficient, and feasible (22%). Comments that fell under the *Visceral* level included aesthetic preference for this device using words such as “attractive”, “looks better”, and “very stylish and chic”, and that the design is “...less bulky” and “...more neutral”. All participants who shared a *Reflective* comment specified the concept’s similarity to existing underarm crutches. The participants who selected that they do not like either device did not provide a reason. Reasons for selection of *Concept B* are shown, as written by participants, in Table 12.

Emotional Reasoning for Selection:
<p>Visceral</p> <p>Looks less bulky and slicker than A. Very stylish and chic, looks like something I'd happily use. Attractive, looks like it could work- fashionable. Looks better. Better looking. A lot more appealing. The individual in Concept A looks like they are a superhuman of some sort, or wearing detached, assless chaps. I think the design is a little more neutral and would appeal to a broader scope.</p>
<p>Behavioral</p> <p>Looks like all the support in Concept A is in the crotch and would cause chafing. This concept looks more stable. I would feel more comfortable using this design vs. the first concept. Seems more secure, like I am in more control. Seems a bit more feasible, although hard on the hands. No back up loading/support option like the armpit pads on existing crutches. Both concepts are interesting- testing and prototyping will tell a better story of which to choose. Allows sufficient support. More practical and would seem more supportive biomechanically. Looks stable. Looks more stable and supportive. Looks practical, efficient, and effective.</p>
<p>Reflective</p> <p>This is more of a traditional crutch melded with a more athletic style and feel. I think these look less strange, as they're just sleeker, newer looking crutches. The other reminds me of Forrest Gump in leg braces. It's more similar to the current style of crutch. It seems to be a style that can be easily accepted by society today. Easy to understand. Seems like an ergonomic approach to an existing model. The design appears more familiar to individuals requiring mobility assistance. The arm attachments help move the legs forward.</p>

TABLE 12: PUBLIC'S REASONING FOR SELECTION OF CONCEPT B

The *Anthropometric Analysis* method identified that forearm and underarm crutches share more postural risks than differences. The shared risks identified are *Wrist Abduction*, *Wrist Supination*, *Wrist Pronation*, *Wrist Flexion*, and *Elbow Flexion*. Differences in postural risks pertained to *Wrist Extension*, *Shoulder Abduction*, and *Shoulder Extension*. These risks were corroborated and additional risks were identified by participants in the *Existing Crutch Questionnaire* method, who also noted

discomfort in the back and chest. Participants who participated in Method 2 also rated the aesthetics of existing crutches, with neither device rated highly, but an aesthetic preference to underarm rather than forearm crutches. Those who are current or past users of crutches were asked to reflect on whether their devices aligned with their self-identities; if they were treated differently as a result of their crutch use or felt stigmatized. The results indicate that most participants felt the crutches did not align with their self-identities, with the majority feeling as if they were treated differently and stigmatized. Explanations for participants' perceived stigma commonly noted they were *Perceived Differently*, but also included *Indifference*, *Environmental Limitations*, and unsolicited acts of *Kindness*. Participants also preferred underarm crutches due; *Aesthetics*, *Prior Experiences*, *Device Perception*, and lower levels or no *Stigma* if they were to choose to use an existing device.

When analyzed, the immediate responses by DAG members within the third method upon the three initial concepts centered around *Aesthetics* and *Function*. All three concepts were viewed as appealing, but each concept was also visually categorized as *Medical Equipment* by at least two members. Other selected product categories include *Fashion*, *Other (Science Fiction)*, and *Sports Equipment*. Members had a preference for *Concept 3* and *Concept 1*. Suggested improvements and inspiration came from generated keywords, members' experiences, and own custom crutches. Their experiences highlighted the need for more than one final concept, to best suit users' needs. *Concept A* and *Concept B* formed evolved versions of *Concept 1* and *Concept 3*, respectively. Comments pertaining to *Concept A* focused

upon *Function*, whereas those for *Concept B* were split between complimenting perceived device *Function* and *Aesthetics*, with suggestions for individualization and customization. *Concept B* was highly preferred, with one DAG member stating, as written by them, they "...would use these TODAY".

The results of the fourth method, the *New Crutch Concepts Questionnaire*, which evaluated the publics' perception of *Concept A* and *Concept B* indicated a distinct preference for *Concept B*. The aesthetics of both final concepts were rated considerably higher than those of existing devices. The majority of respondents rated *Concept A* visually as *Neutral*, followed by *Somewhat Attractive*. The majority of respondents rated *Concept B* visually as *Somewhat Attractive*, followed by *Very Attractive*. Suggested changes for *Concept A* centered around increasing perceived stability and support, but also changing the form as the *Aesthetics* were found to be masculine and feminine in nature by respondents. Suggested changes for *Concept B* included adjusting the size of the arm hold as well as materials and customization possibilities. Participants' preferences for either concept when were mapped using Norman's (2004) three *Emotional Levels of Design*. *Concept A* elicited responses placed primarily beneath *Behavioral*, while those of *Concept B* were spread across all three levels that Norman (2004) suggests are required to have design.

Chapter 5: Discussion

This section discusses the findings relative to the study's research questions and insights presented in the literature review. This thesis identifies postural risks related to crutch use, presents findings related to people's use and perceptions of existing forearm and underarm crutches, and discusses crutch concepts designed with SMEs and evaluated by the general public to help inform the future design of crutches or other walking aids. We begin this chapter with the implications of this research and contribution, followed by a more detailed discussion of the results, concluding with study limitations and possible improvements to the study design.

5.1 Research Implications and Contributions

This study focused on exploring aesthetic and functional considerations of crutches and how current devices have shaped the experiences and perception of crutches in the eyes of users and non-users. Design considerations related to crutches were highlighted in a literature review, identified in an *Anthropometric Analysis* and further explored through a public questionnaire. The *Existing Crutch Questionnaire* provided formal insight into the perceptions of existing crutches aesthetically, feedback from current and past users on areas of bodily pain, and how they were/are perceived due to their usage of crutches. Displeasure with the aesthetics of current crutches was noted by authors within the literature review, but this study formulated the only known formal collection of public sentiment and quotes

towards aesthetic perceptions of these devices and the impact these perceptions have upon device the selection and effects on people who use them. Firsthand feedback from current and past users provides an opportunity to explore considerations in design that address needs more comprehensively. These needs include the mental and physical well-being of people using these products in the future, rather than solely focusing on their functional needs.

In comparing current and past users' reported areas of discomfort with those identified in the literature review and *Anthropometric Analysis*, we have identified other body areas that require more attention to the design of crutches to provide postural support. Literature around postural considerations identified issues related to the whole body, as well as the axilla, hand, wrist, and shoulder, but there was no distinct mention of pain in the chest or back, as was found in this study (Lee et al., 2013; Rasouli & Reed, 2019; Shortell et al., 2001; Smidt & Mommens, 1980). Each of these postural considerations should be considered in further research to comprehensively assess physical support. The findings from this study suggest that further research with crutch users may be required to identify all affected bodily areas that are strained as a result of postural deviation from neutral positioning, respective to each individual, to provide further support and prevent injury.

This study also presents the feedback, development, and perception of conceptual devices developed with SMEs to progress the design of crutches. Designing with the aid of SMEs provided an opportunity to explore device forms that progressed from the current common image of crutches to conceptual designs they

felt may better address postural risks and align to users' identities. The concepts that were developed offered an understanding of the value of consultation with users and how their expertise and opinions may influence other assistive devices to support alignment between devices and individuals. Authors within the literature review suggested the redesign of crutch elements such as the handle or grip and tip or foot with end-users and customization of current devices, but none undertook the redesign of the overall device (Olander, 2011; Shinohara & Wobbrock, 2011). The concepts developed alongside the SMEs may formulate the first iterations of what crutches developed with end-users, to address all their needs, may look like.

5.2 Crutch Design Considerations Related to Posture

In this section, we discuss aspects of the literature review, the *Anthropometric Analysis*, and feedback collected through the *Existing Crutch Questionnaire* and with DAG members to answer *How might a user-centered and interdisciplinary design process reshape crutches to improve our understanding of postural risk factors related to existing crutch use?*

5.2.1 Anthropometric Analysis & Design Considerations

The *Anthropometric Analysis* of persons using underarm and forearm crutches using photo and video-based analysis, revealed risk factors related to the shoulder, elbow, wrist, and hip. Underarm crutches were found to feature five main postural risks; *Wrist Extension*, *Elbow Flexion*, *Shoulder Abduction*, *Wrist Abduction*, and *Shoulder Extension*. Lee et al. (2013), Rasouli and Reed (2019), and Shortell

(2001) also found these bodily areas to be at risk. These typically had a high number of instances, appearing in an average 16 of 20, or 80% of images and videos. The three main postural risks identified pertaining to underarm crutch use included wrist abduction, elbow flexion, and wrist extension. These risks were also noted with forearm crutches but less common, appearing in an average of 14 of 20, or 70% of images and videos analyzed. While forearm crutches exhibited fewer postural risks in this particular analysis, wrist abduction was more commonly noted with forearm crutches, resulting from the position of the hand and wrist on the handgrip.

The observed postural risks were generally common for both devices. However, shoulder extension and wrist extension were more commonly noted with underarm crutch use than forearm crutches. This analysis highlights that forearm crutches bear fewer postural risks, but still pose many of the same risks that are common to underarm crutches and in some cases (wrist abduction, wrist pronation, and elbow extension) forearm crutches may carry increased risk in comparison. The most prominent postural considerations for these two devices appear to arise from the handgrips and the possibility of improper crutch height adjustment respective to the user's anthropometric measures. The handgrip from neither device places the user's hand or wrist in a neutral posture. This may in turn result in the user compensating for improper positioning by bending the elbow and/or elevating or lowering the shoulder in an effort to place the wrist in a neutral position, especially if the device is not properly fit to the user.

The neutral postures of users within the *Anthropometric Analysis* were compared relative to ranges of best fit per *Bodyspace: Anthropometry, Ergonomics and the Design of Work* (Pheasant & Haslegrave, 2006). However, “[w]hen comparing and contrasting the measurable characteristics of different groups of people, we will always be dealing with within-group variability as well as between-group variability” (Pheasant & Haslegrave, 2006, p. 55). There will be persons for whom their neutral postures fall outside of the suggested ranges. Considering humankind as a whole, it is debatable that currently available data would constitute a representative sample of all of humankind and ethnic groups at the present moment. While within-group variability of ethnic groups may be large, between-ethnic group variation is significantly larger (Ibid.). When studying neutral body posture of crew members in zero gravity, NASA found that no single member exhibited the typical posture that was suggested in the MSIS (Man-Systems Integration Standards) neutral body posture diagram (Mount, Whitmore, & Stealey, 2003). Some crew members showed postures that deviated slightly from the MSIS diagram, while three exhibited extreme deviations. As a result of these deviations their study concluded that one composite posture may not be adequate and instead a range of postures may be more constructive for design purposes (Ibid.). While their study evaluated postures in zero gravity, the deviations they found may translate to persons using crutches on earth as well.

5.2.2 Participants' Discomfort with Existing Crutches and Design

Users and past users of crutches in the *Existing Crutch Questionnaire* reported several bodily areas where they experienced discomfort from using underarm and forearm crutches. The majority, or 39 of the 60 participants, had past or current experience using crutches (65%); typically for short-term use (0-2 months). The most commonly used device was the underarm crutch, used four times as often as forearm crutches, walking canes, or other devices. Pain or discomfort in use was mentioned by the majority of past and current users, noting four locations or combinations of: the *Underarm* or the *Underarm and Arm*, *Underarm and Hand/wrist*, or *Underarm and Chest/back*. This may be a result of misuse and/or lack of training provided to the user by their medical expert in correct device use and adjustment (Cohen & Viellion, 1979; Rasouli & Reed, 2019). Additional training should be given to individuals about the importance of placement to support neutral postures, and the device should also be designed in a manner that prevents misuse and reduces reliance on training.

5.2.3 DAG Members' Perceived Conceptual Design Pain Points

In reviewing the initial design concepts, members of the DAG made comments related to anthropometrics, physical comfort and pain, using words like “pinching”, “rubbing”, and “nerve entrapment”. To address postural risks associated with wrist extension and abduction for example, some of the initial concepts featured mounting ideas where the individual would slide their arm within the device to wear it rather

than use a handgrip, with the intent of reducing pressure on the hand and wrist. However, members suggested to avoid any areas that wrapped more than 180 degrees around the arm. The members of the DAG commented that these types of features, in combination with edges of the device structure intended to provide support, may pinch the person when taking steps with the device. This mounting option may reduce wrist and hand pressure, but also introduce new pain points higher up the arm in areas that are typically not used for supporting oneself. Preference was given towards a hands-free option or underarm crutch with improved postural considerations.

The *Anthropometric Analysis* and *Existing Crutch Questionnaire* highlighted common postural risks and pain points for users of both forearm and underarm crutches in the wrist and shoulder, which we suspect may be the result of the handgrip design. However, the primary area of discomfort discussed by participants of this study was the underarm; all other regions were noted in one of three combinations with the underarm or beneath *Other*. It is important to note that the majority of participants who had/use(d) crutches used underarm crutches. Past and current crutch users reported areas of pain that went beyond what the literature review and *Anthropometric Analysis* revealed. The literature reviewed in this study highlighted the shoulders, underarm, forearm, palms, and wrists as potential areas of pain and discomfort (Lee et al., 2013; Rasouli & Reed, 2019). Although these areas were all listed by current and past users, study participants also noted pain experienced in the chest, pectoralis major, as well as the upper and lower back. While

underarm pain from past users was the primary area of discomfort specified, it did not prevent non- or past users them from indicating that they would subsequently select underarm rather than forearm crutches.

5.3 Creation of DAG Conceptual Crutches

In this section, we discuss the feedback and impact of SMEs participating in the design of crutch concepts with the intention of answering *How might a user-centered and interdisciplinary design process reshape crutches to reimagine the product's aesthetics to move this category towards people's personal aesthetic and social preferences, and the realm of fashion and wearables?*

5.3.1 SME Feedback and Development of Initial Concepts

The three initial concepts or discussion prototypes shown to the subject matter experts (DAG) members elicited immediate responses that were categorized in one of the two categories of *Function* or *Aesthetics*. These categories highlight the need to develop products that satisfy all of the wearers' needs through a whole-system approach, as noted by Ravneberg and Soderstrom (2017). Responses categorized into *Function* contained concerns regarding usability and discomfort in use. Members perceived that two of the concepts, *Concept 2* and *Concept 3*, may cause pinching and postural issues as they required the wearer to place their arm through/alongside the device body. These new conceptual forms may result in postural risks that were not previously areas of focus with existing devices, and as a result do not appear in the literature review nor the *Anthropometric Analysis*.

Members did not question the functionality of *Concept 3*, which they described as a “play on an existing product” and looking as if an “underarm and forearm crutch had a child”.

DAG members’ categorization of the concepts’ aesthetics within product categories other than *Medical Equipment* highlighted that reimagining the form was successful toward portraying the device differently. The reflections of DAG members upon their past treatment highlighted the stigma they had experienced related to crutch use and how crutches serve as social signifiers that crutch users are disabled, as discussed by Olander (2011) and Shinohara and Wobbrock (2011). The discussion surrounding P4’s custom wooden crutches highlighted inspirational form and features, but also the member’s dissatisfaction with existing crutches. The custom wooden crutches were identified as a device that aligned with P4’s self-identity and a symbol of pride, something that they should be proud to show to others (Ravneberg & Soderstrom, 2019). This custom device serves as an example of customization as discussed by Shinohara and Wobbrock (2011).

5.3.2 SME Final Concepts Takeaways

The two final concepts shown (*Concept A* and *Concept B*) featured modified and evolved variants of *Concept 1* and *Concept 3*, the ‘hands-free’ and amalgamated ‘underarm’ crutch concepts.

DAG members’ immediate responses for *Concept A* were rather cautious, with the majority noting perceived positive and negative *Functional* aspects, rather

than *Aesthetic*. Most participants noted that while *Concept A* retained its playful form and welcomed the addition of a locking knee hinge, release mechanism, and body harness, the extra complication did not considerably aid stability and impaired usability in comparison to a device not attached to the body.

However, the discussion surrounding *Concept B* focused upon the flow of the device contours along the body, possibility of device colours and skins/graphics, and discussion and ideation of accessories as means of personalization. The familiar form, though evolved, appeared to elicit a sense of instinctive comfort and function within the device.

The immediate response of DAG members demonstrates how device aesthetics and familiarity of form, and familiar use, alongside the possibility of personalization may combine the *Visceral*, *Behavioral*, and *Reflective* levels of emotion in design which Norman (2004) states are necessary to have *design*. This discussion also confirms Ravneberg and Soderstrom's (2019) comments that these devices are "important body parts" and changing or decorating the device conveys a different interpretation, not of failure or personal tragedy, but enhancement and representation of oneself (Ravneberg & Soderstrom, 2019). The act of customization provides the user/wearer with intrinsic value and is not entirely a response to devices they perceive as ugly (Faucett et al., 2017). Customization is a practice of visibility, self-expression or identity assertion. It enables a person to associate themselves and identify with a product in a manner that matches or acts as an extension of their identity to imply feelings of pride, status, joy, and a sense of belonging rather than

shame and stigma (Vaes et al., 2012). Just as a person selects their attire, accessories, and other worn objects to represent their identity, using an expressive, customized device with elements like those suggested by the DAG may empower users to express themselves, their identity, and disability in new ways and move past societally imposed restrictions (Profita et al., 2018).

5.4 Public Perception of Existing and Conceptual Crutches

By asking members of the general public about their perception of existing and conceptual crutches through the two online questionnaires, the lead researcher sought to gather information about people's experiences with crutches (as applicable) and perceptions of crutches. The questionnaires were also a means of gauging people's immediate reactions to existing crutches and the new crutch concepts to frame them within the three levels of design developed by Norman (2004). This activity was designed to explore two research questions: *How might a user-centered and interdisciplinary design process reshape crutches to improve our understanding of people's perceptions of existing crutch designs in terms of use and aesthetics?* and *could new concepts move the devices ...towards people's personal aesthetic and social preferences, and the realm of fashion and wearables?*

5.4.1 Design Considerations Relating to User Preferences and Experiences with Existing Devices

Differential treatment and *Stigma* were experienced by the majority of people who participated in the *Existing Crutch Questionnaire*, illustrating how device use may shape non-users' perception of crutch users as different. Comments related to the theme *Perceived Differently* came up frequently in participant experiences. However, some participants noted an apparent *Indifference* from others in use, while others mentioned receiving unsolicited acts of *Kindness* from strangers triggered by their device, like holding doors, or carrying books and groceries. The treatment of device users appears to be dependent on the social environment and standards, with other participants feeling as if they were “stared at”, “viewed as weak”, “judged”, or “invisible” during use.

Participants preferred underarm crutches over forearm crutches, with most participants rating underarm crutches as *Neutral* or *Unattractive*, while rating forearm crutches as *Very Unattractive* or *Unattractive*. The theme of *Stigma* featured more comments than any other. Comments regarding *Stigma* reinforced negative public sentiment related to the use of forearm crutches and preference toward the underarm crutch as a result. Individuals expressed concerns around being stigmatized if they used forearm rather than underarm crutches due to the association of the forearm crutch with conditions and diseases, rather than an association of injury like underarm crutches. The difference in association of device use is noted by Hernigou (2014) who discusses the historical association of forearm crutches with polio and other

diseases within the United States (Hernigou, 2014). Participants also placed an emphasis on the 'reliable', 'user friendly', and 'familiar' nature of the underarm crutch, highlighting how the reassurance of familiarity of a product impacts product selection and sets expectations with mobility and ability (Pullin, 2010). Familiarity appears to bring with it a sense of comfort to those who are in the process of selecting or using crutches. Both existing devices carry stigma with them, but the familiarity of form, use, and lower stigma of the underarm crutch contributed to its preference among participants.

5.4.2 Perceptions of Existing Crutches Versus Crutch Concepts

Existing crutches had widely different perceptions between them. Aesthetically speaking, underarm crutches were perceived as *Neutral* and *Unattractive* by the majority of participants, while forearm crutches were *Very Unattractive* and *Unattractive*. Likewise, the majority of participants would select underarm crutches if given a choice between devices, giving reasons related to *Stigma, Aesthetics, and Prior Experience*.

Suggested changes for *Concept A* were greater in number than those of *Concept B* and focused primarily upon addressing a perceived lack of stability and support for the wearer. Other changes addressed the category of *Aesthetics*, noting form, suggesting it fit more closely to the body, and two opposing comments on the perceived gender of the concept; one participant stated that the masculine form may not suit everyone's taste while the other at first glance saw the device as a dress

which may put off men's willingness to use it. Aesthetic judgments such as these highlight that *Concept A* was effective at moving the device toward the world of fashion in the eyes of some participants. The possibility of considering this device category as *Fashion* was also reinforced by the participants who selected the *Fashion* category, but it's important to note that the *Medical Device* category was selected over others by far in classifying the concepts.

The rationale given by participants for selecting one of the two concepts presented to them was categorized according to Norman's (2004) three elements critical for design; *Visceral*, *Behavioral*, and *Reflective* qualities. Those who chose *Concept A* primarily gave 'functionalist' reasons for choosing this concept, reasons related to perceived *Behavioral* attributes of the device. This indicates that the concept did not appear to immediately 'attract' users to the device or tap into their identity (e.g., through familiarity or recall of memories). The responses to the final concepts, *Concept A* and *Concept B*, differed greatly in feedback collected from the general public in the *Crutch Concept Questionnaire*, with the majority preferring *Concept B*.

The suggested changes given for *Concept B* were fewer but did not mention a perceived lack of stability or support. Instead, participants gave recommendations for material properties of the upper armband and customization possibilities for on-device storage of small daily carry items and how to personalize it as one's own. These comments fall in line with those given by the DAG which indicate a desire to explore how the device can be individualized. By expressing comments around

customizing and personalizing the device, this may indicate the desire to develop a relationship with the product, and evidence for the ability of such design explorations to capture Norman's (2004) *Reflective* attribute. In making these suggestions, participants express how it could be 'theirs' and part of their identity, not something they feel disconnected from and hesitant to use. Unlike *Concept A*, participants' rationales for selecting *Concept B* were almost evenly spread across Norman's (2004) three levels, suggesting it has potential to fully respond to participants' emotional needs. Participants' *Visceral* comments described *Concept B* as "attractive" and "stylish and chic", with the concept appearing to immediately appeal to participants. Noted *Behavioral* attributes of "sufficient support" and looking "more stable" than *Concept A* indicated a perceived belief in device functionality and performance. In addition, all comments categorized as *Reflective* noted the visual familiarity to the current underarm crutch, appearing to elicit a memory or experience with existing devices. This maybe a result of crutch designs staying largely the same across the thousands of years that they have been used (Hernigou, 2014; Rasouli & Reed, 2019; Shortell et al., 2001). *Concept B*, an evolution rather than revolution of the underarm crutch, showed a clear preference in the eyes of participants over not only *Concept A* but also existing devices as well. Although the participant sample was different in both questionnaires, the reactions indicate that the new concepts were perceived as more aesthetically pleasing than existing devices. Interestingly, the immediate responses of DAG members to the designs were similar to those

members of the public. The results indicate that evolution rather than revolution may be the best approach to crutch design, at this time.

The perception(s) of *Concepts A* and *B* to users and non-users indicate a shift toward mainstream product perception and potential pride that may arise with users as a result of having a device that matches or accentuates their self-identity and emphasizes device visibility, rather than invisibility. Many current users do not see their devices as a source of pride, but rather as inconvenient or restricting, particularly in social spaces (Brooks, 1991). Positive attitudes such as pride in crutch use, may minimize the user feeling as if they must hide the use of their device (Olander, 2011). By addressing creative tensions between function and fashion and evolving from a purely medical aesthetic, these concepts may support identification of disability in a positive light that legitimizes or empowers the wearer (Shinohara & Wobbrock, 2011). Participant aesthetic ratings and explanations show that both final concepts are perceived more positively than existing devices, but also that the familiarity of *Concept B* to an underarm crutch may hint toward its acceptance as a mainstream product. By viewing crutches, and *Concept B*, as a mainstream product they may follow the progression of eyeglasses to eyewear; not directly combatting stigma short-term but beginning a shift that refines and potentially removes crutches from the category of stigmatized assistive devices. Assistive devices are rarely viewed as mainstream products. To create devices that are perceived as mainstream and to eliminate stigma requires changing product design elements and peoples' values and prejudices (Faucett et al., 2017, Olander, 2011). A balance must be struck between

the user's self-image in relation to products, how products are perceived by others, while considering stigmatisation as well. By appealing to users and non-users alike, *Concept A* and *Concept B* appear to be taking a step toward achieving this balance.

5.5 Study Limitations

The emergence of the COVID-19 pandemic introduced limitations to research within not only this study, but many disciplines around the world. The reliance on technology and remotely conducted meetings as means of virtual research hindered data collection and reframed the study away from physical prototyping and evaluation. As a result, the conceptual elements found in *Concept A* and *B* such as hand positioning, device mounting, and overall form were influenced and formed upon data collected within the literature review, postural analysis, existing crutch questionnaire, and feedback from DAG members and their real-world functionality could not be verified.

Furthermore, time limitations of DAG members prevented the conceptual ideation and discussion that would allow for a more close-knit and interactive design process and final concepts. An additional meeting placed between the initial and final meetings focusing solely on concept development using their prior feedback may have allowed for more developed group ideation and further evolved concepts within the study. A final concept was not developed from the findings of *Concepts A* and *B* due to limited time for development, prototyping, real world testing, and distribution to participants to ensure all of their needs and concerns were adequately addressed.

The order in which concepts were shown to study participants did not differ throughout testing. As a result, potential bias may have occurred to one concept or another due to subconscious priming. By altering the order concepts were shown, changes in perception of the concepts may have occurred and more participants may have had a preference toward a different concept.

Additional data on user discomfort and pain points was intended to be collected through a *Body Map Diary Study* (Appendix G). Due to low participant interest within current device users, this method was removed from the study. This additional method sought to collect detailed data pertaining to user discomfort with their device 3 times throughout the day, in the morning, midday, and evening with participants noting bodily areas on an adapted body map diagram (Corlett & Bishop, 1976).

This study did not explicitly take into account the potential for recall bias when participants self-reported their current and past experiences using crutches. Wayne LaMorfe of the Boston University School of Public Health states “[r]ecall bias occurs when there are systematic differences in the way subjects remember or report exposures or outcomes” (LaMorfe, 2020). Participants answered a self-administered questionnaire, but no other methods were employed. Their ability to accurately recall experience(s) using crutches may be skewed as a result.

The design and development of the DAG meetings were conducted by solely the lead researcher, which may have limited individual’s participation levels. Further consultation with group members on how to form and conduct the meetings may

have better supported individual preferences as well as allowed for more active participation in ideation activities. Increased participant ideation may have resulted in differing device features and/or overall form of the final concepts or culmination in a singular final concept.

The lead researcher's location, outreach to Canadian centres, and friend group who reside primarily in North America, where underarm crutches are more commonly used in comparison to Europe, where forearm crutches are favoured, may have skewed the results related to perception of the crutch categories.

5.6 Possible Research Improvements

This study serves as a wholistic approach to walking aid design. As noted by Ravneberg and Soderstrom (2019), not all the needs of clients with walking aids are taken into consideration, stating “[a] whole-systems approach is needed that encompasses not only posture and basic mobility but also the well-being, lifestyle choices, and emotional and mental needs of individuals” (Ravneberg & Soderstrom, 2019, p. 78). This coincides with some of the points raised in the *Existing Crutch Questionnaire*, where participants highlighted issues with discomfort, perceived treatment, and device perception. This study also presents an opportunity to explore postural risks more deeply as the findings showed discomfort in areas not highlighted within the literature review. Furthermore, areas of discomfort may change throughout the day as individuals use their crutches for different lengths of time. We felt it is

necessary to review all areas of the body, as suggested by Smidt and Mommens (1980) to explore postural risks across all types of crutches.

Another takeaway from this study relates to participants' perceptions around support, stability, and amount of load applied to limbs with the concepts. Due to the pandemic, physical prototypes were not developed for this study for evaluation. We recommend that works-like prototypes should be developed to test the validity of conceptual solutions in addressing user's needs and perceived concerns with sketch prototypes. Another finding that requires further research to supplement this study's findings relates to the perception of devices. This study's findings highlighted a preference toward underarm crutches within the participant group with *Stigma* often noted as a reason against selecting forearm crutches. An additional study conducted either within Europe or with international participants, rather than solely North America may shift overall device preferences. North American citizens are either given underarm crutches by medical professionals, or self-prescribe underarm crutches for minor injuries, while in Europe and various other continents, forearm crutches are used instead (Hernigou, 2014). Cultural considerations may alter the form of concepts generated elsewhere, due to different practices and/or preferences.

Future studies may benefit from an enlarged DAG to make it more representative and robust. Members should include not only an industrial designer, chiropractor, and users, but experts from all steps of development, from ideation, prototyping, testing, marketing, prescription, and use. Further research would benefit from a DAG that builds upon the current members to also feature a physiotherapist,

biomechanical engineer, mechanical engineer, fashion designer, graphic designer, and additional industrial designer. A grouping such as this would ensure that the final concept(s) truly address all of the current and potential users' needs and wants.

Chapter 6: Conclusion

This study provides insight into the potential and experienced, physical and psychological pain points, stigma, and risks of crutch use faced by persons every day and perceptions toward crutches from current, past, and non-users. A literature review was conducted to develop an understanding of stigma, postural risks of crutch use, and importance of emotion within design. This study used a mixed-methods approach including an anthropometric analysis, questionnaires, and meetings with subject matter experts to determine postural risks, points of discomfort, experiences, and perception of crutches from current, past, and non-users to shape both, our understanding of users' needs, and conceptual assistive devices. The findings reveal various factors influence people's experiences and/or their perception of crutches with a preference found toward underarm crutches. We found that users experience discomfort in more bodily areas than the literature review and postural analysis highlighted and have a greater likelihood of selecting underarm rather than forearm crutches as a result of the device aesthetics, perceptions toward the device, prior experience and reduced stigma associated with underarm crutches versus the forearm crutch. These findings then shaped a series of conceptual designs which were analyzed and developed further with subject matter experts and shared to collect public perception. The comments and conceptual device perception indicated a comfort toward familiar form and interest in product personalization which begins to satisfy the visceral, behavioral, and reflective levels of emotion required to

support a more wholistic design. These findings coincide with emerging design methods within assistive devices and highlight the value of developing concepts with users. By shaping the design of the device with users, we may be able to shape their social interactions by altering perceptions of assistive devices in social contexts and moving crutches toward the realm of fashion and wearables.

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Appendices

Appendix A Ethics Protocol #115799



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CERTIFICATION OF INSTITUTIONAL ETHICS CLEARANCE

The following research has been granted clearance by the Carleton University Research Ethics Board-B (CUREB-B). CUREB-B is constituted and operates in compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2).

Ethics Clearance ID: Project # 115799

Project Team Members: Mr. Daren Dzumhur (Primary Investigator)

Prof. Chantal Trudel (Research Supervisor)
Claire Davies (Research Supervisor)

Study Title: Examining Stigma Through the Reimagination of Crutch Design

Funding Source: (If applicable):

Effective: July 20, 2021

Expires: July 31, 2022

This certification is subject to the following conditions:

1. Clearance is granted only for the research and purposes described in the application.
2. Any modification to the approved research must be submitted to CUREB-B via a Change to Protocol Form. All changes must be cleared prior to the continuance of the research.
3. An Annual Status Report for the renewal or closure of ethics clearance must be submitted and cleared by the renewal date listed above. Failure to submit the Annual Status Report will result in the closure of the file. If funding is associated, funds will be frozen.
4. During the course of the study, if you encounter an adverse event, material incidental finding, protocol deviation or other unanticipated problem, you must complete and submit a Report of Adverse Events and Unanticipated Problems Form.
5. It is the responsibility of the student to notify their supervisor of any adverse events, changes to their application, or requests to renew/close the protocol.
6. Failure to conduct the research in accordance with the principles of the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans 2nd edition* and the *Carleton University Policies and Procedures for the Ethical Conduct of Research* may result in the suspension or termination of the research project.

IMPORTANT: Special requirements for COVID-19:

If this study involves **in-person research interactions with human participants**, whether on- or off-campus, the following rules apply:

Appendix B Existing Crutch Questionnaire

Start of Block: Current Product Feedback

Q1 In this survey, we will be asking you questions about your experience and thoughts on current crutch/walking aid designs. Your answers will help improve our understanding of your experience and perception of these products.

Q14 Are you currently using crutches/walking aids?

Yes (1)

No (2)

Display This Question:

If Are you currently using crutches/walking aids? = No

Q15 Have you used crutches/walking aids in the past?

Yes (1)

No (2)

Skip To: Q8 If Have you used crutches/walking aids in the past? = No

Display This Question:

If Are you currently using crutches/walking aids? = Yes

Or Have you used crutches/walking aids in the past? = Yes

Q2 If you are currently using or have used crutches/walking aids, what type have you used?

Please select all that apply.

Forearm Crutch (1)

Underarm/Axillary Crutch (2)

Walking Cane (3)

Other (4) _____

Q3 How did you select your crutch/walking aid?

It was prescribed for me by a healthcare professional and I was given options to select a device (1)

It was prescribed for me by a healthcare professional and I was not given options to select the device (i.e., the device was selected by the healthcare professional) (2)

I was not prescribed the product and I selected it myself (3)

Q4 What was/is the period of use?

Short-term (0-2 months) (1)

Long-term (3+ months) (2)

Q5 Do you feel the device aligns/aligned with your identity?

- Yes (1)
- No (2)
- No opinion (3)

Display This Question:

If Have you used crutches/walking aids in the past? = Yes

Q16 In using crutches/walking aids, did you experience any pain or discomfort?

- Yes (1)
- No (2)

Display This Question:

If In using crutches/walking aids, did you experience any pain or discomfort? = Yes

Q19 Please describe briefly where you experienced any pain or discomfort.

Q23 Did or do you feel as if you were/are treated differently due to your crutches?

Not at all (1)

A little (2)

Moderately (3)

A lot (4)

Q6 On the scale below please rate whether you feel/felt stigmatized using crutches/walking aids

	Not at all (1)	Very Little (2)	A little (3)	Occasionally (4)	Often (5)
How stigmatized did you feel? (1)	<input type="radio"/>				

Q7 Can you please explain your answer?

Q8 Please rate the aesthetic appeal of this walking aid

	Very Unattractive (1)	Unattractive (2)	Neutral (3)	Somewhat Attractive (4)	Very Attractive (5)
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Display This Question:

If Please rate the aesthetic appeal of this walking aid = Very Unattractive

And Please rate the aesthetic appeal of this walking aid = Unattractive

Q9 Can you provide a brief explanation of your rating?

Q10 Please rate the aesthetic appeal of this walking aid

	Very unattractive (1)	Unattractive (2)	Neutral (3)	Somewhat attractive (4)	Very Attractive (5)
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Display This Question:

If Please rate the aesthetic appeal of this walking aid = Very unattractive

And Please rate the aesthetic appeal of this walking aid = Unattractive

Q11 Can you provide a brief explanation of your rating?

Q12 Out of the two aids, which would you rather use and why?

Underarm Crutch (1) _____

Forearm Crutch (2) _____

Display This Question:

If Are you currently using crutches/walking aids? = Yes

Q20 Would you be willing to participate in a 1 week long, compensated daily Body Map Diary Study? This study would involve noting your discomfort on a template which illustrates a map of a human body three times each day; during the morning, mid-day, and evening and should not take more than 15-30 minutes per day.

Yes (1)

No (2)

Display This Question:

*If Would you be willing to participate in a 1 week long, compensated daily Body Map Diary Study?
Thi... = Yes*

Q21 Thank you for agreeing to participate in this Body Map Diary Study. Please enter your email below and the lead researcher will share the study with you.

End of Block: Current Product Feedback

Appendix C Crutch Use Pain Points

Areas of Discomfort:
Underarm Underarm Underarms Underarms Armpits Underarms Pinched underarm skin Strenuous on underarms Chafing in armpit Axilla Underarms very sore
Underarm and Arm Arm numbness & underarm pain Underarm and biceps Arm soreness where crutches rubbed + tired arms
Underarm and Hand/Wrist Arm and hand pain Chafed armpits and pain in palms Wrists and armpits Bruising on underarms and hands
Underarm and Chest/Back Underarms, chest, pecs, lower back Armpits and upper back/deltoid area
Other Tired using manual wheelchair Forearms

Appendix D Participant Reflections on Stigma

Reflections on Stigma
<p>Perceived Differently People look at you differently. Perceived as if I'm too young to be using a mobility aid. Feeling invisible. I'm often judged by my crutches before someone gets to know me. People look at me and see the crutches and make a "pity" face – they underestimate me. Other times, people assume because I have them that I can do anything including stairs. I felt that people 'felt sorry' while I was using crutches or my cane. Also felt a sense of weakness/vulnerability. Treated incapable of doing things others can do without the use of aids. Dependent on others. Very obvious handicap. People seemed annoyed that I was moving slowly. Extra unneeded attention. I had an ankle injury. I wasn't a soldier returning from battle. No need for the extra attention. Getting stared at on a daily basis and having people judge my capabilities based on the fact I need to use crutches. People tend to pity you, which sucks, or they try to be too nice to you when otherwise strangers wouldn't talk to you. I was treated differently when using a cane. People tended to avoid eye contact and would give me a wide berth. Additionally, I felt that people were more nervous when interacting with me or were sometimes quite condescending. The assumption of most people when meeting me or seeing me for the first time is that I am injured, weak, or in need of assistance. People perceive those with crutches or other walking aids as ill or weakened, generally they are a bit kinder or helpful. Very rarely do you come across someone acting aggressively towards them someone utilizing them. When using mobility aids that appear temporary I tend to get a lot of questions. People felt sorry for me and bought more things from me at work. That was a minor benefit but also made me feel slightly infantilized when people assumed I was unable to do things. I do cosplay, fashion design, social media, etc... in these communities people focus on beauty (fashion) or accuracy (cosplay) so many times, I am called out for not being "accurate" due to my aids. I'm treated differently sometimes. And people of course are more willing to be rude over social. Most people are very kind, especially in person.</p>
<p>Kindness People helped me without asking them. Given space, people tend to be more helpful. Temporarily on crutches for a foot injury and people hold doors more often or offer assistance. Everyone always is good with helping out for various things but when being helped it does feel like you are a burden to most people. Occasional staring on public transportation and while walking. People also offer help if I'm carrying items such as groceries or school supplies. I was temporarily on crutches for a foot injury so people did not seem to think much of it, perhaps just hold doors open more often or offer assistance more than off crutches.</p>

Indifference

Most people understand when you are using the standard underarm crutches.

People would give me space, no attention or extra attention.

Sometimes I get questions and sometimes people ignore them [my crutches].

I broke my leg as a kid in elementary school. My friends and classmates didn't treat me any differently while using crutches to recover.

Never noticed much as it was short term.

I have used crutches on several occasions during my youth. As I have sprained ankles numerous times through sports. The healing process was always a bummer as I couldn't do the things I loved and/or was limited on completing tasks as quick. For example, getting from one class to the next always took a bit longer and people would joke around with you in regards to your inability. So there was stigma displayed unfortunately.

Environment Limitations

Hard to find elevators and some places don't even have them and just have stairs.

Appendix E Participant Reasons for Device Selection

Participant Reasons for Selecting Underarm Crutches
<p>Physical Comfort I find this type of crutch more functional and comfortable. Afraid of MSDs caused by forearm crutch. Less painful on back. More Support.</p>
<p>Aesthetics “Looks...” Visually looks better? Looks more comfortable. Looks easier to use. Looks more stable, less strain on wrists. Visually more appealing and I guess it's more universally used? Less accessory attached on my body allowing for my orbits to stand out instead of aid.</p>
<p>Prior Experience I have experience with these so I lean towards them. I'm more familiar with an underarm crutch. Definitely these, my issue/need is not sever enough to require forearm crutches. Easier to use. Getting up and down. More fun for big steps. Easier to use. This is the only type of aid I've used. I am familiar and already own this one so I would use it.</p>
<p>Stigma No stigma. Less stigma. Seems more socially acceptable. More approachable. Associated with physical injury rather than disability. Injury as opposed to condition. These crutches are less stigmatized and seen more as temporary. They look less permanent, more like an injury instead of a disease. I think it depends on the nature of the injury or handicap, but the underarm crutch seems more common and possibly has less of a stigma around it.</p>
<p>Device Perception “Seems...” Seems to allow you to walk more normally. Seems more comfortable. Seems more convenient. The forearm scares me that if I fall now my arm is in danger of breaking bad. I see the underarm more for I feel like it's more reliable and user friendly. This one because it seems like it would provide more support and mobility of the arms, but it would depend on the individual's limitations.</p>

It seems like it would be less work to use it due to the weight being mostly transferred under your armpit rather than mostly to your wrists.
I think it's more stable as body's resting point on the crutches is higher than the forearm crutches.
I also think the forearm crutches can cause discomfort because they stretch and pull on your skin.
I feel like the underarm makes most sense as I can lean into it and still utilize my arms.

Participant Reasons for Selecting Forearm Crutches

Device Perception
I bet it's easier to move around on.
Seems more stable.
They are more official.
Seems more comfortable to put your weight on for longer periods of time, and easier maneuverability. Also feels a bit more sleek and discreet.
I heard this one is better ergonomically, never tried it though.
I imagine it would be a bit more comfortable to not have something under my arms. Additionally, forearm crutches might be less likely to wrinkle my clothes. Both are pretty aesthetically unattractive for long term use...

Aesthetics- "Looks..."
Less visually disruptive.
Looks more comfortable.
They're less bulky.

Prior Experience
I use the forearm crutches. They work better for my disability and are smaller and easier to use for me.
You have more maneuvering space.
More functional. I feel better aligned, and somehow they speak more to permanent (i.e. people less likely to think this is temporary).
Increased mobility, less axillary pain.
More comfortable.

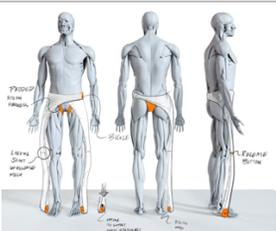
Appendix F New Crutch Concepts

Questionnaire

Start of Block: Current Product Feedback

Q1 In this questionnaire, we will be asking you questions about your thoughts on conceptual crutch/walking aid designs. Your answers will help improve our understanding of your perception of these products.

Q8 What is your immediate reaction to this concept?

	Very Unattractive (1)	Unattractive (2)	Neutral (3)	Somewhat Attractive (4)	Very Attractive (5)
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q25 What category would this concept be placed?

- Personal Goods (1)
 - Sports equipment (2)
 - Medical equipment (3)
 - Fashion (4)
 - Other (please explain below) (5)
-

Q26 Is there anything you would change, and if so, why?

Yes (please explain below) (1)

No (2)

Q10 What is your immediate reaction to this concept?

	Very unattractive (1)	Unattractive (2)	Neutral (3)	Somewhat attractive (4)	Very Attractive (5)
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q27 What category would this concept be placed?

Personal Goods (1)

Sports equipment (2)

Medical equipment (3)

Fashion (4)

Other (please explain below) (5)

Q24 Is there anything you would change, and if so, why?

Yes (please explain below) (1)

No (2)

Q12 Out of these concepts, which would you rather select and why?

Concept #1 (explain below) (1)

Concept #2 (explain below) (2)

I do not like either (explain below) (3)

End of Block: Current Product Feedback

Appendix G Body Map Diary Study

Thank you for participating in the daily diary study!

Instructions

Feel free to print and write or edit each PDF directly.

Please take a moment during your morning, mid-day, and evening (noting the time) at about the same time to mark the bodily areas in which you are experiencing discomfort as a result of your crutch usage. Please also include the side of the body it is on and level of your discomfort.

We are looking for 5 days worth of data over the course of 1 week. They do not need to be consecutive days and ideally days you anticipate heavier crutch use.

If you have any additional comments about the activities you were doing at the time of crutch use, please add them at the bottom of each page.

Day | _____
 Morning
 Time | _____

Instructions |

Please mark any areas of discomfort you experienced during this period of time on the chart below. Note the side (if applicable) and the level experienced on a scale ranging from 1 to 7. A score of 1 is very minor and 7 is very painful. If you have any comments, you may write them at the bottom of the page.

A Technique for Assessing Postural Discomfort 2.0

Body Area	Side (L/R)	Level of Discomfort 1 - 7						
		Very minor (1) to Very painful (7)						
		1	2	3	4	5	6	7
Neck		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shoulders		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upper Back		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upper Arms		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mid Back		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lower Arms		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lower Back		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Buttocks		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hands		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Thumbs		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fingers		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Thighs		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Knees		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Legs		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ankles		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Feet		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Body Regions.

Comments | _____

Day | _____
 Mid-day
 Time | _____

Instructions |

Please mark any areas of discomfort you experienced during this period of time on the chart below. Note the side (if applicable) and the level experienced on a scale ranging from 1 to 7. A score of 1 is very minor and 7 is very painful. If you have any comments, you may write them at the bottom of the page.

*A Technique for
 Assessing Postural Discomfort 2.0*

Body Area	Side (L/R)	Level of Discomfort 1 - 7						
		Very minor (1) to Very painful (7)						
		1	2	3	4	5	6	7
Neck		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shoulders		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upper Back		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upper Arms		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mid Back		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lower Arms		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lower Back		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Buttocks		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hands		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Thumbs		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fingers		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Thighs		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Knees		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Legs		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ankles		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Feet		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Body Regions.

Comments | _____

Day | _____
 Evening
 Time | _____

Instructions |

Please mark any areas of discomfort you experienced during this period of time on the chart below. Note the side (if applicable) and the level experienced on a scale ranging from 1 to 7. A score of 1 is very minor and 7 is very painful. If you have any comments, you may write them at the bottom of the page.

*A Technique for
 Assessing Postural Discomfort 2.0*

Body Area	Side (L/R)	Level of Discomfort 1 - 7						
		Very minor (1) to Very painful (7)						
		1	2	3	4	5	6	7
Neck		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shoulders		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upper Back		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upper Arms		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mid Back		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lower Arms		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lower Back		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Buttocks		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hands		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Thumbs		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fingers		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Thighs		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Knees		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Legs		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ankles		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Feet		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

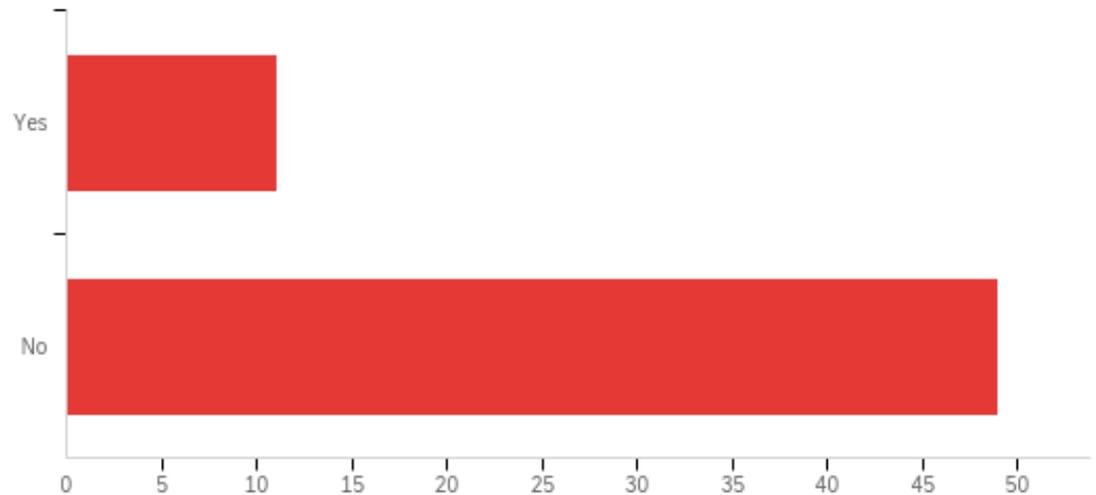
Body Regions.

Comments | _____

Appendix H Existing Crutch Questionnaire

Results

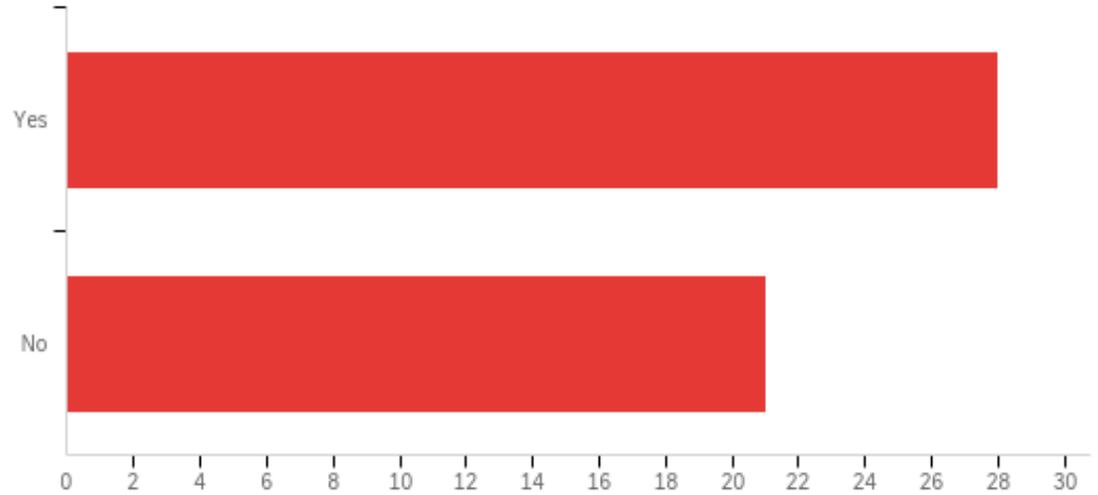
Q14 - Are you currently using crutches/walking aids?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Are you currently using crutches/walking aids?	1.00	2.00	1.82	0.39	0.15	60

#	Answer	%	Count
1	Yes	18.33%	11
2	No	81.67%	49
	Total	100%	60

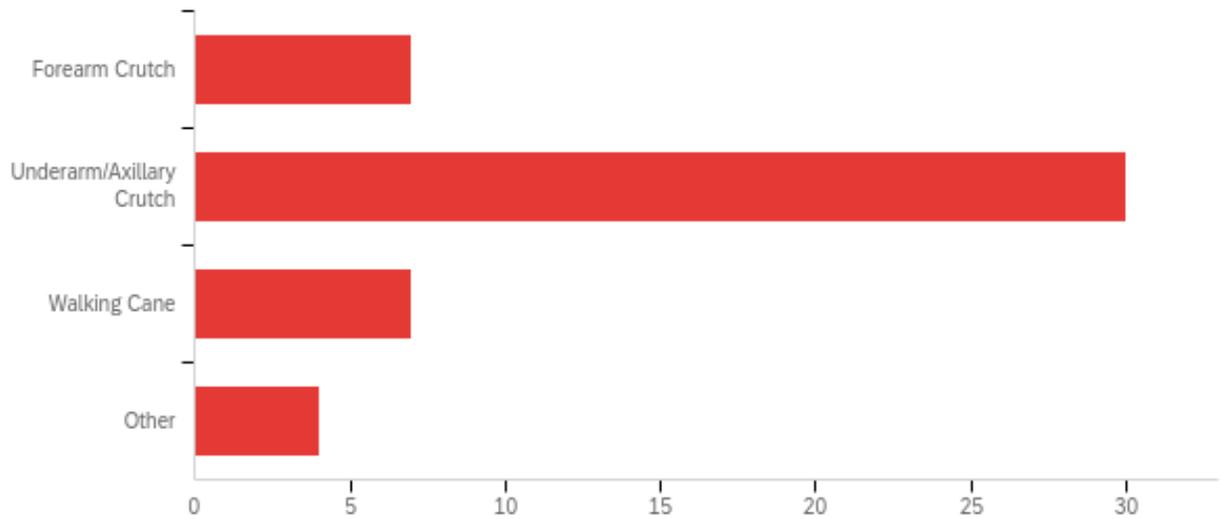
Q15 - Have you used crutches/walking aids in the past?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Have you used crutches/walking aids in the past?	1.00	2.00	1.43	0.49	0.24	49

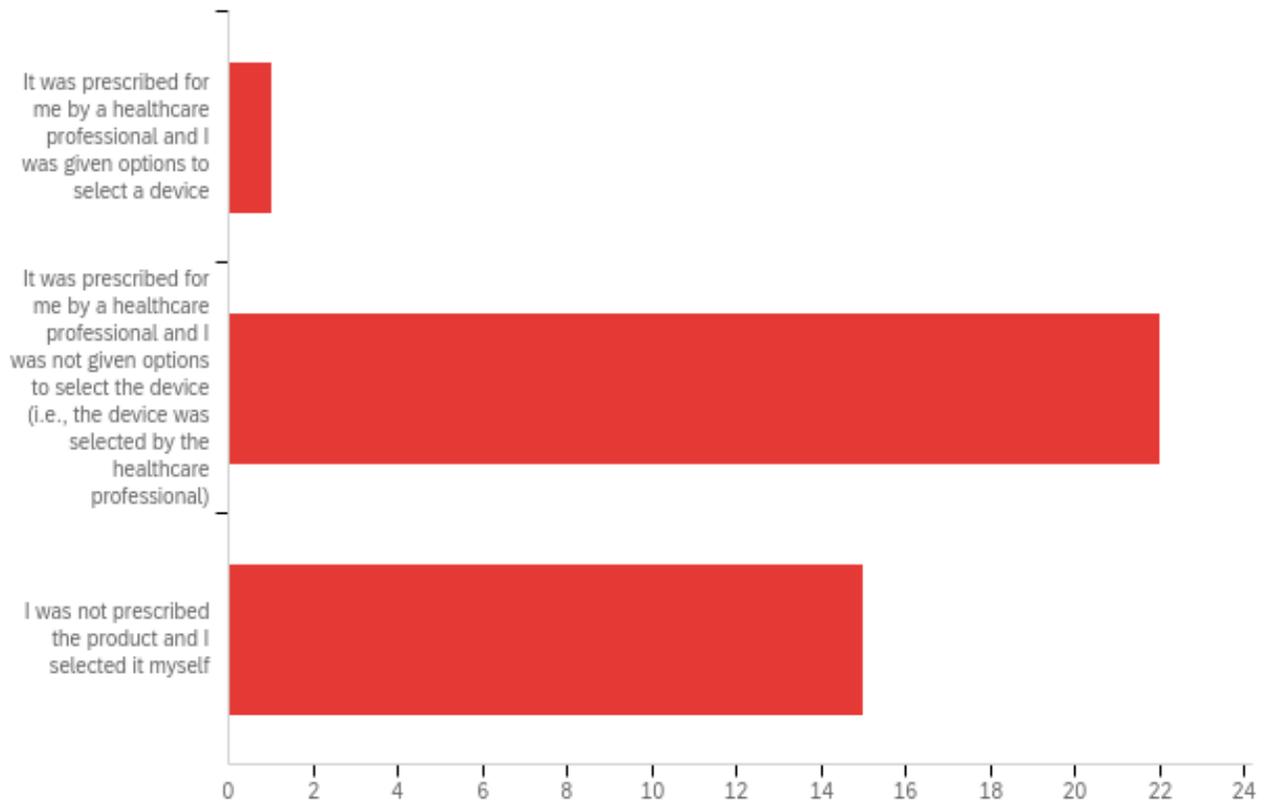
#	Answer	%	Count
1	Yes	57.14%	28
2	No	42.86%	21
	Total	100%	49

Q2 - If you are currently using or have used crutches/walking aids, what type have you used? Please select all that apply.



#	Answer	%	Count
1	Forearm Crutch	14.58%	7
2	Underarm/Axillary Crutch	62.50%	30
3	Walking Cane	14.58%	7
4	Other	8.33%	4
	Total	100%	48

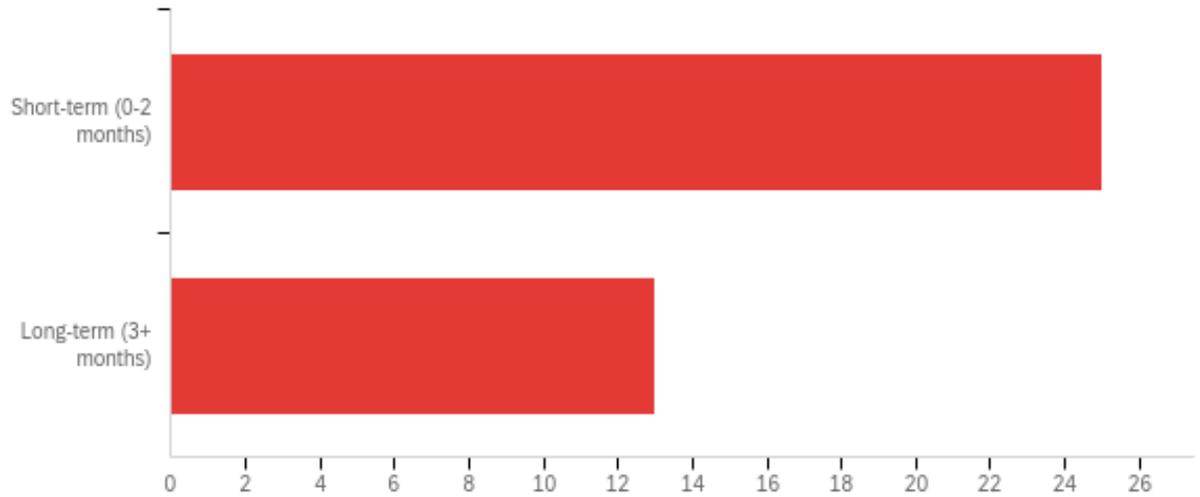
Q3 - How did you select your crutch/walking aid?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How did you select your crutch/walking aid?	1.00	3.00	2.37	0.53	0.29	38

#	Answer	%	Count
1	It was prescribed for me by a healthcare professional and I was given options to select a device	2.63%	1
2	It was prescribed for me by a healthcare professional and I was not given options to select the device (i.e., the device was selected by the healthcare professional)	57.89%	22
3	I was not prescribed the product and I selected it myself	39.47%	15
	Total	100%	38

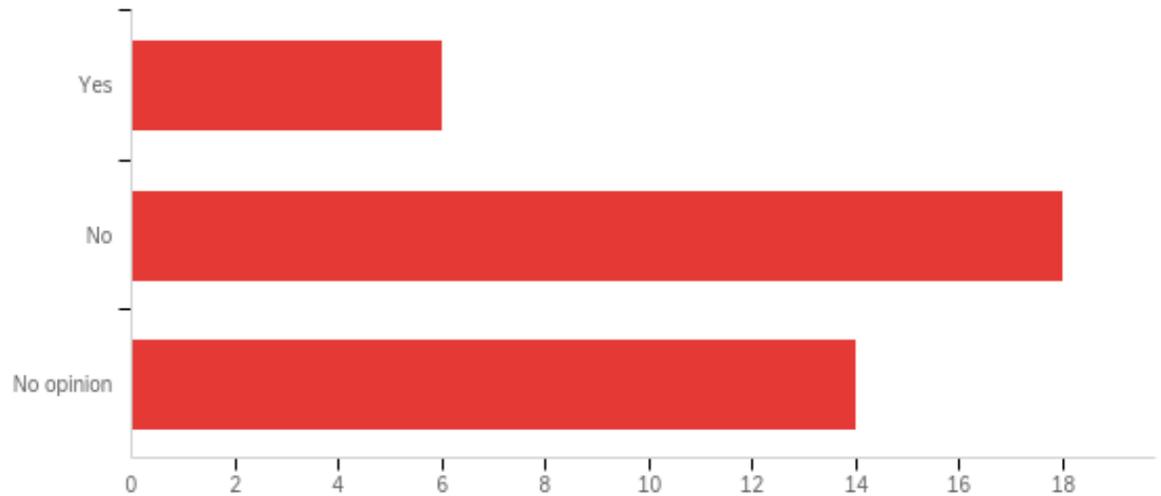
Q4 - What was/is the period of use?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What was/is the period of use?	1.00	2.00	1.34	0.47	0.23	38

#	Answer	%	Count
1	Short-term (0-2 months)	65.79%	25
2	Long-term (3+ months)	34.21%	13
	Total	100%	38

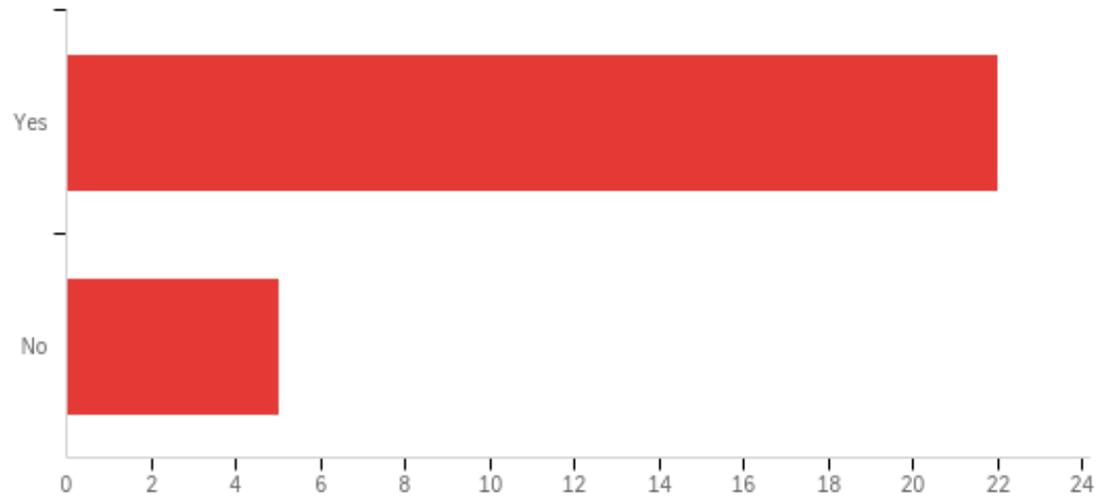
Q5 - Do you feel the device aligns/aligned with your identity?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do you feel the device aligns/aligned with your identity?	1.00	3.00	2.21	0.69	0.48	38

#	Answer	%	Count
1	Yes	15.79%	6
2	No	47.37%	18
3	No opinion	36.84%	14
	Total	100%	38

Q16 - In using crutches/walking aids, did you experience any pain or discomfort?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	In using crutches/walking aids, did you experience any pain or discomfort?	1.00	2.00	1.19	0.39	0.15	27

#	Answer	%	Count
1	Yes	81.48%	22
2	No	18.52%	5
	Total	100%	27

Q19 - Please describe briefly where you experienced any pain or discomfort.

Please describe briefly where you experienced any pain or discomfort.

underarm pain, wrist pain

Arms would be sore where the crutches rubbed against me, arms would get tired after a while

I had to work in retail while using crutches and the pain in my wrists and l'm my arm pit was really terrible.

The underarm area after a long walk

Underarm pain

In the axilla specifically when walking around campus for extended periods of time.

Under arms and arms

Bruising under the arms and on the hands

Tired of using the manual wheelchair

Under armpits and upper back/deltoid area

Under arms, chest, pecs, lower back

Arm pain and hand pain

Under arm pain/arm numbness

Under arms/armpits

forearm

My underarms were very sore

Underarm and biceps

Underarms

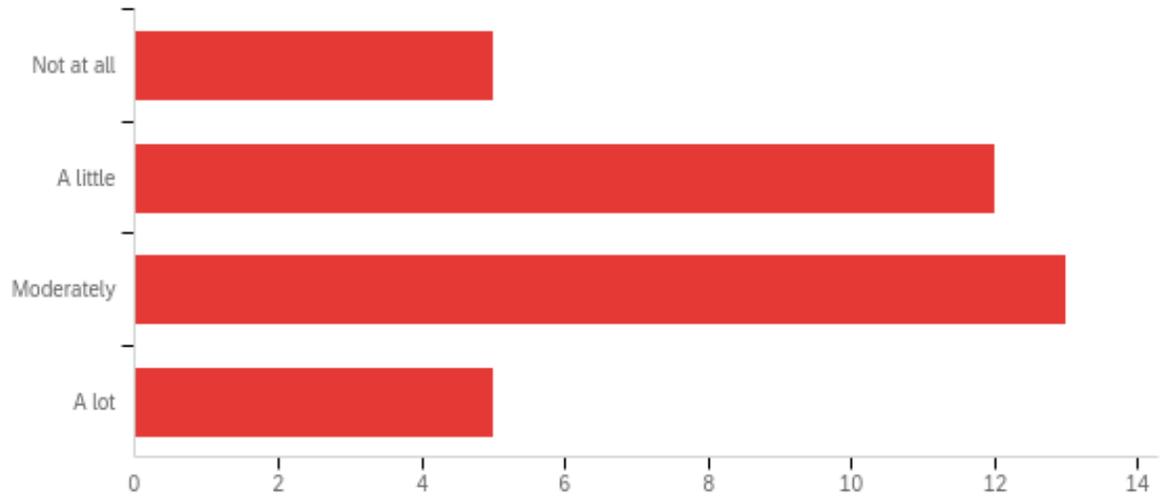
Really strenuous on your under arms

Armpit chaffing, pain in palms

Chafing in armpit

It was pinching my underarm skin.

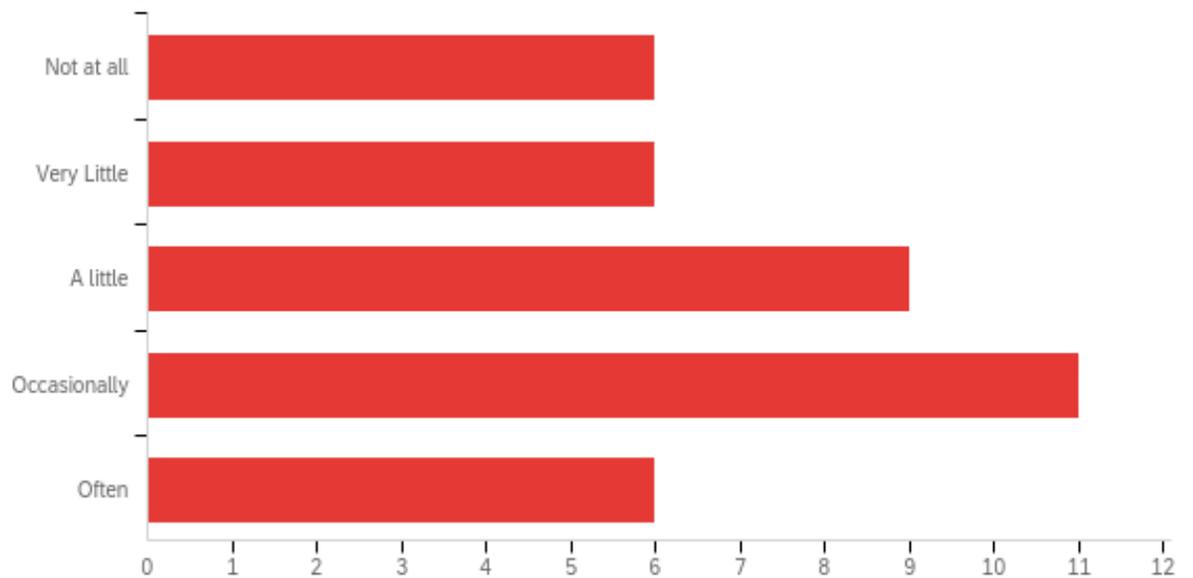
Q23 - Did or do you feel as if you were/are treated differently due to your crutches?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Did or do you feel as if you were/are treated differently due to your crutches?	1.00	4.00	2.51	0.91	0.82	35

#	Answer	%	Count
1	Not at all	14.29%	5
2	A little	34.29%	12
3	Moderately	37.14%	13
4	A lot	14.29%	5
	Total	100%	35

Q6 - On the scale below please rate whether you feel/felt stigmatized using crutches/walking aids



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How stigmatized did you feel?	1.00	5.00	3.13	1.30	1.69	38

#	Answer	%	Count
1	Not at all	15.79%	6
2	Very Little	15.79%	6
3	A little	23.68%	9
4	Occasionally	28.95%	11
5	Often	15.79%	6
	Total	100%	38

Q7 - Can you please explain your answer?

Can you please explain your answer?

I'm young and people stared some.

Underarm crutches are more associated with an injury thus less being 'stigmatized'

People perceive those with crutches or other walking aid device as ill or weakened, generally they are a bit kinder or helpful. Very rarely do you come across someone acting aggressively towards someone utilizing them.

I did not feel very stigmatized because I was wearing a cast so people understood why I was using crutches but the crutches did draw attention to me

People felt sorry for me and bought more things from me at work. That was a minor benefit but also made me feel slightly infantilized when people assumed I was unable to do certain things.

Occasional staring on public transportation and while walking. People also offer help if I'm carrying items such as groceries or school supplies

No

Everyone always is good with helping out for various things but when being helped it does feel like you are a burden to most people.

I feel like most people understand when you use the standard under arm crutches

I do cosplay, fashion design, social media...etc. in these communities people focus on beauty(fashion) or accuracy(cosplay) so many times, I am called out for not being "accurate" due to my aids. I'm treated differently sometimes. And people of course are more willing to be rude over social. Most people are very kind, especially in person

The assumption of most people meeting me or seeing me for the first time is that I am injured, weak, or in need of assistance.

Treated incapable of doing things others can do without the use of aids. Dependent on others

I'm often judged by my crutches before someone gets to know me

Sometimes I get questions and sometimes people ignore them

I felt that people 'felt sorry' while I was using crutches or my cane. Also felt a sense of weakness/ vulnerability

When using mobility aids that appear temporary I tend to get a lot of questions.

Feeling invisible

Extra unneeded attention. I had an ankle injury. I wasn't a soldier returning from battle. No need for the extra attention

People would give me space, no attention or extra attention

People tend to pity you, which sucks, or they try to be too nice to you when strangers otherwise wouldn't talk to you

Getting stared at on a daily basis and having people judge my capabilities based on the fact that I need to use crutches.

Given space, people tend to be more helpful

Very obvious handicap

no problems at all, many people even helped me (without asking them)

I was temporarily on crutches for a foot injury so people didn't seem to think much of it, perhaps just hold doors open more often or offer assistance more than off crutches.

I was treated very differently when using a cane. People tended to avoid eye contact and would give me a wide berth. Additionally, I felt that people were more nervous when interacting with me or sometimes were quite condescending.

Na

People would seem annoyed that I was moving slowly

I have used crutches on several occasions during my youth. As I have sprained my ankles numerous times through sports. The healing process was always a bummer as I couldn't do the things that I loved and/or was limited on completing tasks as quick. For example, getting from one class to the next always took a bit longer and people would joke around with you in regards to your inability. So there was a stigma displayed unfortunately.

Never noticed it much as it was short term

Can't do sh*t anyway, I would just say it's hard to find where the elevators are. Some places don't even have them and just have stairs

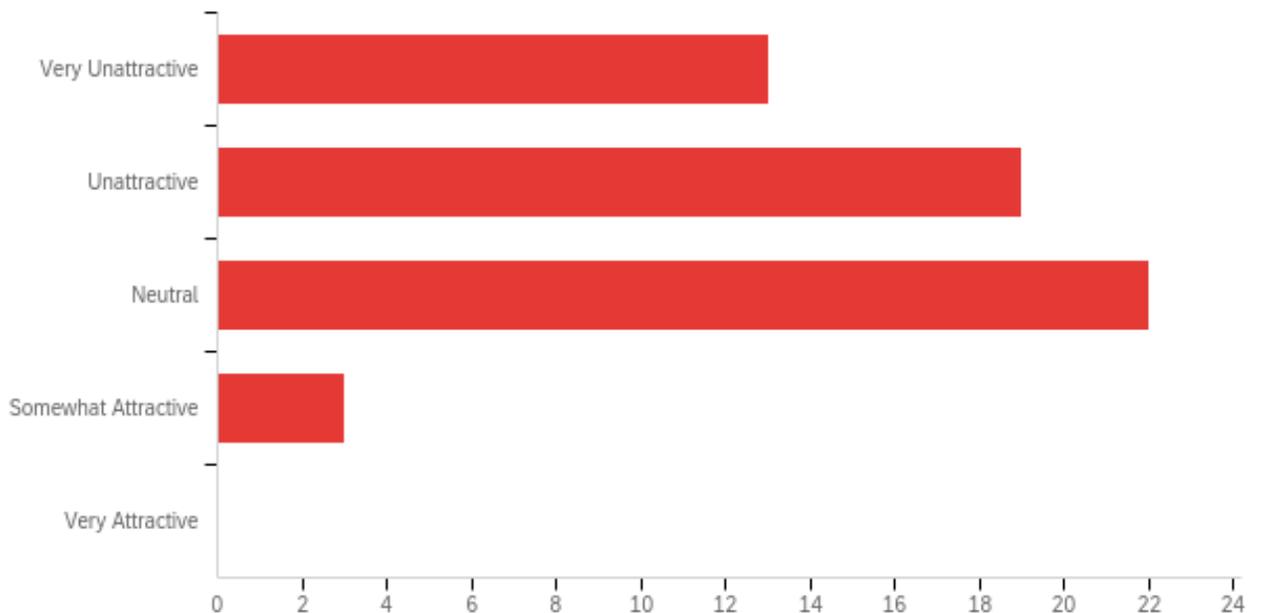
I broke my leg as a kid in elementary school. My friends and classmates didn't treat me any differently while using crutches to recover

People look at you differently.

perception: I'm "too young" to be using a mobility aid.

People look at me and see the crutches and then make a "pity" face - they underestimate me. Other times, people assume because I have them that I can do anything including stairs.

Q8 - Please rate the aesthetic appeal of this walking aid

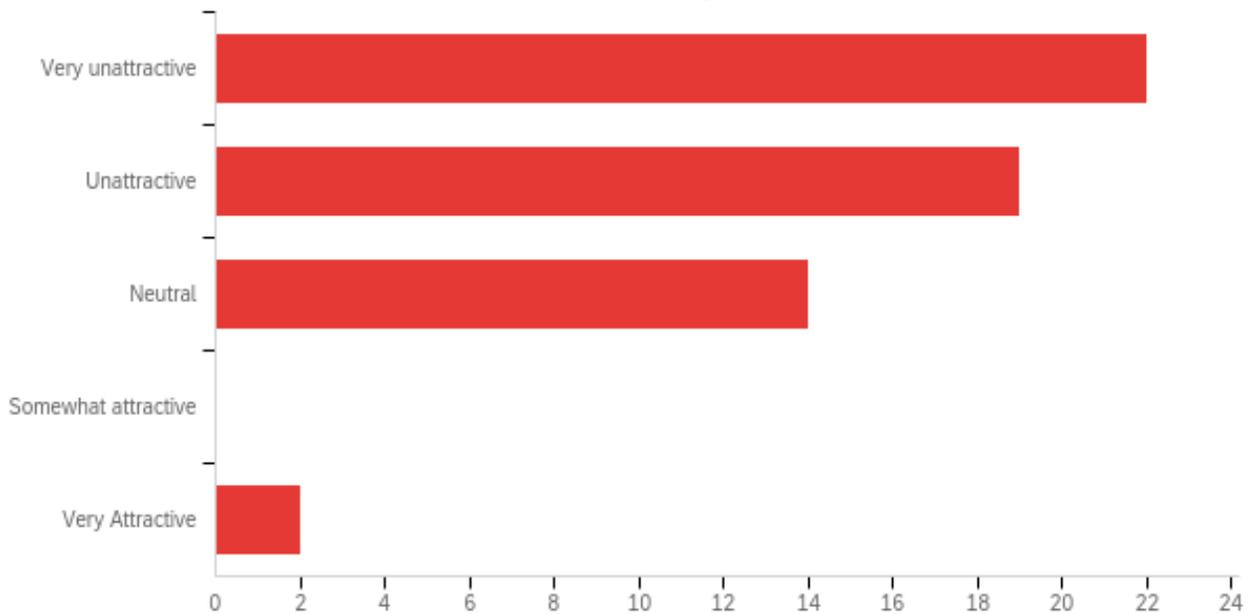


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Underarm Crutch	1.00	4.00	2.26	0.87	0.76	57

#	Answer	%	Count
1	Very Unattractive	22.81%	13
2	Unattractive	33.33%	19
3	Neutral	38.60%	22
4	Somewhat Attractive	5.26%	3
5	Very Attractive	0.00%	0
	Total	100%	57

Q9 - Can you provide a brief explanation of your rating?

Q10 - Please rate the aesthetic appeal of this walking aid

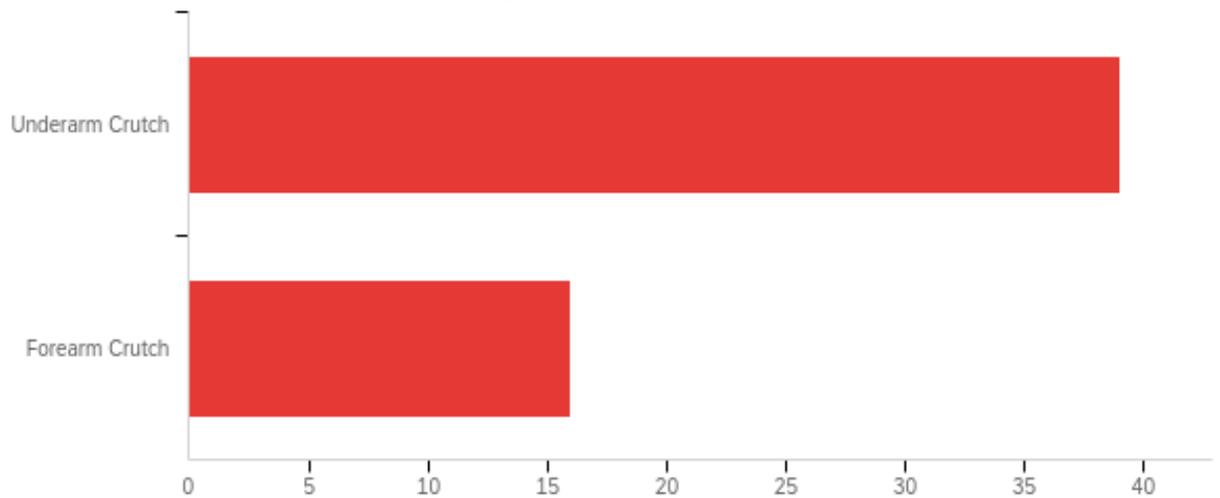


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Forearm Crutch	1.00	5.00	1.96	0.97	0.95	57

#	Answer	%	Count
1	Very unattractive	38.60%	22
2	Unattractive	33.33%	19
3	Neutral	24.56%	14
4	Somewhat attractive	0.00%	0
5	Very Attractive	3.51%	2
	Total	100%	57

Q11 - Can you provide a brief explanation of your rating?
Can you provide a brief explanation of your rating?

Q12 - Out of the two aids, which would you rather use and why?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Out of the two aids, which would you rather	1.00	2.00	1.29	0.45	0.21	55

use and
why? -
Selected
Choice

#	Answer	%	Count
1	Underarm Crutch	70.91%	39
2	Forearm Crutch	29.09%	16
	Total	100%	55

Underarm Crutch

I have experience with this crutch and seems easier to use

Definitely these, my issue/need is not severe enough to require forearm crutches.

These crutches are less stigmatized and seen more as temporary

I think it's more stable as your body's resting point on the crutches is higher than the forearm crutches. I also think forearm crutches can cause discomfort because they stretch and pull on your skin

More fun for big steps

No stigma

Looks easier to use

I find this type of crutch more functional and comfortable.

Less accessory attached on my body allowing for my orbits to stand out instead of aid

Visually more appealing and I guess it's more universally used?

This is the only type of aid I've used.

Easier to use. Getting up and down

Seems more comfortable

Looks more comfortable

They look less permanent, more like an injury instead of a disease

Looks more stable, less strain on the wrists

Injury as opposed to condition

I am familiar and already own this one, so I would use it

It allows you to walk more normally.

Easier to use

Less stigma

I have experience with these so I lean towards them.

It seems like it would be less work to use it due to the weight being mostly transferred under your armpit rather than mostly to your wrists.

I feel like the underarm makes most sense as I can lean into it and still utilize my arms

I'm more familiar with an underarm crutch.

I think it depends on the nature of the injury or handicap, but the underarm crutch seems more common and possibly has less of a stigma around it

The forearm scares me that if I fall now my arm is in danger of breaking bad I see the underarm more so I feel like it's more reliable and user friendly

Associated with physical injury rather than disability

Less painful on back

More approachable

This one because it seems like it would provide more support and mobility of the arms, but it would depend upon the individuals limitations.

More support

Seems more socially acceptable

I would use this one if it was more comfortable and less industrial looking. The reason is the forearm crutch looks more physically demanding than this one.

Seems more convenient

visually looks better?

afraid of MSDs caused be forearm crutch

Forearm Crutch

seems like less pressure

I bet it's easier to move around on

Increased mobility, less axillary pain

I use forearm crutches. They work better for my disability and are smaller and easier to use for me.

They're less bulky

Looks more comfortable

More comfortable

Seems more stable

I imagine it would be a bit more comfortable to not have something under my arms. Additionally, forearm crutches might be less likely to wrinkle my clothes. Both are pretty aesthetically unattractive for long term use...

They are more official

you have more maneuvering space

Seems more comfortable to put your weight on for longer periods of time, and easier maneuverability. Also feels a bit more sleek and discreet.

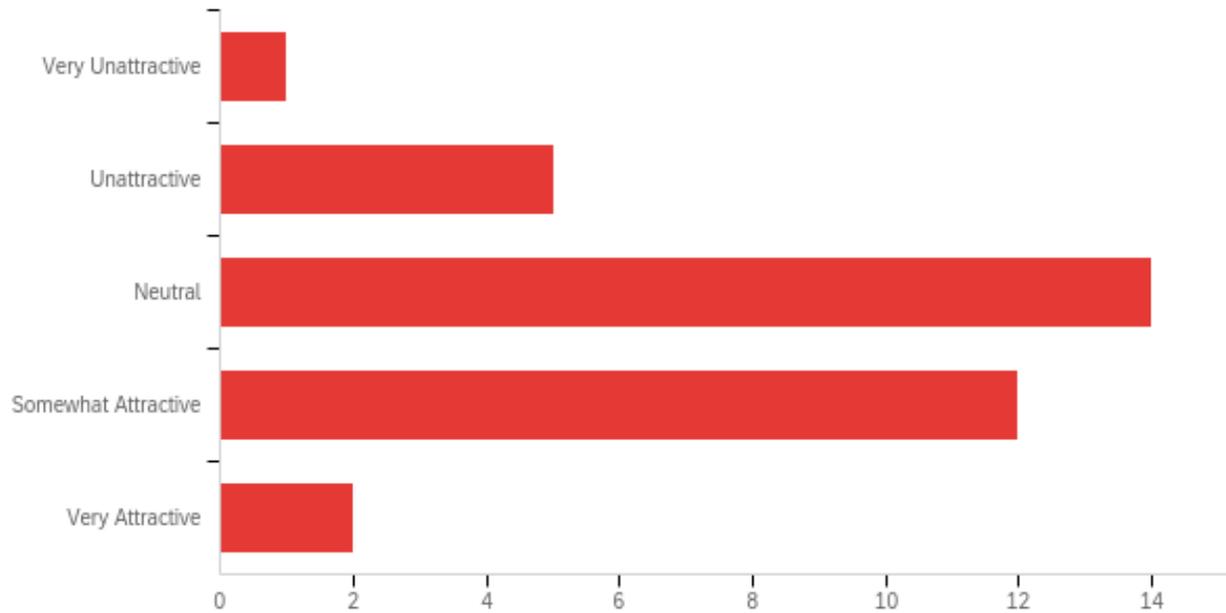
I heard this one is better ergonomically, never tried it though

Less visually disruptive

more functional. I feel better aligned. and somehow they speak more to permanent (i.e., people less likely to think this is temporary)

Appendix I New Crutch Concepts Questionnaire Results

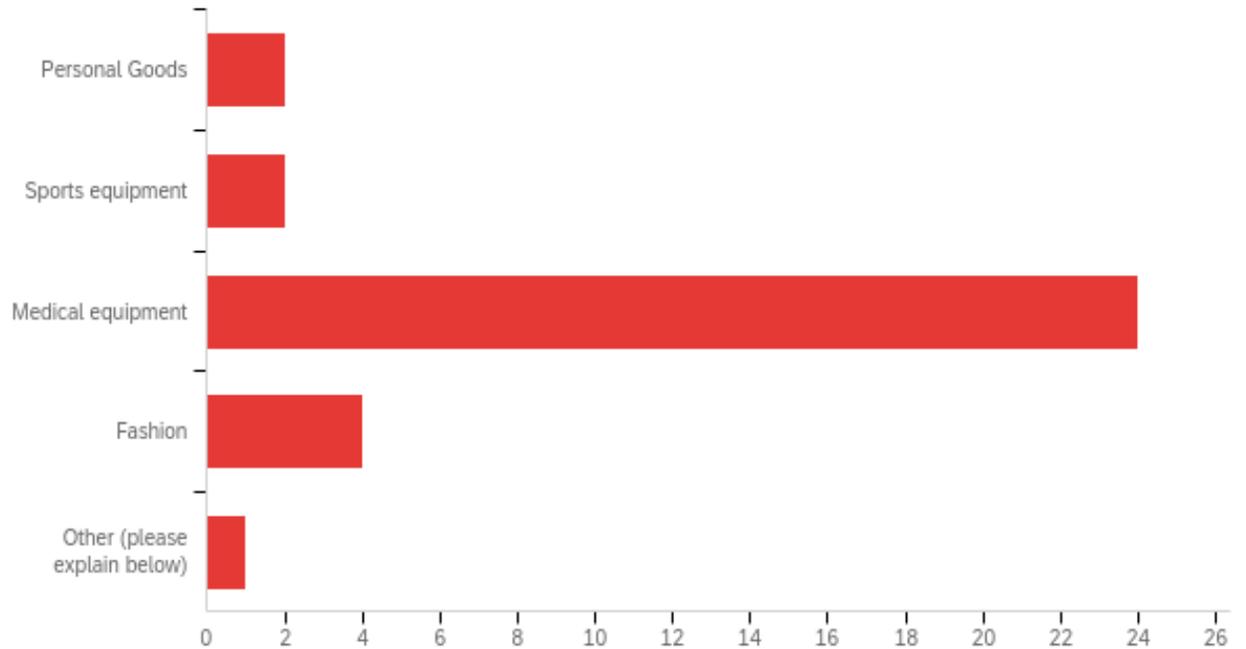
Q8 - What is your immediate reaction to this concept?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Concept #1 - Hands Free	1.00	5.00	3.26	0.88	0.78	34

#	Answer	%	Count
1	Very Unattractive	2.94%	1
2	Unattractive	14.71%	5
3	Neutral	41.18%	14
4	Somewhat Attractive	35.29%	12
5	Very Attractive	5.88%	2
	Total	100%	34

Q25 - What category would this concept be placed?



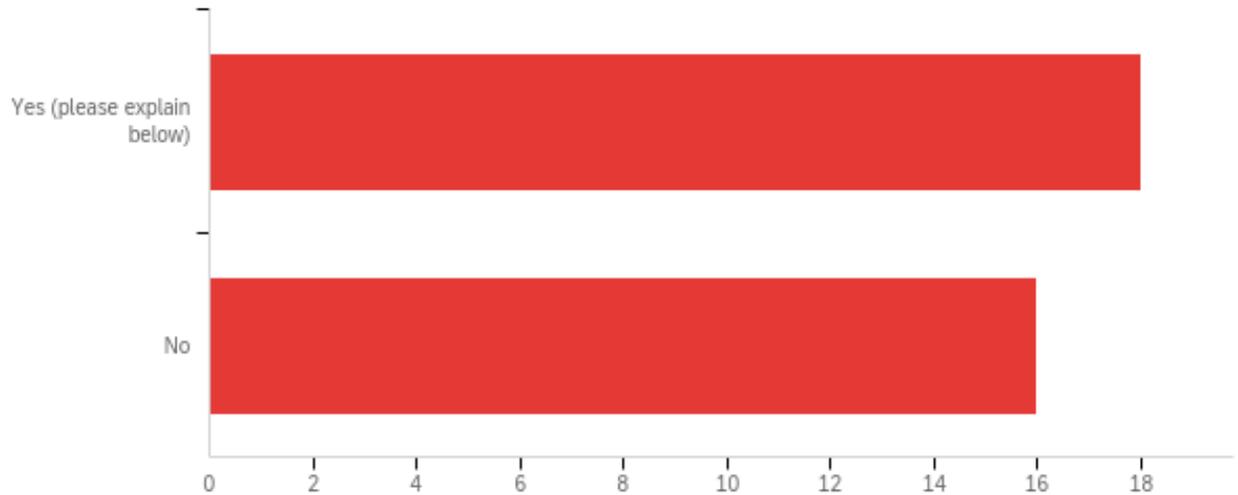
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What category would this concept be placed? - Selected Choice	1.00	5.00	3.00	0.74	0.55	33

#	Answer	%	Count
1	Personal Goods	6.06%	2
2	Sports equipment	6.06%	2
3	Medical equipment	72.73%	24
4	Fashion	12.12%	4
5	Other (please explain below)	3.03%	1
	Total	100%	33

Other (please explain below)

Looks like someone tied a sweater around their waist

Q26 - Is there anything you would change, and if so, why?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Is there anything you would change, and if so, why? - Selected Choice	1.00	2.00	1.47	0.50	0.25	34

#	Answer	%	Count
1	Yes (please explain below)	52.94%	18
2	No	47.06%	16
	Total	100%	34

Yes (please explain below)

Yes (please explain below) - Text

Support through lower back too

I wish I could change those people's mind who just pity me all the time. Its really stressful.

At first glance I see a dress, which might put off some men's willingness to use.

I would like the leg supports to be more form fitting so they are less bulky. That would make them less noticeable.

Not sure... functionality is critical... this does not appear to be a fashion statement - it is a functionality device.

Make it look less awkward

Make it as narrow as possible as to avoid environmental barriers

Seems that it needs more support

Consider increasing the size of the area that contacts the ground to help with stability

Not sure about the little rolling wheel. Not sure how it works yet, does it just roll? Or is it like a crutch/new leg? Might need a bit more support into the torso to carry the weight of a human.

It looks a little stiff. It looks like it will need to flex near the waist/hip.

Seems unstable? In normal crutches arms provide support and mobility. Not sure how mobile you could be with these

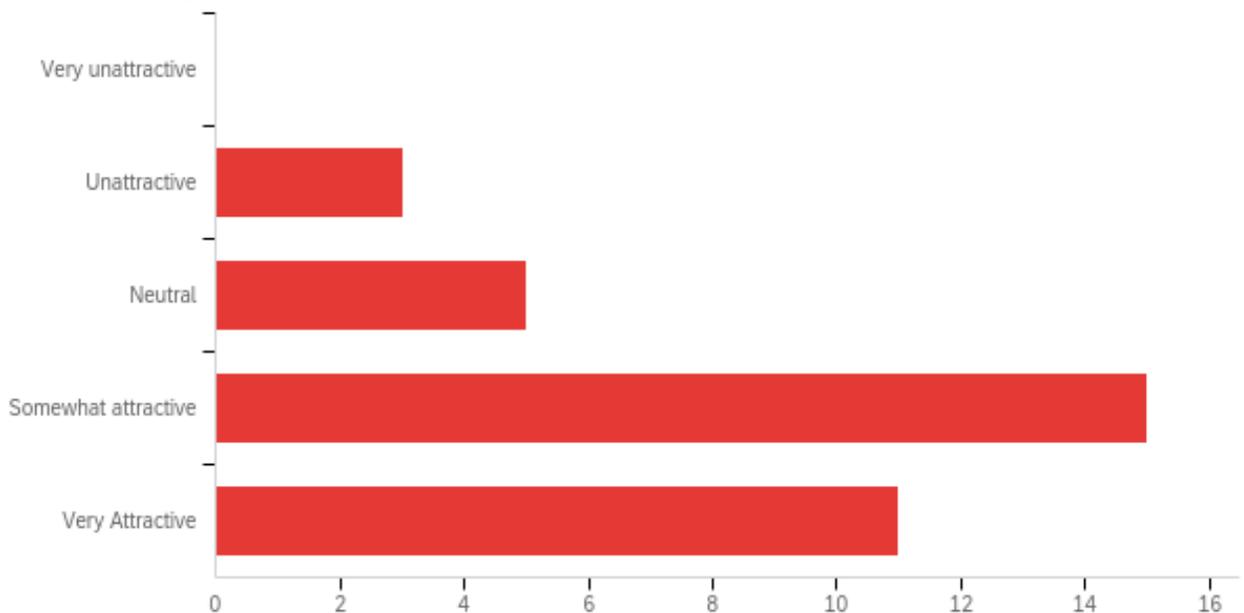
The design is very masculine, and might not suit everyone's taste

Less organic (alien - like)

It doesn't look very supportive

It looks a bit flimsy

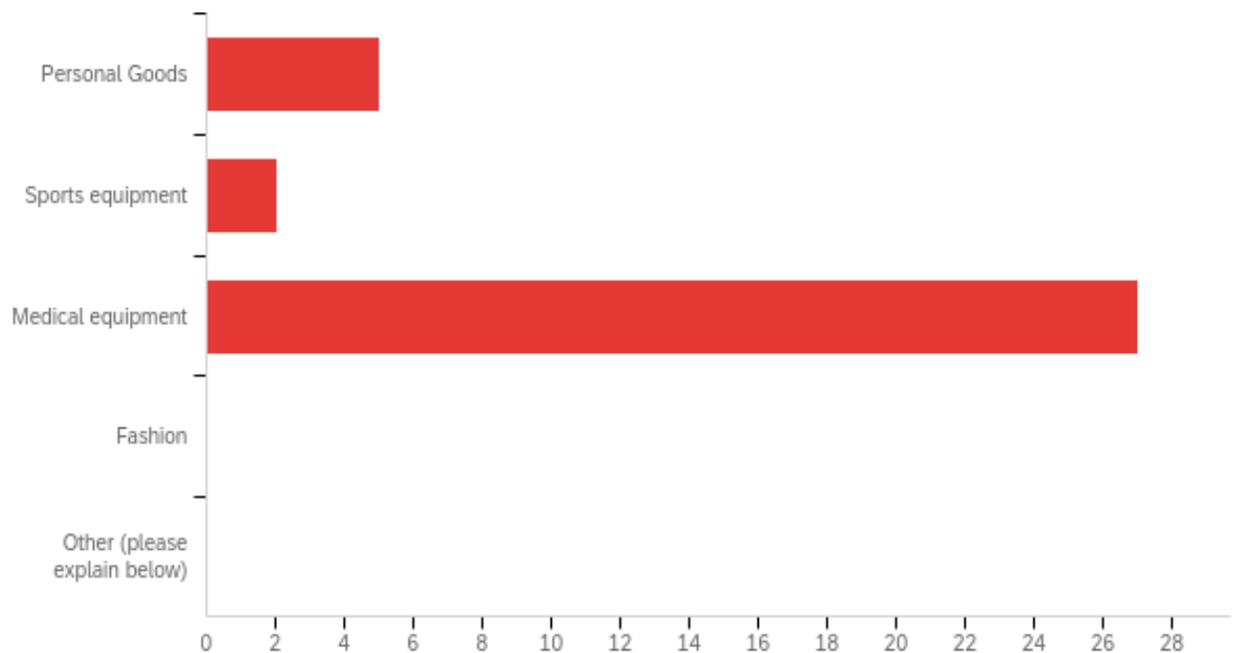
Q10 - What is your immediate reaction to this concept?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Concept #2	2.00	5.00	4.00	0.91	0.82	34

#	Answer	%	Count
1	Very unattractive	0.00%	0
2	Unattractive	8.82%	3
3	Neutral	14.71%	5
4	Somewhat attractive	44.12%	15
5	Very Attractive	32.35%	11
	Total	100%	34

Q27 - What category would this concept be placed?

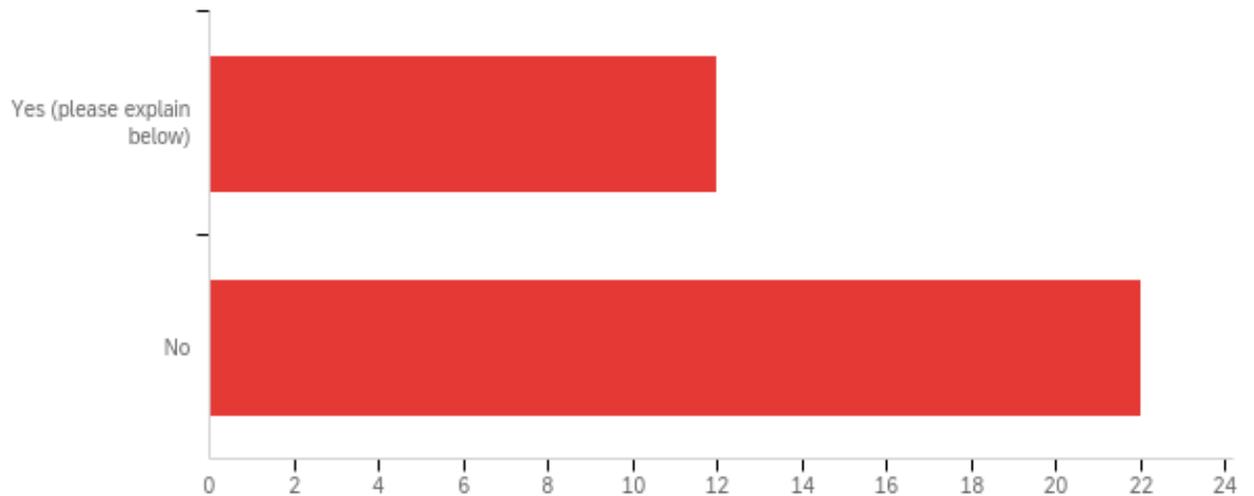


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What category would this concept be placed? - Selected Choice	1.00	3.00	2.65	0.72	0.52	34

#	Answer	%	Count
1	Personal Goods	14.71%	5
2	Sports equipment	5.88%	2
3	Medical equipment	79.41%	27
4	Fashion	0.00%	0
5	Other (please explain below)	0.00%	0
	Total	100%	34

Other (please explain below)

Q24 - Is there anything you would change, and if so, why?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Is there anything you would change, and if so, why? - Selected Choice	1.00	2.00	1.65	0.48	0.23	34

#	Answer	%	Count
1	Yes (please explain below)	35.29%	12
2	No	64.71%	22
	Total	100%	34

Yes (please explain below)

People's mindset

It looks to be more comfortable than "crunches", especially the under arm discomfort. I would be concerned about the needed arm strength for proper functionality.

The band around the upper arm should be breathable & flexible/stretchy if possible

Very nice

I prefer the first model, but this one may be more functional and similar to current crutches (user may learn to use it faster, but it is traditional). The first model blending in to the environment better.

Looking at the image it looks rather restrictive for your hands/arms. With a standard crutch you could stick it in your armpit and still use your arms, this looks as if it would not give the same result.

The arm wrap thing looks annoying

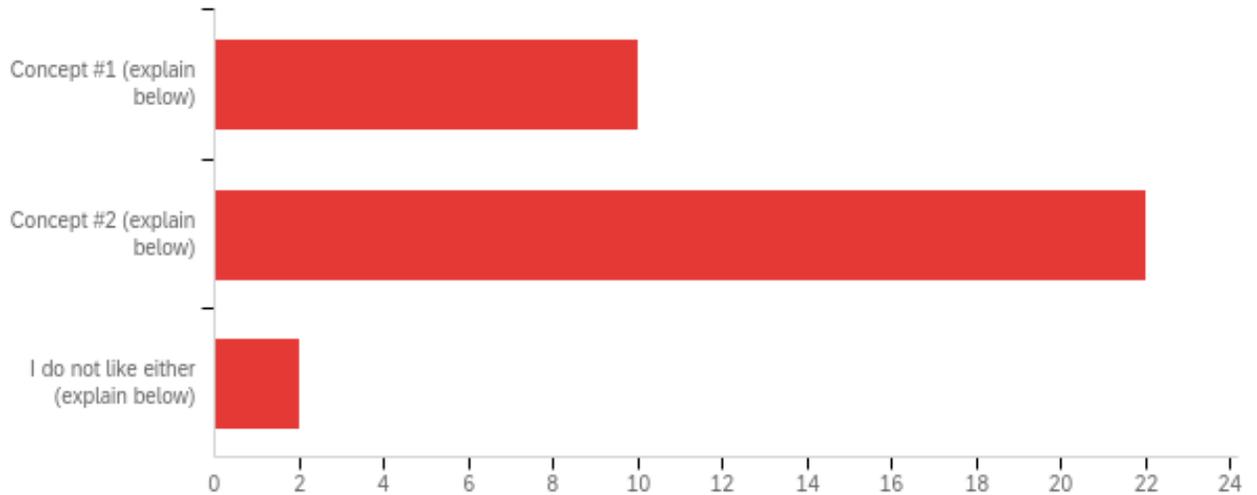
Looking good. Angle of the grip?

Where it wraps around the arm, it would be nice to have a leather pouch with a zipper for credit cards or something. Even something to put your favorite hockey team logo on so share your pride.

Should the arm part wrap around that much?

Make them lighter

Q12 - Out of these concepts, which would you rather select and why?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Out of these concepts, which would you rather select and why? - Selected Choice	1.00	3.00	1.76	0.55	0.30	34

#	Answer	%	Count
1	Concept #1 (explain below)	29.41%	10
2	Concept #2 (explain below)	64.71%	22
3	I do not like either (explain below)	5.88%	2
	Total	100%	34

Concept A

This, I wish they understand

Hands free

If this truly supports and is an easy "grab/go" I would choose this due to the arm freedom concept.

Wheels seem more stable for someone who is struggling to ambulate. They both seem like good ideas but this one seemed more user-friendly.

Less upper body requirements

I would prefer choosing concept 1 if it took the same load off as the second model, and provided the same level of comfort. But I prefer the curves on concept two better.

Seems less restrictive to upper body movement

Appears to offer less disruptive fit/adjustment to various body forms. Lesser impact to clothing.

looks easier

I like this one. I feel like it will take the pressure off of your arms

Concept B

I think these look less strange, as they're just sleeker, newer looking crutches. The other hands free remind me of Forrest Gump in leg braces

Looks better

This design appears more familiar to individuals requiring mobility assistance. The arm attachments help move the legs forward.

This is more of a traditional crutch melded with a more athletic style feel

More practical and would seem more supportive bio mechanically

Looks stable

Very stylish and chic, looks like something I would happily use

Looks less bulky and slick than #1.

Better looking

Allows sufficient support

Look practicable and effective and efficient

Seems a bit more feasible, although hard on the hands. No back up loading/support option like the armpits pads on existing crutches. Both concepts are interesting, testing and prototyping will tell a better story of which to choose.

Seems more secure like I am more in control

It's more similar to the current style of crutch. It seems to be a style that can be easily accept by society today. more

Looks more stable and supportive

I think the design is a little more neutral and would appeal to a broader scope of people

Attractive, looks like it could work, fashionable

Concept 2. Easy to understand. Seems like an ergonomic approach to an existing model

Looks like all the support in concept one is in the crotch and chaffing would be a b**ch.

This concept looks more stable. I would feel more comfortable using this design vs. the first concept.

a lot more appealing and the individual in concept one looks like they are a superhuman of some sort. or wearing detached, assless chaps.