JOINT DISLOCATION MANAGEMENT: PROMOTING INCLUSIVITY TO ENHANCE MEDICAL TRAINING DEVICES

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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DEVELOPMENT OF A JOINT REDUCTION TRAINER FOR DISLOCATION MANAGEMENT AND AN EXAMINATION OF STAKEHOLDERS

Broadly, the U.S. has among the highest number of hospitalizations from preventable causes and the highest rate of avoidable deaths, spending twice as much on healthcare compared to peer nations (Tikkanen & Abrams, 2020). The greater use of medical technology, and their associated prices, have contributed to disparities in the U.S. patient care that negatively affect rural and low-income groups (Tikkanen & Abrams, 2020; Douthit, 2015; Claxon, et al., 2022). This has grown difficult to ignore by medical professionals, many are leaving their jobs due to the injustices of medical care becoming more evident following the COVID-19 pandemic (Reinhart, 2023). Among preventable hospitalizations are joint dislocations, in which a medical professional's first time performing the treatment is typically on patients, increasing the likelihood of complications (Luna Labs, 2020). A model that mimics a dislocated joint will be produced to allow medical professionals, and most recently qualified athletic trainers, to practice the reduction technique, although the model has the potential to cause harm through inaccurate training that could affect many patients (Luna Labs, 2020). The decreasing availability of medical professionals, athletic trainers becoming newly qualified in performing the procedure, and ongoing healthcare disparities raise concerns for the trainer's implementation. It will be important to carefully analyze key decisions that are involved in the model's development, in order to produce a device that is sound to individual groups' needs (Johnson, D. M., 2005).

The STS paper seeks to characterize the nature of medical orthopedic training technology in the U.S. particularly concerning the new inclusion of athletic trainers for treatment, and preexisting differences among rural and low-income groups. It investigates the mandatory relationships and associated negotiations that are critical for development through the lens of the social construction of technology (SCOT) framework, pioneered by Trevor Pinch and Wiebe Bijker (Bijker & Pinch, 1984). SCOT emphasizes the device's interpretive flexibility, providing insight into more efficient ways of providing a more sustainable device for newly included users, and revealing social patterns and possible avenues for an investigation of a course of action for future medical devices (Johnson, D. M., 2005). The design thinking method, while augmenting human factor engineering (HFE), can provide a promising and comparable avenue to SCOT for implementation among the design process for medical devices, keeping a clear user focus throughout development, promoting usability to ensure the device can be used by many groups once implemented (Saidi et al., 2019). This analysis is relevant to any medical training technology regarding orthopedics, such as the technical project.

The technical project seeks to develop a realistic, hands-on model of an elbow joint, the joint reduction trainer (JRT), that allows the user to practice performing the dislocation reduction technique an unlimited number of times, prior to treating a patient (Luna Labs, 2020). Medical professionals typically perform a dislocation relocation for the first time on a patient, increasing the risk of complications from error or hesitancy (Luna Labs, 2020). There is a sense of urgency when performing treatment, as fast and prompt reduction contributes to healthier outcomes (Wright et al., 2020). The trainer has the potential to alleviate this issue, and promote a safer and reliable way to treat patients with dislocations, and avoid essentially training on them.

Linking the STS paper and the technical research reveals an outside perspective of the relationships within the JRT's development that play a critical role in the shaping of the technology. The analysis of the sociotechnical nature of medical devices reveals potential focuses for future development, demanding further research and implementation of protocol to ensure the societal aspects are sound, rather than just the technical, as SCOT promotes the idea that "Technology shapes society and society shapes technology," co creating one another (Johnson, D. M., 2005, p. 1792). A majority of the design and evaluation of the trainer is based on feedback, reflecting that society plays a vital role in the device's construction. Although the trainer has the potential to alleviate many issues and pre-existing disparities, an inaccurate training model can pose harmful consequences for various groups.

LIMITED PREVENTABLE MEASURES AMONG U.S MEDICAL TREATMENT

The U.S. contributes twice as much toward healthcare compared to the average spent in 36 high-income countries, contributing to high priced healthcare, and high rates of preventable disorders and deaths (Tikkanen & Abrams, 2020). High priced medical technologies cause many users to avoid its use due to financial strains and become left out of distribution (Tikkanen & Abrams, 2020). Injustice issues have grown difficult to ignore by medical professionals; following the start of the COVID-19 pandemic, many doctors are leaving, as they are no longer able to only emphasize their focus on personal responsibilities or rationalize the disparities in deaths from underinvestment and uneven distributions of medical infrastructure (Reinhart, 2023). It is essential to recognize rural and low-income groups in the U.S. economic-based medical system when implementing medical devices, as their needs are often ignored, which could lead to asymmetrical benefits from their implementation. Focusing on groups that are often rejected would help form a more inclusive technology that would reduce harm, and grant aid to those already receiving inadequate healthcare.

Preventable measures are limited for joint dislocations, which occur when the ends of bones are forced from their normal positions, deforming and immobilizing the joint, giving the recipient intense pain, numbness in the joint, and limited ability to move (Mayo, 2022; Wright et al., 2020). Joint dislocations account for 3.6% of ER visits for U.S. sports-related injuries only, not accounting for falls or auto accidents (Meixner & Loder, 2019; Mayo, 2022). The treatment is typically performed by a medical professional for the first time on a live patient, reflecting the clinician's lack of mastering the technique, leading to ultimately training patients (Luna Labs, 2020). The typical nonsurgical treatment for a dislocation involves physically "reducing the gap" between the ends of bone, through a closed reduction procedure, by applying various forces and ranges of motions on the patient for stabilization of the joint (What is, 2019; Yu, n.d., para. 1). Performing the technique for the first time on a live patient is likely to create unreliable outcomes, increasing the likelihood of complications from error in technique, hesitancy, or nervousness (Luna Labs, 2020). An inaccurate reduction procedure can lead to further damage to the soft tissue, nerves, blood vessels, and cause new fractures and the promotion blood clots (Wright et al., 2020; DeBerardino, 2022). This is important to address, as doctor burnout has increased and more are leaving, and for the few remaining doctors, with more patients, it will be of the utmost importance to keep skills up to date (Reinhart, 2023). It is essential for professionals to be an expert in the technique, as prompt reduction has led to more successful relocation rates, and less complications, improving patient outcome.

RURAL AND LOW-INCOME HEALTHCARE DISPARITIES

Pre-existing healthcare disparities among rural and low-income groups only exacerbate the risks of the complications from joint dislocations, and need to be addressed in medical device development to avoid adding to the strain. Limiting disproportionality in patient care should be a priority, as positive projections for the medical system are not predicted to get any better (Reinhart, 2023). Significant differences are evident in rural areas compared to their urban counterparts, as financial challenges, scarcity of services, a lack of trained physicians, and insufficient public transport, all negatively contribute to the residents' health (Douthit, N., 2015). Prompt examination for treating dislocations is more difficult to obtain in rural areas; a study stated that there have been more hospital closures than hospital openings in the US and about two-thirds of them have been in rural areas since 2011 (Kannarkat, J.T., 2022). When prompt reduction is not received, the likelihood of complications increases, requiring an orthopedic specialist (Fu et al., 2013). Figure 1 reflects a significant difference between the number of orthopedic specialists available per 100,000 people compared to urban areas, displaying a significant difference (Fu et al., 2013).

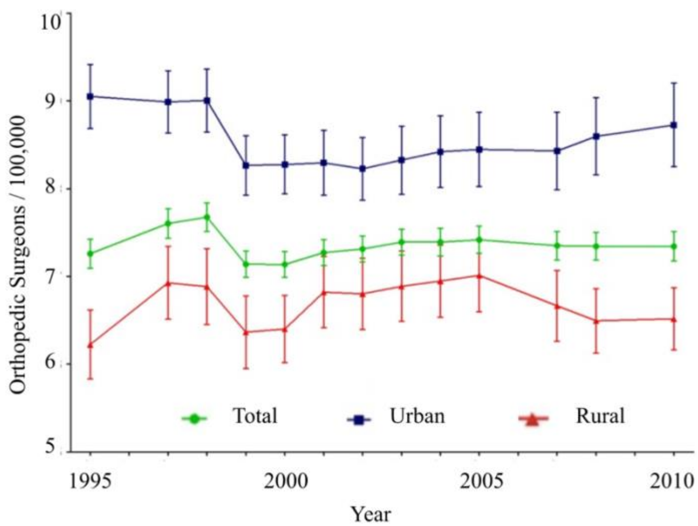

Figure 1: Orthopedic Surgeons in Rural vs. Urban Areas in 1995 - 2010. The graph shows the orthopedic surgeon density per 100,000 patients, producing significant discrepancies between urban and rural with rural having fewer surgeons (Fu et al. 2013).

Over 20 million rural Americans live in areas that have a provider-to-patient ratio of 1 to 3,500 or less, in which it is recommended to have a ratio of one primary care physician to every 2,000 individuals (Health, 2019). Thus, rural areas have a lack of needed specialists causing these groups to depend on more generalized physicians, such as primary care physicians. Limited specialists make it more difficult for these groups to get specialized care; this, along with far drives to hospitals, contributes to these residents' poorer health, increased risk of complications, and higher costs (Douthit, N., 2015).

Low-income groups spend a significantly higher share of their income on healthcare compared to higher-income groups (Claxton et al., 2022). Figure 2 shows the difference in expenditure of groups below and above the Federal Poverty Level; in 2020, for a family of four the poverty threshold was $26,200 (Claxton et al., 2022).

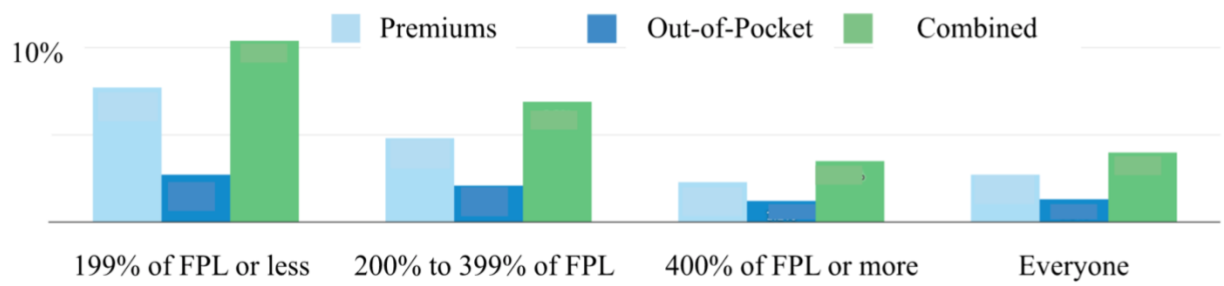

Figure 2: Average Share of Family Income Toward Health Costs at Various Poverty Levels in 2020. This shows an analysis of the Current Population Survey to observe the share of family income people with employer-based coverage pay toward their premiums and out-of-pocket costs, limited to non-elderly people living with one or more family members who are full-time workers and have employer-based coverage. It shows a downward trend as incomes increase, thus reflecting how low-income families spend a larger share (Claxton et al., 2022).

The lowest income group contributes the highest average share of income, thus creating severe financial strain that affects other needs, contributing to an increased risk for health complications and less access to healthcare, as these factors are interconnected and play an important role in the residents' lives (Claxton et al., 2022). The disproportionate patient care in the healthcare system is emphasized by uneven training distributions and availability in these areas, and needs to be addressed in order to limit its exacerbation, and to properly aid these groups and train their users when distribution becomes affordable.

CONCERNS WITHIN JOINT DISLOCATION MANAGEMENT

Recently in 2019, the National Athletic Trainers' Association (NATA) clarified that joint reductions are within athletic trainers' scope of practice, and provided them with clinical legal recommendations and guidelines (National Athletic Trainer's Association, 2016). This introduces a dire preventable measure that could greatly improve the functional outcomes of a dislocated joint from on-site, prompt reduction (Wright et al., 2020). However, their recent eligibility raises a concern about their ability to perform the technique responsibly, as they lack medical support, medical training, and accountability (Luna Labs, 2020). The Social Construction of Technology Framework is a "multidirectional model," that will be used to help guide the analysis of the affiliated relationships that are necessary for the development of the technical project, while recognizing the inclusion of athletic trainers in order to better satisfy their needs and increase usability (Bijker & Pinch, 1984, p. 411). The technology heavily relies on feedback from various groups for its production and overall function, and it will be necessary to gain an understanding in the sociotechnical perspective. This is especially crucial throughout the device's development to avoid negatively impacting groups that already experience disparities, or who are new to the technique and have less of a powerful opinion (Johnson, D. M., 2005). Including athletic trainers could be a crucial step in reducing complications from this injury as they are in the most optimal position to perform on-site reductions, improving the results of treatment as well as providing more availability to rural and low-income groups.

THE DEVELOPMENT OF THE JOINT REDUCTION TRAINER

In order to combat these preventable complications, Luna Labs developed a model of a glenohumeral (shoulder joint) in 2019 that imitates a shoulder dislocation, allowing users to practice the joint reduction technique an unlimited number of times, without practicing on a patient (Luna Labs, 2020). Figure 3 shows the biofidelic, table-top shoulder JRT that allows a realistic, hands-on experience, and encompasses a variety of reduction techniques, as well as efficient portability (Luna Labs, 2020).

Figure 3: Luna Lab's Shoulder Reduction Trainer. This shows an image of Luna Lab's table-top accessible, Shoulder Reduction Trainer being used in the classroom (Luna Labs, 2020).

An Elbow Joint Reduction Trainer was designed, prototyped, and tested, following similar procedures as the shoulder model. The JRT will enhance the training of medical professionals and newly certified athletic trainers in the reduction technique, specifically in terms of the elbow as it was discovered through outreach that this would be the most beneficial joint to model due to its daunting and complicated nature. Figure 4 represents an x-ray of a left posterior elbow dislocation, which is classified by the position of the radio-ulnar joint relative to the humerus (Oppenheim, 2018).

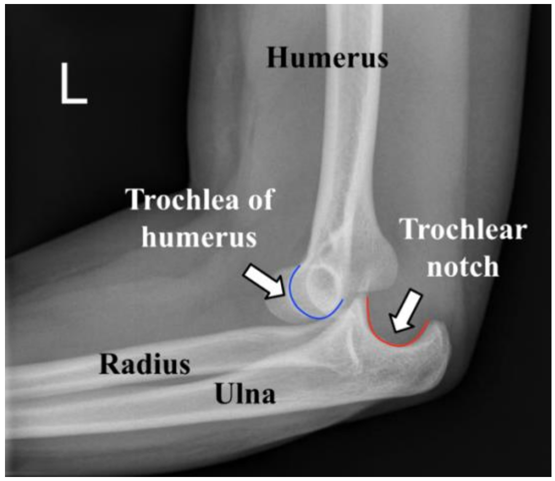

Figure 4: Posterior Elbow Dislocation. This shows an x-ray of a left posterior elbow dislocation of a 15-year-old girl following a wrestling match. The concerned bones are labeled in black and the displaced joint is labeled in white prior to reduction (Oppenheim, 2018).

The figure shows the radius and ulna displaced posteriorly with respect to the distal humerus, and the empty trochlear notch of the ulna displaced posteriorly relative to the trochlea (Oppenheim, 2018). The model of the trainer aims to mimic the behavior of an adult posterior elbow dislocation and a realistic reduction. The general process of the technical report is outlined in Figure 5, which is more detailed in the technical report.

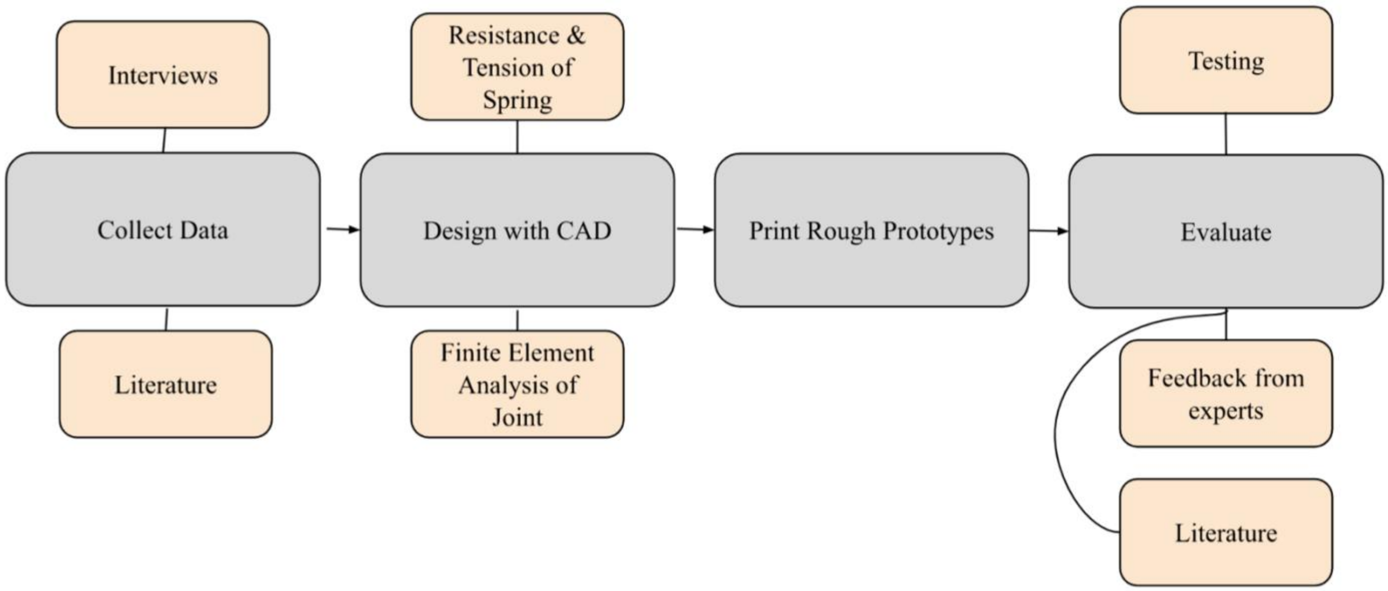

Figure 5: Joint Reduction Trainer Design Process. A visual of the progression of steps when developing a Joint Reduction Trainer (Ambrose, 2022).

Outreach is the foundation of the technical project, as it was conducted in order to gain input from medical professionals and athletic trainers. Outreach was conducted through questions involving: what dislocations are the most common in their experience, key anatomical landmarks of the joints they are the most familiar with, how they determine on-site reductions, how joint reductions are taught in their experience, if there are noticeable differences in gender, etc. The feedback was used to determine the type of trainer, general designs, and future feedback for evaluations. Thus, SCOT will best describe this relationship to aid its development as well as help understand different dynamics between groups, and ultimately a better idea of how to better portray the groups needs and successfully distribute them. This holds importance as it is necessary that the amount of force needed to reduce the simulated joint is close to physiological values, as well as proper ranges of motion for the incorporated technique to produce an accurate training model, while most of the design is based on feedback (Luna Labs, 2020).

It was noticed that only athletic trainers and medical professionals around the area who work in more well-known, high-income areas, were requested to be interviewed for feedback in the development. These included orthopedic surgeons, physicians, and athletic trainers residing at the University of Virginia (UVA), Virginia Commonwealth University (VCU), Ohio State University (OSU), Virginia Tech (VT), and UVA-Culpeper Medical. The SCOT theory acknowledges the device's interpretive flexibility, which will be important due to differences in feedback regarding techniques, patient injuries, and the overall feel of the trainer (Bijker & Pinch, 1984). It will be essential to recognize various relevant groups so they can maximize usability, and accurately learn the techniques, as athletic trainers have been recently given new medical obligations, and rural and low-income areas have reflected differences in patient care. Understanding the needs of these groups and the tradeoffs that occur between stakeholders would aid in better representing them in the development of the trainer, in turn adding value to the device and promoting usability, which will be analyzed in the SCOT model.

USING THE SOCIAL CONSTRUCTION OF TECHNOLOGY LENS TO BETTER OPTIMIZE MEDICAL TRAINING

The path to technological development is often complex, involving powerful forces at work in shaping development, adoption, use, and meanings associated with it (Johnson, D. M., 2005). The social construction of technology (SCOT) framework pioneered by Trevor Pinch and Wiebe Bijker, recognizes the visualization of these critical social negotiations between technology and science, and takes into account the device’s interpretive flexibility, having different interpretations by various groups, as well as in the design (Bijker & Pinch, 1984). Recognizing its interpretive flexibility can help bring to light conflicting technical requirements, conflicting solutions to the same problem, and moral conflicts among groups, which create an additionally different chain of solutions (Bijker & Pinch, 1984). As Bijker and Pinch (1984) suggest, technology and science co-create one another, and certain agreements have to be made for its development, and often controversy is always existent in the medical field (Bijker & Pinch, 1984). It is essential to have detailed descriptions of relevant social groups in order to better define the device's function, with respect to each group (Bijker & Pinch, 1984).

The degree of stabilization is expected to grow and diminish at varying levels throughout different social groups, making it important to recognize the social aspect for all groups impacted following production, and ensure the device consistently upholds positive standards for a specific group (Bijker & Pinch, 1984). The SCOT lens reveals which social groups have power over through the technology, opening up possibilities of change and recognition of undesirable social patterns (Bijker & Pinch, 1984). Once a device reaches stabilization, smaller changes begin to be made, often due to relevant social groups becoming convinced it fits their needs (Bijker & Pinch, 1984). It is important to address the stakeholders who are required for the trainer to exist, while understanding the sociocultural and political situations in which it is being implemented, which shape norms and values, influencing meaning to technology (Bijker & Pinch, 1984). Figure 6 shows the stakeholders: medical professionals, athletic trainers, the military, investors, regulators, and rural and low-income groups.

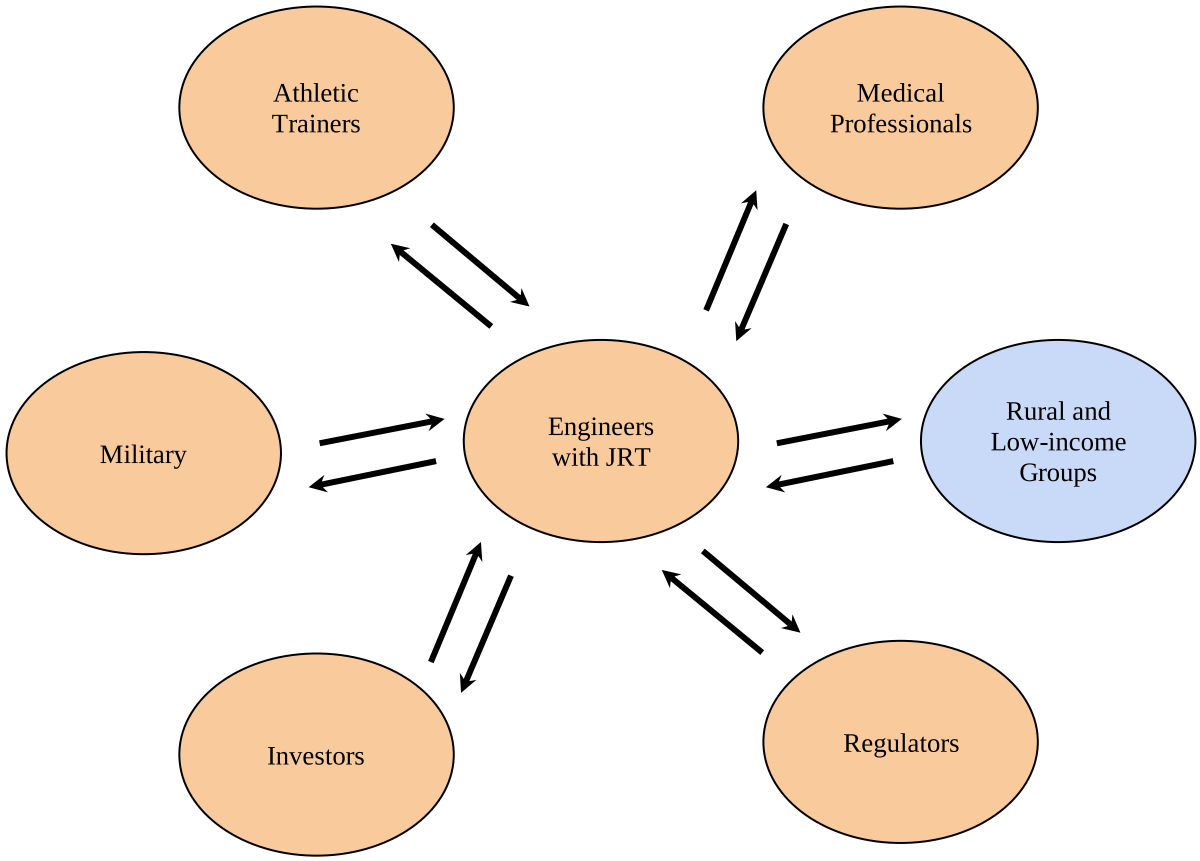

Figure 6: The Social Construction of Technology Model: Joint Reduction Trainers. This diagram represents the social construction of joint reduction trainers and their affiliated group interactions for development. The arrows represent two-way negotiations between the groups and the engineer. Rural and low-income groups of both athletic trainers and medical professionals are represented by the blue circle to be incorporated in this construction in order to limit harm and exacerbation of healthcare disparities (Adapted by Ambrose (2022) from Carlson, 2009).

The framework describes the negotiation between the technology and its affiliated groups in the orange, and the blue indicates limited access groups, which will be highlighted throughout the development process (Bijker & Pinch, 1984). “The primary point of focus of the developmental process should be the perception of problems and solutions by members of specific social groups,” instead of only considering technical functioning (Bijker & Pinch, 1984, p. 41). This is essential to recognize the different groups involved as the JRT can carry various perceptions and different needs in design from various stakeholders, as well as for disproportionate areas. It is important to separate rural and low-income groups in the model as they carry unique perspectives that are often diminished, to accurately portray their needs. The transactions between these groups and the engineer are shown by the arrows, as the groups inform the engineer about the characteristics of their needs concerning the JRT, while the engineer is providing something to each group (Bijker & Pinch, 1984).

Medical professionals are of the utmost importance in the process because their input regarding design characteristics is fundamentally necessary, and in return they expect to enhance their skills in the technique. Athletic trainers are a huge motivator since they have been recently qualified to perform joint reductions, and open up a promising window to limit preventable complications. Athletic trainers may additionally provide a differing input based on the location and the specific sport they tend to oversee. This group should be especially focused on as they have only been qualified a few years ago, and have significantly different experiences compared to medical professionals in hospitals. Both groups are an important influence during outreach when considering anatomical landmarks of the specific joint dislocation, reduction techniques, common dislocations to determine the specific type of JRT, etc. The government may additionally utilize JRTs for military purposes, as they have already done with Luna Lab's SJRT, due to the high prevalence of dislocations in military activity (Luna Labs, 2020). This group may request differences in sizes of models, due to having larger patients to assist. Investors play a necessary role as the trainer could not be adopted for hospitals, athletic departments, medical schools, or military facilities, without the interest and funds. In return, the engineer is expected to simplify the parts of the model in order to reduce these costs of production, however constraining the engineer to only focus on major interactions and their respective forces and ranges of motion. Regulators will be important in this process in order to check the accuracy of the model and its overall safety for users and their patients, as it would be harmful to teach professionals the wrong technique, and in exchange, the engineer fixes any issues regarding regulation. Regulation holds importance for change as it can promote development in certain directions and foreclose development in other directions (Johnson, D. M., 2005).

Rural and Low-Income Group Inclusion Through the Social Construction of Technology

It is proposed that medical professionals and athletic trainers from rural and low-income areas with limited healthcare access will be fully recognized in design discussions in the future in order to address their unique needs more thoroughly, in which the majority of the feedback was not diverse, as they resided in the same area were affiliated with well-known and respected colleges and hospitals. Providing this recognition has the potential to alleviate the already existing problem of limited specialists and a higher risk of complications, but enhancing the functionality of the device for these groups. For example, the engineer may need to consider more generalized doctors as stakeholders when considering outreach to these areas, rather than orthopedic specialists, in order to gain insight into their specific training needs, such as different common dislocations. There may be less interest by investors in these limited access areas, and will therefore need an increase in funding or simplified production costs to achieve this distribution. Further research should use the SCOT model for future implementations of this device to gain an understanding of how to be more inclusive toward limited access groups to avoid harm and further exacerbating disparities, as well as understanding newly established athletic trainers. The SCOT lens addresses that cultural meanings can influence the design of artifacts, and while significant differences lie between groups, this should be investigated to best promote the trainer. Medical devices in general that are heavily impacted by professional feedback need to be regulated in a sociotechnical manner in order to promote optimal patient care and better functionality of the devices implemented for all.

Design Thinking Methods in Addition to the Social Construction of Technology

As medical devices are being used more broadly by users, Saidi et al. communicates that for the safety of users, they should have sound human factors (Saidi et al., 2019). FDA considers human factor engineering (HFE) a critical component that provides guidelines and requirements for human centered design to promote compatibility, and focuses on minimizing poor design of medical devices, reducing errors, and aims to enhance and provide evidence-based practice for usability (Saidi et al., 2019). However, the researchers claim HFE has many parts, and encompassing usability could be broadly construed, and aspects such as understanding its organizational context, considering stakeholders and users, barriers of regulatory requirements, and trying to prevent the isolation of MDs from their social context need to be better understood, to improve usability to various groups (Saidi et al., 2019). Design thinking provides a similar focus as SCOT, granting an avenue that keeps a clear user focus throughout development, driven by feedback from users, involves the inclusion of multi-disciplinary teams, the principle of failing fast and often, and the consistent use and understanding of prototypes involved, while emphasizing empathy (Saidi et al., 2019).

POSITIVE SOCIETAL IMPACTS

Enhancing medical training will be important in the coming future as healthcare workers are becoming overworked and burnt out, quitting their jobs, and leaving many hospitals and clinics understaffed, and to provide better initial training (Reinhart, 2023). The trainer has the capacity to limit the practice of first-time reductions on patients, improving joint integrity and function, while reducing monetary costs from ER visits as well as psychological trauma to the patient, which would greatly aid rural and low-income groups (Wright et al., 2020). The implementation of JRTs could have the potential to help suppress these disparities by training rural physicians at a more uniform level to their urban counterparts, and providing easy portability for professionals to practice at home due to such far distances to the hospital (Lam, 2020 & Luna Labs, 2020). The JRT also has the capacity to reduce the influx of patients to hospitals as it will allow athletic trainers/primary care physicians to perform reductions on site, possibly reducing the strain on doctors in understaffed hospitals and providing cheaper medical care (Reinhart, 2023). The inclusion of athletic trainers in the technique has provided a better way to prevent further complications and reduce costs, and focusing on enhancing and distributing to ATs in limited access healthcare communities, which may need relief regarding joint dislocation management to these groups who lack accessible healthcare.

FUTURE IMPLICATIONS OF STS ANALYSIS AND MEDICAL TRAINING

The acknowledgement of the sociotechnical relationships through the STS analysis in this thesis will be important for future research to maintain positive medical contributions to society. It is important to ensure the device is usable, and be mindful of the social factors that produce the design and feedback of the trainer due to the trainer's interpretive flexibility, and its inclinations in regard to other groups who were not as involved, in which research should seek to find a more concrete implementation that enforces this recognition. The cost of the final model needs to be addressed as this is the main limiting factor according to the SCOT model and U.S. medical statistics, as athletic trainers and rural and low-income areas in general will need an avenue for funding to implement these groups. Regulators may also provide aid as they may be able to better create consistent inclusive programs that could aid rural and low-income groups. The lens of the SCOT theory should be consistently used in the future to help identify differences to better determine routes to make changes, as making slight differences in the trainer could greatly aid certain groups. It may be difficult to create completely different trainers, therefore more research is needed to fully determine the routes to provide this funding; the SCOT model would be beneficial in determining the parameters and funding of future joint reduction trainers.

I additionally propose to incorporate design thinking into the design process of the trainer, which would positively impact groups that are already being ignored, in line with the SCOT theory. It is not feasible to correctly predict the outcomes of any technology, and is thus necessary to avoid producing more problems stemming from usability and outdated human centered design practices that do not fully encapsulate the needs of the stakeholders.

The focusing on the social patterns of the stakeholders and the groups impacted by medical devices can help provide a better picture “between the wider milieu and content of technology” (Bijker, & Pinch, 1984, p. 429). Along with understanding different needs for the design of the trainer, future research should focus on proper access implementation and inclusivity measures, to enhance its value, and greatly help groups who need it the most.

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