

**THE ANALYSIS OF THE ETHICS AND ACCESSIBILITY OF MEDICAL  
TREATMENTS AND MEDICAL ROBOTICS WITHIN LOW-INCOME SOCIETIES**

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science  
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree  
Bachelor of Science, School of Engineering

Taha Shamsie  
Spring 2023

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

Advisor  
Joshua Earle, Department of Engineering and Society

***Introduction:***

In 2022, Wisconsin native, Joe Piatzo, woke up feeling completely normal, but that all changed when suddenly he lost his fine motor functions. Piatzo determined that something was wrong with his neural system. He knew he needed to go to the hospital, however the looming fear of all the costs of the procedures used within the ER began to overwhelm him. Coming to terms with his situation, he decided to go to the hospital and receive the devastating diagnosis: Brain cancer. Just a day before his surgery, he was contacted by his insurance company. They stated that, since one procedure was deemed “not necessary” in the eyes of the insurance company, they would no longer cover him for the given procedures and treatments (Levey et al., 2022). This left him and his family having to deal with procedure and rehabilitation costs out of pocket. After receiving the required surgeries and treatments to remain alive, the constant costs of extensive rehabilitation and medical bills soon began to weigh down on him. Now, the house he dreamed of living in with his significant other and their five children becomes impossible to reach with fears of bankruptcy looming over their shoulder. In exchange for his life, he and his wife must pay off over \$350,000 in medical debt (Levey et al., 2022). The culprit? Healthcare and health insurance policies within the United States of America and the lack of an all-encompassing, affordable plan for all.

In the case of Susanne LeClair, after being diagnosed with breast cancer, she required numerous surgeries and treatments that seemed to be covered under her insurance (PNHP, 2019). Once she arrived at the hospital, she paid her \$300 copay and underwent surgery (PNHP, 2019). Luckily the procedure went well, and she was discharged from the hospital. However, at this same time, she began receiving invoices from the hospital and, seemingly overnight, her medical bill totaled over \$100,000 (PNHP, 2019). It was then she found out that her copay payment

through insurance only covered the cost of the hospital bed (PNHP, 2019). Being in financial hardships at the time, LeClair had to file for bankruptcy as a result of the piling debt.

Sadly, financial hardships due to medical debt happen all too often for those with and without health insurance plans in the United States due to a lack of quality, accessible, and affordable healthcare plans. In particular, this issue is affecting those in low-income regions due to the greater lack of accessible and affordable healthcare coverage for the residents. However, it is not only those requiring procedure costs, but also those requiring post-operative care that experience these issues. In most cases, those requiring post-operative care require numerous sessions requiring trained professionals for assistance. This appointment-based cost of these services is incredibly expensive and can be unrealistic to achieve given a patient's socioeconomic status. For example, those suffering from brain injuries who require the use of assistive medical technologies can expect to pay \$1,600 per day and a total of \$46,000 to receive the treatment they require, a large sum of money that takes countless months or even years to pay off (Brain Injury Association of America, 2003).

Given the prevalence of crippling medical costs in rehabilitation and healthcare, in this paper I focus on dissecting the root-cause and developing potential solutions to counteract these effects. I am particularly focusing on the integration of affordable medical robotics and how their production and distribution can assist patients in receiving the service they require at an affordable price. In the next section, I describe the technical backgrounds and history of medical robotics and healthcare that need to be known to allow for complete transparency and clarity throughout the paper. In the following sections, I highlight the ethical concerns that come with the implementation of medical robots and uncover the methods of how I am approaching this issue in terms of researching this topic. Finally, I discuss the overall results of my research and

provide potential solutions to the given issue based off the research conducted, ending the paper with future efforts that are to strive for.

***Methodologies:***

To investigate the wide-reaching effects of non-accessible healthcare and unjust insurance companies, I employ numerous methodologies to attain the information I hope to convey. I use personal stories to illustrate the financial challenges faced by people suffering from debt due to the treatments they have undergone. Understanding these individuals' stories allows me to develop a diverse view on the overall accessibility of these devices and how the current costs of these treatments may lead to potential financial hardships as the years progress. Given the fact that numerous corporations are profit driven in the modern era, I investigate the current costs of medically distributed rehabilitative devices. Learning of these costs allows me to gain insight into the potential biases that could arise when determining the overall pricing of the product. Through this insight, I then research potential alternatives that provide the same care for a far cheaper price, proving efficacy with a reduced price. Also, I look into current policies pertaining to medical services within the United States, allowing me to determine whether there is an internal issue on the governmental level that may potentially lead to a division in fair access between people. Finally, I research potential alternatives to some rehabilitative facilities, allowing for alternative options for those requiring care to come to light for implementation.

I use the social construction of technology (SCOT) framework to understand this information. This is done through analyzing a low-income society and their need for developing affordable medically rehabilitative solutions. For example, when analyzing rehabilitative facilities, one finds that they may serve different purposes for different social groups. This can be seen through the fact that a gym, for example, can serve as a ground for working out but also as a

facility where one can receive rehabilitation from an injury. This is an example of how interpretive flexibility is exercised within my research and society itself. Through having different uses within one facility, this flexibility may offer an accepted solution, closure, within the community.

***Background on Healthcare:***

It is important to understand how the United States medical system works and how citizens can receive medical assistance. The United States utilizes a “mixed system” of healthcare in which there is a public option through government financed Medicare and Medicaid and numerous private options of health insurance which are typically offered through the citizens employment at a given rate (ISPOR, n.d.).

Medicare and Medicaid are two separate public options of health insurance that target specific demographics. Medicare is a federally covered program that provides those above the age of 65 or those suffering from disabilities with medical assistance, no matter the income, whereas Medicaid is a program through both state and government where you are offered health coverage if your income is “very low” (Medicare Interactive, 2022). Although Medicare and Medicaid seem to be fair and accessible, the requirements are strict, especially for Medicaid, meaning that many individuals in low-income regions will remain uninsured and at risk of medical debt. The implementation of Medicaid does not fully assist those encompassed within the plan as well, leaving countless individuals with thousands in medical debt from post-visit and monthly premium payments to uphold.

Most private healthcare options are offered through an individual’s employer given the employee makes higher wages within specific industries (U.S. Bureau of Labor Statistics, 2020). These insurance options often have high monthly premiums that must be paid in order to be

enrolled within the plan. Through employment benefits, these plans are generally affordable given the income of the employee. However, it is important to note that there is no federal law requiring companies to offer health insurance to their employees. This issue is particularly exasperating for low-wage workers. According to the U.S. Bureau of Labor Statistics in 2019, out of the employees in the lowest 25 percent of wage earners for private companies, only 36% were offered employer-sponsored medical plans (U.S. Bureau of Labor Statistics, 2020). In contrast, out of those in the next level of wages, the second 25 percent of wage earners, 70% were offered employee-sponsored medical plans (U.S. Bureau of Labor Statistics, 2022). This leaves millions without even an option of medical assistance and, even if the employee is offered health insurance through their employer, countless individuals reject the given offer due to highly expensive premiums (U.S. Bureau of Labor Statistics, 2022).

In total, when analyzing all of America all together, it is seen that the private form of insurance is the most popular amongst Americans under the age of 65, with 63.2% of them electing to use this form of insurance (CDC, 2022). This leaves the public option of health insurance as the choice of 27.7% of Americans under the age of 65 (CDC, 2022). Finally, those who are uninsured make up roughly 11.0% of Americans under the age of 65 which leaves 29.6 million Americans across the country without any form of insurance coverage to assist with medical costs (CDC, 2022).

### ***Background on Medical Robotics:***

To understand the current rise in medical robotics, it is important to investigate the different types of robots that exist within the medical sector. There are three major facets of medical robotics that are highly sought after and developed across the globe: surgical robots,

rehabilitative robots/assistive exoskeletons, and prosthetic robotics. For my research project, I will mainly be focusing on rehabilitative robotics and their uses throughout the US.

Rehabilitative robots help patients to retain regular muscle use with hopes of mitigating pain (DO-IT, 2022). These technologies are often employed for patients who struggle with neuromuscular conditions. To assist patients in recovering lost movements, the patient attaches a robotic exoskeleton that utilizes actuation methods to achieve desired motions that would originally be impossible (DO-IT, 2022). These robotic exoskeletons are designed to assist the user in a way such that the user is able to exercise a given muscle in a way that mitigates stress and pain. Robotic exoskeletons are used in roles that require heavy lifting, such as construction or packaging, where users can employ wearable exoskeletons that allow for fluid motions and mitigated stress when lifting heavy objects.

### ***History of Medical Robotics:***

Medical robotics has been an emerging field of research that has enamored scientists and engineers for years. The first conception of robotic manipulators came to the public's attention in 1958 when General Motors developed a robotic arm to assist in automotive production (Hockstein et al., 2007). These robots allowed for precise picking and placement of heavy items. Seeing the potential usefulness of robotic manipulators for medical applications, many began to experiment with applying this technology to medical surgeries. This experimentation continued until 1985, when the first surgical robot was employed during a brain biopsy (Hockstein et al., 2007). This practice soon began to spread globally, with new inventions being developed in nearly each decade with the purpose of assisting doctors with surgical practices. Although these robots were initially used for surgical purposes, new developments within the field allowed for an expansion of robotic uses for patient assistance and rehabilitation. This was brought about in

1994 with the development of MIT-MANUS, a neurorehabilitative robot that helps patients to train upper limb movements for neuromuscular patients (Gassert et al., 2018). With the onset of these changes, the field has only grown since then with numerous, privately owned companies now developing and releasing diverse medically assistive robotics.

Medical robots can be incredibly expensive. In the case of surgical robots, hospitals can expect to spend around \$1,000,000 on average, with higher end robots costing upwards of \$2,000,000 (Smith et al., 2019). Along with the costs of these robots, hospitals must spend around \$900 on each tool that is to be equipped onto the robot. In terms of rehabilitative medical robots and wearable assistive exoskeletons, patients can expect to make a one-time payment of \$20,000 - \$80,000 depending on the model (Cost Charts, 2017). In some cases, there may even be a monthly charge for those renting one of these machines. For example, in the case of Honda's Walking Assistant, patients can expect to spend up to \$375 a month (Cost Chart, 2017). Because of these prices, rehabilitative devices can exacerbate a patient's medical debt. It is this fear of debt and payments that historically leaves these devices out of reach for those in lower-income regions.

### ***Ethical Questions Behind Rehabilitative Robots:***

The question of ethicality is a reoccurring issue that these rehabilitative exoskeletons and robots are exposed to. Is it ethical to allow these machines to become an extension of ourselves? Is it ethical to allow these machines to control our movements? Should these devices be employed on children? These are all major questions that have come up throughout the development and testing of rehabilitative robots. Within this section, I hope to highlight the major ethical questions while responding with responses to the questions, proving ethicality of the topic.



In the article *Roboethics - Making Sense of Ethical Conundrums*, Majeed dives into the ethical issues of using rehabilitative robotics on children (Majeed, 2017). This issue derives from the fact that in many cases, these rehabilitative robots may take control over an aspect of one's body. This makes it difficult to tell whether it would be ethical to allow children, a group viewed as being vulnerable, to use these devices. Majeed argues that by considering the ethical principles that come with the use of rehabilitative robotics on children and applying them to medical practice, these robots should be considered acceptable (Majeed, 2017). It is important to fully understand that these devices must be ethical and applicable to all, regardless of race, age, disability, or class. Allowing these devices to be used on children bridges this gap of age disparities, allowing for all to truly have access to these assistive devices.

Another ethical dilemma revolves around a robot's ability to accurately assist a patient in receiving the care they require for full rehabilitation. Is it truly okay to trust a robot to oversee a human's body and treatment? In the article *Roboethics in Remote Human Interactions and Rehabilitative Therapeutics*, Maddahi and coauthors address this exact issue. Maddahi and coauthors argue that these technologies would only be considered ethical if given parameters are met. These parameters include: ensuring that the treatment program by the robot is approved by healthcare professionals, that the treatment is consistent and reliable, and ensuring that the skills of the robot will not act to the detriment of a patient's health (Maddahi et al., 2022). In order to verify that the rehabilitative robot meets all of them given parameters, Maddahi et al. suggests that scientists and engineers should test the abilities of the robot against that of current medical practices, ensuring that the robot is performing up to standard (Maddahi et al., 2022). Through these criteria, I believe that these robotic exoskeleton and treatment plans are ethical within the scope of human use. If it is ensured that the quality and safety of treatment is equal or greater

than that of standard care practices, then there should be no ethical issues that come into play when these products are in use.

***Results and Analysis:***

From analyzing stories, such as Joe Pitzo's or Susanne LeClair as discussed earlier, the access and costs of healthcare seem to cripple those who are both insured and uninsured. For Joe Pitzo, although he was insured, his network did not cover essential procedures that were required for him to preserve his life. As a result of this broken system, he is stuck with paying these astronomical costs, forcing him to give up a potential house for him and his family (Levey et al., 2022). Another effect of these crippling medical debts can be manifested as an instantaneous large drop in credit (Levey et al., 2022). With low credit, options become limited with receiving loans to assist with payments, forcing patients to struggle by themselves. With the current systems in place, Joe was essentially bullied out of an ideal life with his wife and children, instilling worries of prolonged retirement and homelessness while leaving him in hundreds of thousands of dollars in debt. This is also reflected in Susanne LeClair as well. Susanne had insurance as well, but was still failed by the system, leaving her in so much debt given her income that she was forced to file for bankruptcy (PNHP, 2019). These stories are just two of millions who are negatively affected by the healthcare system present in America.

Investigating the need for healthcare policy change within the United States it becomes apparent that healthcare policies regarding low-income residents needs to be addressed and reworked. In the article *Access to health insurance, barriers to care, and service use among adults with disabilities*, Sommers examines the accessibility of health insurance and medical services for those with disabilities, uncovering gaps in access to rehabilitative programs. Sommers argues that it is not those with disabilities that lack access to healthcare and rehabilitative services, but

those in low-income communities that do, pushing for more policy attention to mitigate this issue. According to Sommers, out of the low-income individuals struggling with healthcare finances, over one third of the individuals were uninsured (Sommers, 2006). This point is furthered through the analysis of Bright and collaborators' article *A Systematic Review of Access to Rehabilitation for People with Disabilities in Low- and Middle-Income Countries*. The authors of this piece investigate the accessibility of rehabilitation for those with disabilities from varying socioeconomic backgrounds. Bright and coauthors argue that uninsured patients with physical disabilities generally have little to no access to assistive devices used for the purpose of rehabilitation (Bright et al., 2018). Policy makers should use this research to determine a cause as to how those lacking access are being discriminated against, as was done in the article, allowing for change to occur.

Given the expensive costs of implementing these rehabilitative robots within hospitals and clinics, countless patients experience higher costs in care. However, many have begun developing low-cost systems, allowing for patients of all socioeconomic backgrounds to have access to the given medical treatments. In their article *Budget Impact Analysis of Robotic Exoskeleton use for Locomotor Training Following Spinal Cord Injury in Four SCI Model Systems*, Pinto and coauthors investigate the current budget of hospital spending's on rehabilitative technologies dealing with spinal cord injuries. Pinto and collaborators argue that by implementing low-cost robotic exoskeletons into hospitals' rehabilitative technologies, hospitals would be able to mitigate costs on expensive machines while maintaining the effectiveness of the treatment plan (Pinto et al., 2020). In fact, multiple examples of these low-cost rehabilitative technologies have been developed already by those researching these issues. For example, Slucock found low-cost actuation methods that would allow for efficient lower-limb assistance

(Slucock, 2022). Slucock ultimately discovers a low-cost design that would allow for mitigation of gait increase in the knees at a non-serious financial investment, allowing those within lower-income treatments to receive care/assistance for their rehabilitation. This concept is further investigated by Ullas and collaborators in which they were able to develop a design for a low-cost lower limb assistive technology that allowed for the maintaining of the adjustability and modularity of the given design (Ullas et al., 2021). These examples of successful developments prove that there are methods to develop and distribute these rehabilitative technologies at a low financial investment. Through further investment into these studies, many in low-income regions will then be able to receive affordable care, even if uninsured.

Due to the high costs of machine-assisted rehabilitation, investigations regarding alternatives have begun across the world. In the article *Low-Cost Gymnasium for Robotic Rehabilitation of Stroke Survivors*, Bustamante and coauthors explore a new method of receiving treatments for rehabilitative care that has been developed in a developing country (Bustamante et al., 2017). In this case, Bustamante and collaborators investigate a rehabilitative robotic gym in Mexico known as the RoboRehab Gym in which low-income citizens are able to afford low-cost treatments using communal robotic devices for stroke rehabilitation (Bustamante et al., 2017). Through this study, Bustamante et al. discovered that the gym fostered an enhanced sense of stimulation to the targeted injury and also led to a greater compliance of a given treatment overall (Bustamante et al., 2017). Another example of a low-cost alternative to certain treatment plans can be seen through the research done by Gaardsmoe and coauthors. Gaardsmoe and collaborators prioritized the development of a more cost-effective method of treatment and assessment for those suffering from strokes. In this case, Gaardsmoe and coauthors were able to determine a new design for a force balance board that is able to prevent patients from being

susceptible to injurious falls (Gaardsmoe et al., 2020). In the end, Gaardsmoe and collaborators were able to develop a system of utilizing low-cost force balance boards in low-cost rehabilitation gyms with significant results (Gaardsmoe et al., 2022). Through their research, they were able to develop the system in a cost-effective manner, reducing costs from \$10,000 to just \$500 (Gaardsmoe et al., 2022). These drastic changes in prices allow for those in financial hardships to realistically access these rehabilitative technologies.

***Potential Solutions:***

As discussed above, there were numerous methods to mitigate the gap in accessible medical treatments for those in lower-income regions.

Health care policy should focus most on those in lower-income regions. This is reinforced by the fact that the majority of individuals within these regions are uninsured or are offered weak healthcare options, allowing for disproportionate access to treatments (Bright et al., 2018). The fact that over one third of those in low-income regions are uninsured is worrying, allowing for policy makers to make strong impacts within their societies (Sommers, 2006).

Another suggestion that I would make is to continue with developing low-cost alternatives to rehabilitative robotic devices and allow them to be commercially available. As seen in countless research studies, low-cost alternatives are producible, allowing for comparable treatment efficacy to their more expensive counterparts (Slucock, 2022). By making these developments commercially available, it allows for all, regardless of gender, race, and socioeconomic status, to have access to medical care.

Finally, I would suggest potentially setting up low-cost robotic gyms that specialize in rehabilitative services. Seeing the success of these given ideas in developing countries, such as Mexico, provides a strong basis for implementation here in the US and elsewhere. As seen in

Mexico, severe stroke patients were not only able to retain high levels of stimulation in muscular activity but were more inclined to remain compliant with given treatment regimens (Bustamante et al, 2017). By implementing these gyms within low-income regions across the country, I believe that those residing within these areas would be more open to accepting medical care.

***Conclusion:***

Based off the presented data and analysis that were proposed within my research topic, I believe there exists a great divide in access to proper medical care and robotic rehabilitation between low-income regions and higher income regions of the United States. This divide is seen to be propagated by poor, expensive healthcare options and policies that are present in the country today. However, through the implementation of ethical, low-cost alternatives and policy change, I believe that we will be able to bridge this gap in access, allowing for all to have equal opportunities of receiving the care they need.

**Bibliography:**

*A brief history: Universal health care efforts in the US.* PNHP. (2021, May 3). Retrieved from

<https://pnhp.org/a-brief-history-universal-health-care-efforts-in-the-us/>

Bright, T., Wallace, S., & Kuper, H. (2018). A systematic review of access to rehabilitation for people with disabilities in low- and middle-income countries. *International Journal of Environmental Research and Public Health*, 15(10).

<https://doi.org/10.3390/ijerph15102165>

Bustamante, K. D., & Johnson, M. J. (2012). Low cost gymnasium for robotic rehabilitation of stroke survivors. *7th International Conference on Appropriate Healthcare Technologies for Developing Countries*. <https://doi.org/10.1049/cp.2012.1458>

Centers for Disease Control and Prevention. (2022, October 27). *FASTSTATS - disabilities or limitations*. Centers for Disease Control and Prevention. Retrieved November 30, 2022, from <https://www.cdc.gov/nchs/fastats/disability.htm>

Centers for Disease Control and Prevention. (2022, September 6). *FastStats - health insurance coverage*. Centers for Disease Control and Prevention. Retrieved December 1, 2022, from <https://www.cdc.gov/nchs/fastats/health-insurance.htm>

*Differences between Medicare and Medicaid*. Medicare Interactive. (2022, August 1). Retrieved from <https://www.medicareinteractive.org/get-answers/medicare-basics/medicare-coverage-overview/differences-between-medicare-and-medicaid>

- Gaardsmoe, S., Ovando, M., Bui, K., & Johnson, M. J. (2020). Development of a low-cost balance assessment system for use in an affordable robot gym in low and middle income countries. *2020 IEEE 11th Latin American Symposium on Circuits & Systems (LASCAS)*. <https://doi.org/10.1109/lascas45839.2020.9069007>
- Garcia-Gonzalez, A., Fuentes-Aguilar, R. Q., Salgado, I., & Chairez, I. (2022). A review on the application of autonomous and intelligent robotic devices in medical rehabilitation. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, *44*(9). <https://doi.org/10.1007/s40430-022-03692-8>
- Gassert, R., & Dietz, V. (2018). Rehabilitation robots for the treatment of sensorimotor deficits: A neurophysiological perspective. *Journal of NeuroEngineering and Rehabilitation*, *15*(1). <https://doi.org/10.1186/s12984-018-0383-x>
- Hockstein, N. G., Gourin, C. G., Faust, R. A., & Terris, D. J. (2007). A history of robots: From science fiction to Surgical Robotics. *Journal of Robotic Surgery*, *1*(2), 113–118. <https://doi.org/10.1007/s11701-007-0021-2>
- How much does an exoskeleton cost?* Cost Charts. (2017, May 3). Retrieved from <https://costcharts.com/exoskeleton/>
- 'I live on the street now': How americans fall into medical bankruptcy.* PNHP. (2019, November 14). Retrieved from <https://pnhp.org/news/i-live-on-the-street-now-how-americans-fall-into-medical-bankruptcy/>



*Inpatient acute rehabilitation hospital bills and costs.* Brain Injury Association of America.

(2003). Retrieved from <https://www.biausa.org/professionals/research/tbi-model-systems/inpatient-acute-rehabilitation-hospital-bills-and-costs>

*Introduction - access to health care in America - NCBI Bookshelf.* (n.d.). Retrieved from

<https://www.ncbi.nlm.nih.gov/books/NBK235885/>

Johnson, M. J., Rai, R., Barathi, S., Mendonca, R., & Bustamante-Valles, K. (2017). Affordable

stroke therapy in high-, low- and middle-income countries: From Theradrive to rehab cares, a Compact Robot Gym. *Journal of Rehabilitation and Assistive Technologies Engineering*, 4. <https://doi.org/10.1177/2055668317708732>

Levey, N., Pattani, A., Noguchi, Y., & Sable-Smith, B. (2022, December 21). *Medical debt*

*upended their lives. here's what it took from them.* NPR. Retrieved from

<https://www.npr.org/sections/health-shots/2022/06/16/1104969627/medical-debt-upended-their-lives-heres-what-it-took-from-them>

*Listening to low-income patients: Obstacles to the care we need, when we need it.* Obstacles for

low-income patients. (2017, December 1). Retrieved from

<https://www.commonwealthfund.org/blog/2017/listening-low-income-patients-obstacles-care-we-need-when-we-need-it>

Maddahi, A., Leach, T. R., Saeedi, M., Dhannapuneni, P. R., Maddahi, Y., Choukou, M.-A., &

Zareinia, K. (2022). Roboethics in remote human interactions and Rehabilitative

Therapeutics. *Applied Sciences*, 12(12), 6033. <https://doi.org/10.3390/app12126033>

- Majeed, A. B. A. (2017). Roboethics - making sense of ethical conundrums. *Procedia Computer Science, 105*, 310–315. <https://doi.org/10.1016/j.procs.2017.01.227>
- Pinto, D., Garnier, M., Barbas, J., Chang, S.-H., Charlifue, S., Field-Fote, E., Furbish, C., Tefertiller, C., Mummidisetty, C. K., Taylor, H., Jayaraman, A., & Heinemann, A. W. (2020). Budget impact analysis of robotic exoskeleton use for locomotor training following spinal cord injury in four SCI Model Systems. *Journal of NeuroEngineering and Rehabilitation, 17*(1). <https://doi.org/10.1186/s12984-019-0639-0>
- Robert S. Kaplan and Michael E. Porter. (2015, November 24). *How not to cut health care costs*. Harvard Business Review. Retrieved from <https://hbr.org/2014/11/how-not-to-cut-health-care-costs>
- Slucock, T. (2022). A systematic review of low-cost actuator implementations for lower-limb exoskeletons: A technical and financial perspective. *Journal of Intelligent & Robotic Systems, 106*(1). <https://doi.org/10.1007/s10846-022-01695-0>
- Smith, E., & Chen, P. (2019, February 22). *UCLA study finds that benefits of robotic surgery outweigh costs*. Daily Bruin. Retrieved from <https://dailybruin.com/2019/02/22/ucla-study-finds-that-benefits-of-robotic-surgery-outweigh-costs>
- Sommers, A. S. (2006). Access to health insurance, barriers to care, and service use among adults with disabilities. *INQUIRY: The Journal of Health Care Organization, Provision, and Financing, 43*(4), 393–405. [https://doi.org/10.5034/inquiryjrnl\\_43.4.393](https://doi.org/10.5034/inquiryjrnl_43.4.393)

U.S. Bureau of Labor Statistics. (2020). *Lower-wage workers less likely than other workers to have medical care benefits in 2019*. U.S. Bureau of Labor Statistics. Retrieved from <https://www.bls.gov/opub/ted/2020/lower-wage-workers-less-likely-than-other-workers-to-have-medical-care-benefits-in-2019.htm>

Ullas, U., & Rajendrakumar, P. K. (2021). Design of a low-cost lower limb rehabilitation exoskeleton system. *IOP Conference Series: Materials Science and Engineering*, 1132(1). <https://doi.org/10.1088/1757-899x/1132/1/012008>

*US Healthcare System Overview-background*. ISPOR. (n.d.). Retrieved from [https://www.ispor.org/heor-resources/more-heor-resources/us-healthcare-system-overview/us-healthcare-system-overview-background-page-1#:~:text=Coverage%20Overview,health%20insurance%20plans\)%20market%20coverage](https://www.ispor.org/heor-resources/more-heor-resources/us-healthcare-system-overview/us-healthcare-system-overview-background-page-1#:~:text=Coverage%20Overview,health%20insurance%20plans)%20market%20coverage)

*What is assistive technology? What is assistive technology? | DO-IT*. (2022, May 26). Retrieved from <https://www.washington.edu/doit/what-assistive-technology>