Design of a Custom 3D-Modeled Ankle Brace

Analysis of Skin Color Representatives in Medical Textbooks and Images

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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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Introduction

Ankle injuries are the most common musculoskeletal injury in physically active populations (Al-Mohrej & Al-Kenani, 2016). In the United States alone, approximately 2 million ankle sprains occur annually, with almost half of sprains developing residual chronic disability and pain (Waterman et al., 2010). In addition, individuals with a prior ankle sprain are 3.5 times more likely to face additional sprains than those who have never sprained their ankle (Herzog et al., 2019). It is important to prevent repeat sprains that result in long-lasting effects through efficient diagnosis and treatment of initial sprains.

Many technical innovations have been developed to address chronic ankle instability (CAI), which is a long-term disability caused by ankle sprains (Al-Mohrej & Al-Kenani, 2016). Al-Mohrej and Al-Kenani (2016) suggest that primary treatments of ankle sprain and CAI include use of ankle braces. However, current ankle brace technologies do not integrate customizable aspects that will make for a more effective treatment of the unique characteristics of different forms and severities of CAI. To address the downfalls of current ankle orthotics, I will propose a custom 3D-modeled ankle brace that allows for multi-axial control and dynamic tensioning and stability.

In addition to effective treatment, efficient and accurate diagnosis of ankle sprains is an important factor of maintaining ankle health. To identify the underlying issues of racial disparity in health diagnoses, I will investigate a case from Lester, Jia, Okoye, and Linos (2020) on the underrepresentation of dark skin tones in COVID-19 rash images. This will bring to light the issues of the visual content healthcare professionals are educated with that hinder their ability to effectively diagnose all patient populations.

To ensure the most ideal outcomes for those who suffer from ankle injuries, the social aspects of effective diagnosis and the technical aspects of effective treatment must both be addressed. In what follows, I will elaborate a technical project that functions to develop 3D-modeled ankle brace designs that will treat multiple forms of CAI. Furthermore, I will apply User Configuration, which investigates the role the designers and engineers of a technology have in shaping the user, to determine the ideas and biases embedded in medical images used to educate healthcare professionals that curb the successful diagnosis of injuries and diseases in patient populations (Woolgar, 1991).

Technical Project Proposal

Chronic ankle instability is defined as the failure of functional rehabilitation after an acute ankle injury and is characterized by looseness of ligaments and mechanical instability that interfere with movement and activity (Herzog et al., 2019). The current primary management practice for CAI is use of orthotic devices such as ankle braces (Al-Mohrej & Al-Kenani, 2016). The first ankle brace device for treatment of ankle sprains was developed by Glenn Walter Johnson Jr., and was patented in May 1976 (Wyatt, 1997). The design and characteristics of ankle braces have changed since the device’s original inception; however, current ankle brace designs are not customized for particular forms of CAI and user needs, are movement-restrictive, and do not provide dynamic tensioning and stability (McGovern & Martin, 2016). These design flaws can have a significant impact on the user's safety and comfortability while using the brace. Prolonged immobilization of the ankle has detrimental effects on muscles, ligaments, and joints (Petersen et al., 2013). In addition, current bracing designs lead to significantly reduced muscle

activity during use (Feger et al., 2014). Lastly, the bulky features of current braces lead to a less comfortable user experience.

This technical project aims to design and create a custom 3D-modeled ankle brace that utilizes dynamic tensioning to more effectively treat CAI. This project will be performed in conjunction with the objectives of Icarus Medical Innovations LLC., and it is their goal to manufacture our final design. Our brace design is based on two key design components. The first component is adjustable stability and tension with the use of a BOA dial, a physical component on our brace that can be manually turned to adjust the amount of tension in the wires, which allows the user to change the amount of support given by the brace to fit their specific need. The second component is multi-axial control. Our device will only constrain and support the ankle in the axis specific to the form of CAI which is being addressed, allowing the user greater range of motion than current bracing designs.

In order to accomplish our goal of creating a marketable, custom 3D-modeled ankle brace, we will execute several project design methods. Ankle brace prototypes will be developed to treat several forms of CAI. To accomplish this task, preliminary research will be conducted to determine the most prevalent forms of CAI and their pathologies relating to the ankle anatomy. The wire vectors in the ankle brace will need to be altered to support the pathologies for each form of CAI. In addition, material research will be performed in order to optimize the brace so that it can be showcased to patients and doctors. Factors that will be considered include ease of manufacturing, cost, comfort, and ease of use. Lastly, research will be performed in order to identify different testing methods for CAI in order to construct a testing protocol which accurately measures the effectiveness of our brace. This protocol will be submitted via an IRB application in order to perform testing on human subjects.

Qualitative data will be collected from survey responses, and quantitative data will be collected from an IRB-approved testing protocol. These datasets will be analyzed to improve the brace design and will make our product better for investment and marketability. In addition, our ankle braces' biomechanical functionality will be validated with an OpenSim model. We chose OpenSim as the biomechanical modeling software because it provides a variety of tools that allow for the ligament dynamics of the ankle to be analyzed (Seth et al., 2011). The intention of the aforementioned data collection and analysis is to iterate and optimize our brace design to create a functional and marketable product.

STS Project Proposal

In January 2020, the Center for Disease Control (CDC) reported the first cases of the 2019 Novel Coronavirus disease (COVID-19) in the United States ("Covid-19 Timeline", 2022). Since the outbreak, COVID-19 has resulted in over 1 million deaths in the United States. However, upon further analysis, a striking racial disparity emerges in morbidity and mortality rates. Black Americans make up about 13% of the United States population, but age-adjusted data shows this group accounts for about 34% of the COVID-19 mortality cases (Holmes et al., 2020). A specific study that may explain some of this disparity is the analysis of documentation for COVID-19-related skin changes. Early detection of COVID-19 is critical to initiate clinical care and limit the spread of the virus. Some cases of COVID-19 do not manifest with viral symptoms, but rather, as rashes on the skin and toes (Lipper, 2020). Skin color analysis of 130 clinical images of COVID-19 rashes collected from 46 articles was performed by Lester, Jia, Okoye, and Linos (2020). This was performed using the Fitzpatrick skin color scale (Figure 1). A total of 92% of images showed skin types I-III, which are classified as light to medium skin tone,

and the other 8% were of skin type IV, which is classified as olive skin tone. There were no images that depicted skin types V (brown skin tone) or VI (black or very dark brown skin tone). In addition, the articles that included race and ethnicity information reported 91% of patients to be white and the other 9% to be Hispanic (Lester et al., 2020). This specific case shows an example of a larger issue of racial disparities in healthcare.

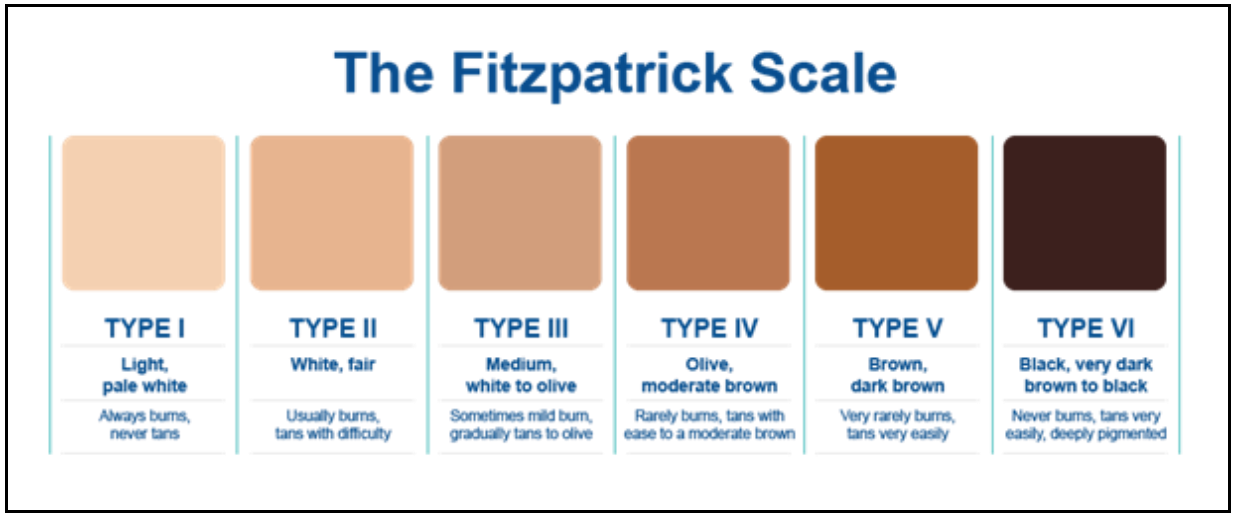

Figure 1: Visualization of the Fitzpatrick skin color scale (Sutton, 2016).

Medical images are tools that educate healthcare professionals in order to aid in the diagnosis and treatment of injuries and diseased of all populations. However, as seen in Lester et al. (2020), lack of representation of different skin tones in COVID-19 skin rash imagery indicate that the writers of these educational articles did not account for the ethnically and racially diverse populations in the United States (Kaundinya & Kundu, 2021). Examining these writers' implicit biases sheds light on the racial bias in healthcare and diagnostics caused by the underrepresentation of racial minorities in the "hidden curriculum," or the uncritical aspects of medical training, such as the visualizations of the COVID-19 rash, that impact medical practice and diagnostics (Louie & Wilkes, 2018). In fact, King and Domin (2007) suggest that groups underrepresented in medical education could experience differential diagnosis and treatment.

Drawing on the concept of User Configuration (UC), I argue that the writers of the COVID-19 skin rash articles embedded racial biases about affected populations into the design of their educational content. UC is the idea identified by sociologist Steve Woolgar (1991) that engineers and designers embed ideas, assumptions and biases about users and affected populations into the technologies they design. This imagined user is defined as the "configured user," and it results in "constrained" interactions with the technology. To support my argument, I will analyze these depictions of COVID-19 skin rashes in medical articles, interviews and testimonials of racial minorities, and epidemiology reports, which will provide information about the biases in medical education imagery and the constraints these biases cause.

Conclusion

The deliverable for the technical project proposal discussed in this paper will be multiple fully functional prototypes of ankle braces that are tailored to provide custom support for specific types of CAI. In addition to functionality, these braces will be sleek, comfortable, and manufacturable. The Science, Technology and Society (STS) project proposed will strive to gain a better understanding of racial bias in medical imaging representations, as well as the effects it has on the health outcomes of racial minorities. This will be accomplished by applying User Configuration to characterize the configured user imagined by the writers and designers of the COVID-19 skin rash articles that were used to educate health professionals to see how effective diagnosis is constrained to certain racial and ethnic groups. I hope to apply the insights of configured users, constraints, and diversity and representation in data to my technical project in order to create a device that is inclusive of all people with CAI. Effective diagnosis, as analyzed

in my STS project, and effective treatment, as proposed in my technical project, are vital in the overarching sociotechnical challenge of ankle sprain management and prevention.

Word Count: 1,713

References

Al-Mohrej, O. A., & Al-Kenani, N. S. (2016). Chronic ankle instability: Current perspectives. *Avicenna Journal of Medicine, 6*(4), 103–108. https://doi.org/10.4103/2231-0770.191446

Centers for Disease Control and Prevention. (2022, August 16). *CDC museum COVID-19 timeline*. https://www.cdc.gov/museum/timeline/covid19

Feger, M. A., Donovan, L., Hart, J. M., & Hertel, J. (2014). Effect of ankle braces on lower extremity muscle activation during functional exercises in participants with chronic ankle instability. *International Journal of Sports Physical Therapy*, *9*(4), 476–487. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4127510/

Herzog, M. M., Kerr, Z. Y., Marshall, S. W., & Wikstrom, E. A. (2019). Epidemiology of ankle sprains and chronic ankle instability. *Journal of Athletic Training*, *54*(6), 603–610. https://doi.org/10.4085/1062-6050-447-17

Holmes, L., Jr, Enwere, M., Williams, J., Ogundele, B., Chavan, P., Piccoli, T., Chinacherem, C., Comeaux, C., Pelaez, L., Okundaye, O., Stalnaker, L., Kalle, F., Deepika, K., Philipcien, G., Poleon, M., Ogungbade, G., Elmi, H., John, V., & Dabney, K. W. (2020). Black-White risk differentials in COVID-19 (SARS-COV2) transmission, mortality and case fatality in the United States: Translational epidemiologic perspective and challenges. *International Journal of Environmental Research and Public Health*, *17*(12), 4322. https://doi.org/10.3390/ijerph17124322

Kaundinya, T., & Kundu, R. V. (2021). Diversity of skin images in medical texts: Recommendations for student advocacy in medical education. *Journal of Medical*

Education and Curricular Development, *8*, 1-3. https://doi.org/10.1177/23821205211025855

King, D., & Domin, D. S. (2007). The representation of people of color in undergraduate general chemistry textbooks. *Journal Of Chemical Education*, *84*(2), 342-345. https://doi.org/10.1021/ed084p342

Lester, J., Jia, J., Zhang, L., Okoye, G. and Linos, E. (2020). Absence of images of skin of colour in publications of COVID-19 skin manifestations. *British Journal of Dermatology*, *183*(3), 593-595. https://doi.org/10.1111/bjd.19258

Lipper, G. (2020, July 27). *COVID-19-Related skin changes: The hidden racism in documentation*. Medscape. https://www.medscape.com/viewarticle/934605

McGovern, R. P., & Martin, R. L. (2016). Managing ankle ligament sprains and tears: Current opinion. *Open Access Journal of Sports Medicine*, *7*, 33–42. https://doi.org/10.2147/OAJSM.S72334

Patricia, L., & Wilkes, R. (2018). Representations of race and skin tone in medical textbook imagery. *Social Science & Medicine, 202*, 38-42. https://doi.org/10.1016/j.socscimed.2018.02.023

Petersen, W., Rembitzki, I. V., Koppenburg, A. G., Ellermann, A., Liebau, C., Brüggemann, G. P., & Best, R. (2013). Treatment of acute ankle ligament injuries: A systematic review. *Archives of Orthopaedic and Trauma Surgery*, *133*(8), 1129–1141. https://doi.org/10.1007/s00402-013-1742-5

Seth, A., Sherman, M., Reinbolt, J. A., & Delp, S. L. (2011). OpenSim: A musculoskeletal modeling and simulation framework for in silico investigations and exchange. *Procedia IUTAM, 2*, 212–232. https://doi.org/10.1016/j.piutam.2011.04.021

Waterman, B. R., Owens, B. D., Davey, S., Zacchilli, M. A., & Belmont, P. J., Jr (2010). The epidemiology of ankle sprains in the United States. *The Journal of Bone and Joint Surgery. 92*(13), 2279–2284. https://doi.org/10.2106/JBJS.I.01537

Woolgar, S. (1991). Configuring the user: The case of usability trials. In J. Law (Ed.), *A sociology of monsters: Essays on power, technology and domination* (pp. 58-99). Routledge.

Wyatt, E. (1997, January 4). Glenn Walter Johnson Jr., 75; invented brace for ankle sprains. *New York Times*. https://www.nytimes.com/1997/01/25/nyregion/glenn-walter-johnson-jr-75-invented-brace-for-ankle-sprains.html#:~:text=in%201972%20after%20he%20invented,Johnson