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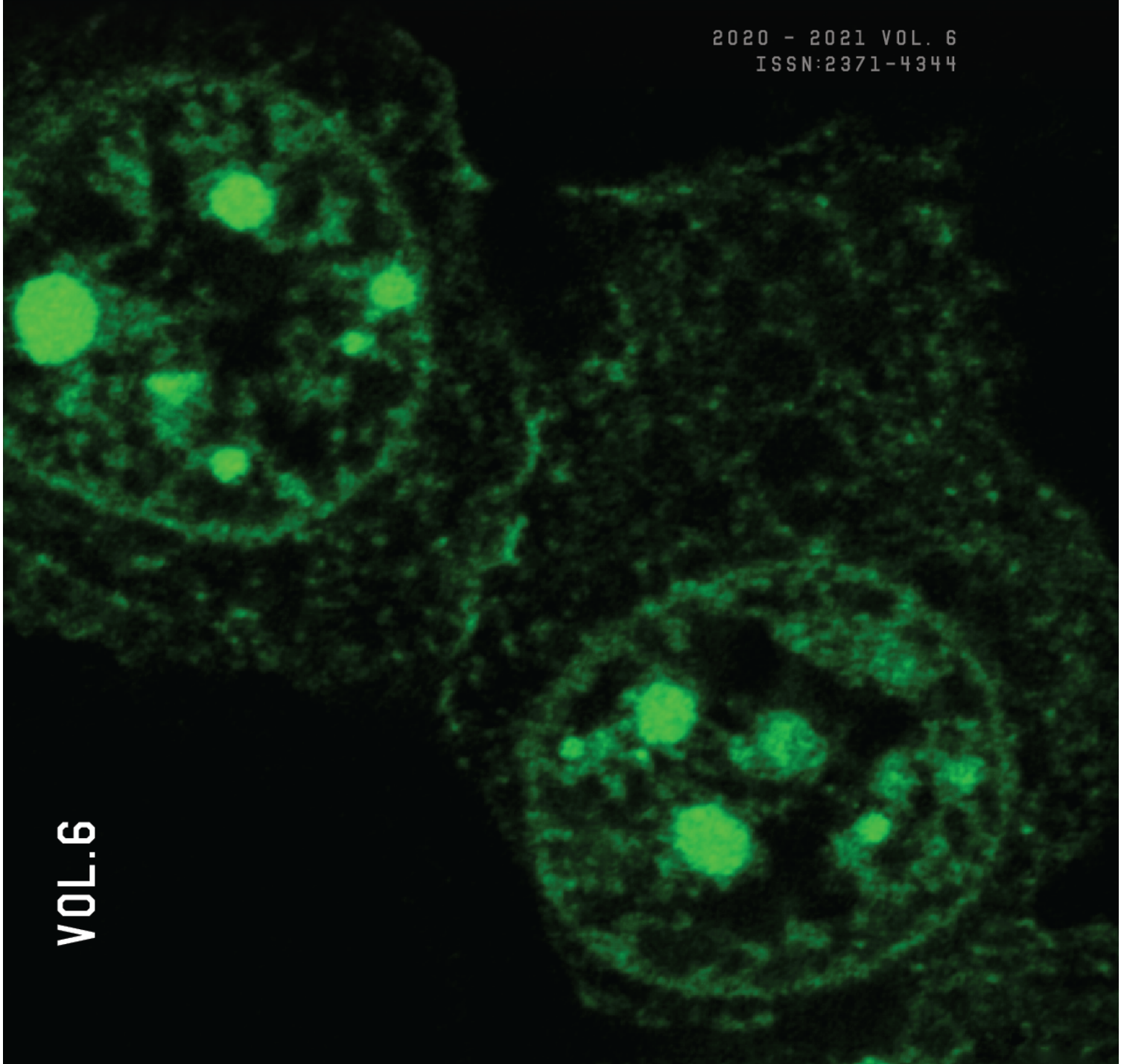

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Cover photo provided by **Sahil Chandhok**

Cover layout and design by **Melissa Tse**

Cover Image Description

Amyloids are highly structured, thermodynamically stable, proteinaceous aggregates that have classically been associated with various systemic and neurological pathologies[1, 2, 3, 4]. However, despite their pathological connections, several studies have actually shown that these aggregates can also possess physiological attributes[2]. In fact, the Audas laboratory at Simon Fraser University, studies a form of physiological, stress-induced amyloid aggregation. It has been observed that, in response to environmental stresses such as heat shock or extracellular acidosis, mammalian cells form subnuclear structures that share several properties with classical amyloid aggregates[5]. These structures, termed as Amyloid-bodies, have a cellular protective effect, and allow the cell to withstand harsh environmental conditions[5]. Mechanistically speaking, a class of long non-coding RNA, transcribed from the ribosomal intergenic spacer region, seed the formation of these structures within the nucleoli[5, 6, 7, 8]. The proteomic composition of these structures is extremely diverse, with several hundred endogenous proteins comprising the Amyloid-body. Proteomic and cell-culture based experiments suggest that this composition varies in a stress-specific manner[5, 9]. The occurrence of Amyloid-bodies is not exclusive to mammalian cells, as a recent paper from the Audas laboratory, has shown that these structures can also form in certain insect, bird and fish species, thus suggesting that this phenomenon is evolutionarily conserved in eukaryotes[10].

As mentioned above the Amyloid-body is a physiological structure that is comprised of several endogenous, non-pathological proteins. However, published[5] and unpublished experiments have shown that several exogenously expressed, pathological proteins and peptides are also capable of aggregating within the Amyloid-bodies. This includes the notorious, Alzheimer's disease associated β-amyloid peptide[5]. This has led to the theorisation that the dysregulation of the Amyloid-body stress response pathway may be linked to pathological amyloid aggregation. The Audas laboratory is currently investigating this possibility.

The image on the cover page of this year's SURJ edition shows two acidosis-treated MCF-7 cells, expressing exogenous, green-fluorescent protein tagged β-amyloid. A large quantity of this protein can be seen in the subnuclear Amyloid-bodies. The image was taken on the Zeiss LSM880 laser scanning microscope using the $63\times$ oil emersion lens.

References

[1] Fabrizio Chiti and Christopher M Dobson. Protein misfolding, functional amyloid, and human disease. *Annu Rev Biochem*, 75:333–366, 2006.

[2] Fabrizio Chiti and Christopher M Dobson. Protein misfolding, amyloid formation, and human disease: A summary of progress over the last decade. *Annu Rev Biochem*, 86:27–68, May 2017.

[3] Christopher M Dobson. The amyloid phenomenon and its links with human disease. *Cold Spring Harb Perspect Biol*, 9(6), June 2017.

[4] Matthew G. Iadanza, Matthew P. Jackson, Eric W. Hewitt, Neil A. Ranson, and Sheena E. Radford. A new era for understanding amyloid structures and disease. *Nature Reviews Molecular Cell Biology*, 19(12):755–773, Dec 2018. ISSN 1471-0080. doi:10.1038/s41580-018-0060-8. URL https://doi.org/10.1038/s41580-018-0060-8.

[5] Timothy E Audas, Danielle E Audas, Mathieu D Jacob, J J David Ho, Mireille Khacho, Miling Wang, J Kishan Perera, Caroline Gardiner, Clay A Bennett, Trajen Head, Oleksandr N Kryvenko, Mercé Jorda, Sylvia Daunert, Arun Malhotra, Laura Trinkle-Mulcahy, Mark L Gonzalgo, and Stephen Lee. Adaptation to stressors by systemic protein amyloidogenesis. *Dev Cell*, 39(2):155–168, October 2016.

[6] Timothy E Audas, Danielle E Audas, Mathieu D Jacob, J J David Ho, Mireille Khacho, Miling Wang, J Kishan Perera, Caroline Gardiner, Clay A Bennett, Trajen Head, Oleksandr N Kryvenko, Mercé Jorda, Sylvia Daunert, Arun Malhotra, Laura Trinkle-Mulcahy, Mark L Gonzalgo, and Stephen Lee. Adaptation to stressors by systemic protein amyloidogenesis. *Dev Cell*, 39(2):155–168, October 2016.

[7] Mathieu D Jacob, Timothy E Audas, James Uniacke, Laura Trinkle-Mulcahy, and Stephen Lee. Environmental cues induce a long noncoding RNA-dependent remodeling of the nucleolus. *Mol Biol Cell*, 24(18):2943–2953, July 2013.

[8] Miling Wang, Xianzun Tao, Mathieu D Jacob, Clayton A Bennett, J J David Ho, Mark L Gonzalgo, Timothy E Audas, and Stephen Lee. Stress-Induced low complexity RNA activates physiological amyloidogenesis. *Cell Rep*, 24(7):1713–1721.e4, August 2018.

[9] Dane Marijan, Ronnie Tse, Keenan Elliott, Sahil Chandhok, Monica Luo, Emma Lacroix, and Timothy E Audas. Stress-specific aggregation of proteins in the amyloid bodies. *FEBS Lett*, 593(22):3162–3172, September 2019.

[10] Emma Lacroix, Lionel Pereira, Byoungjoo Yoo, Krysta M Coyle, Sahil Chandhok, Richard Zapf, Dane Marijan, Ryan D Morin, Stephanie Vlachos, Nicholas Harden, and Timothy E Audas. Evolutionary conservation of systemic and reversible amyloid aggregation. *J Cell Sci*, 134(22), November 2021.

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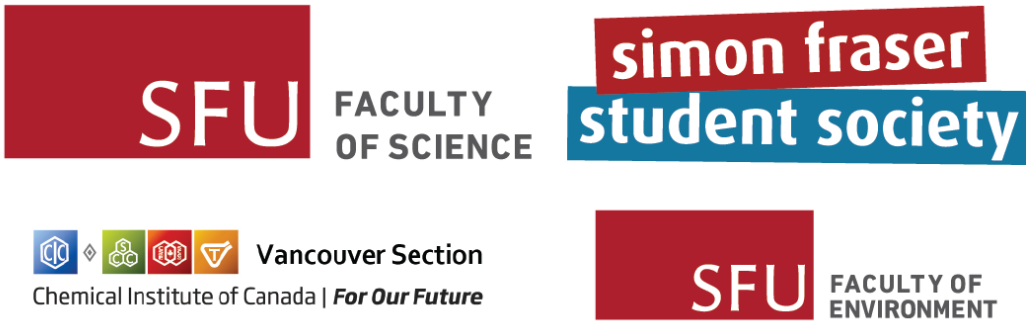

2020-21 Board of Editors

"Science is a way of thinking much more than it is a body of knowledge."
- Carl Sagan

Foreword

Dear Reader,

Since 2015, the SFU Science Undergraduate Research Journal has aspired to expand and nurture budding interests in research by providing opportunities for undergraduate students to exhibit their work. To chase this vision, we continually seek out students and faculty members who are passionate about enriching the scientific community. We hold annual poster competitions, highlight the accomplishments of student researchers on our blog, and publish a yearly journal to encourage scientific discussions. Combining the efforts of SFU undergraduate students and faculty members has allowed us to produce this journal, which carries the desires of all involved to further the boundaries of research.

Facing the remnants of the COVID-19 pandemic, the transition back to in-person activities was undoubtedly exciting, yet challenging. The return to on-campus activities allowed for long-awaited opportunities for social interaction, but it was accompanied by long hours of commute and an immeasurable worry for the safety of ourselves and our family members. In the face of these worries and challenges, the authors, editors, and reviewers advanced through the process with great tenacity. This ability to persevere despite all odds is characteristic of the scientific community, and is further reflected in the research that was put forth. We are truly thankful for the hard work that everyone has put into this publication.

Without further delay, we present to you, the sixth edition of SFU Science Undergraduate Research Journal.

Meghan Dunn and Michelle Lam

Executive Editors

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A Review of the Paradoxical Effects of Microglia in Ischemic Stroke and the Future of Treatment

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Abstract

Deadly if attended to too late, ischemic strokes affect millions of individuals around the world yearly. Microglia are one of the first respondents to brain injury, acting quickly to repair and prevent damage in the event of a stroke. These cells have been long held as beneficial protectors and healers in the neuroimmune response as they are pro-inflammatory and remove toxic debris. Microglia have on the other hand also been found to mediate deleterious effects such as becoming neurotoxic when overactivated, which may compromise the damaged tissue instead of healing. Given its beneficial effects, researchers have attempted to target microglia in ischemic stroke intervention and treatments but due to its paradoxical role in inflammatory response, these attempts have encountered difficulties and many complications. The future of microglial-targeted treatment and intervention methods therefore is uncertain. This review summarizes the main findings of microglia following stroke to exemplify the need for continual research in this area. Currently, modulation of microglia rather than total blockage may be the best option, however, more research must be conducted using methods that can optimize the benefits while minimizing detriments as well as methods that are able to be easily translated to the people who experience strokes.

Keywords — Ischemic Stroke, Microglia, Treatment

1. Introduction

Microglia play an influential yet paradoxical role in the nervous system when damaged, providing both beneficial and harmful injury responses. As the brain's resident macrophages, microglia promote cellular differentiation by providing trophic support for astrocytes, oligodendrocytes, and vessels [1]. After injury, glial cells form containment zones around damaged brain cells and aid in accelerating the recovery process of damaged sites by removing harmful debris [2]. These are beneficial abilities, especially during the recovery process of strokes, however microglia have also been implicated in detrimental effects on the central nervous system post-stroke. In this review, by examining this seemingly paradoxical role of microglia in ischemic strokes, I hope to clarify the role of microglia in the intervention and treatment of stroke, as well as describe the current challenges researchers face with developing effective treatment methods.

Strokes are the third leading cause of death in Canada, with more than 400,000 Canadians living with long-term disability due to stroke [3, 4]. This number is predicted

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to double in the next 20 years by the Heart and Stroke Foundation of Canada [4]. Though there are multiple types of strokes, the focus of this review is on ischemic strokes as they are the most common type, caused by a blood clot in the brain [4]. If the stroke injury is not treated in time, the implications can be deadly as the blockage interrupts the regional blood supply, leading to neuronal dysfunction, and cell death (apoptosis) [5, 6]. The penumbra which surrounds the necrotic core, is an area of constrained blood flow comprised of potentially preserved energy metabolism which can progress to infarction due to the excitotoxicity that results from prolonged oxygen deprivation caused by the vascular blockage [6]. Alongside infarction, other secondary deleterious phenomena may also occur such as accumulation of excessive glutamate in extracellular space due to spreading depolarization, the production of toxic mediators activated by post-ischemic inflammation, and apoptosis of cells [6]. Excitotoxicity mechanisms can also cause inflammation and edema followed by acute cell death, or delayed apoptosis [6]. The severity of these effects however, affects the neuronal ability to recover from the stroke; the more severe, the worse the stroke outcomes [7]. After the site has been deprived of oxygen even for a brief moment, the brain is exposed to systemic responses that further the damage already done, potentially exacerbating the cognitive and physical deficits that occur from a stroke [7].

2. The Beneficial Role of Microglia

Microglia are an important component of the immune response, playing a beneficial role in response to injury. When the stroke injury is attended to in the brief time frame before extensive damage can be done, treatments can prevent further damage [8]. During this period of time, microglia elicit an immune response critical in post-ischemic injury recovery. Comprising 10% of the brain's cells, microglia lead the brain's immune system response following stroke and attend to the injured or damaged site [7]. Microglia are phagocytes which develop after the formation of the blood-brain barrier, making them unique, as they evolve in a specialized neural microenvironment devoid of other types of glial cells [7]. They continuously monitor the brain, responding to changes in brain homeostasis, even in their presumed resting state [9]. In order to search for these changes, microglia send out branching thin processes which survey the microenvironment and detect potential threats [9]. This is an important function of microglia, as it allows for them to remove toxic cellular debris, keeping sites of injury protected [9].

Alongside this function, studies on mice suggest that microglia may play a beneficial role in neuroprotection post-ischemic stroke [10, 11]. Lalancette-Herbert et al., [10] found that microglial proliferation may play a primary role in regulating or modulating both pro- and anti-inflammatory responses following ischemic injury in mice. As the inflammation process initiates, microglia are activated and differentiate into one of two phenotypes: M1 and M2 as a response to stress [12]. M1 microglia act as a pro-inflammatory mediator and defense against pathogens, typically being the first responder to the injury and infection [13]. This inflammation assists with stimulating myelin repair and removing toxic proteins from the central nervous system [14]. M1 is however also implicated in harmful effects which will be mentioned below [13]. M2

acts in opposition to M1 as an anti-inflammatory response and promotes repair gene expression following the initial microglial response [13]. M2 also produces neurotrophic factors, insulin-like growth factors 1 and 2 as well as brain-derived growth factors which aid the inflammation resolution process and promote neuron survival [13].

3. The Deleterious Role of Microglia

Though microglia have been implicated as the primary immune response to injury to the brain, there has been speculation regarding the neurotoxic effects resulting from microglial activation. As microglia carry out their neuroprotective role, they may produce reactive oxygen species and anti-inflammatory cytokines which can inhibit tissue repair when overactivated [15]. Mice studies have shown that when injecting the microglial activation inhibitor, minocycline, secondary oligodendrocytes, and axonal degeneration decrease following an injury to the central nervous system [11, 16]. Minocycline as well as other microglial inhibitors have also been found to provide some neuroprotection following stroke, producing better neurological outcomes with treatment [16]. Inhibition of microglia in these experiments contradicts the previous findings that microglia provide beneficial effects to sites of injury. Microglial overactivation may therefore turn beneficial effects into detrimental effects. Additional studies also indicate that this overactivation can be attributed to either direct stimulation via environmental toxins and endogenous proteins or reactive microgliosis after neuronal damage occurs [17, 18]. These seemingly opposing duties have been long questioned, as microglia play a large role following ischemic injuries.

Gomes-Leal [15] suggests that altered neurons, glia, and blood vessels among other sources, may release both beneficial and detrimental factors into the extracellular space where microglia reside. Other studies have found that in non-infectious diseases such as stroke, the destructive mechanisms used to eliminate pathogens may unintentionally also destroy healthy neurons [19]. Particularly in the case of ischemic strokes, disruption of the blood-brain barrier due to reactive oxygen species produced by overactive microglia can induce great damage within the barrier itself [20]. In doing so, neurotoxic agents may leak into the ischemic tissue, eliciting a cascade of post-ischemic inflammation events which can further damage the barrier [20]. Though these destructive effects appear detrimental, alongside the homeostatic role of microglia, they also play a key role in supporting the barrier and continue to attend the site of injury for hours after the initial damage occurs [21]. This relationship between microglia and the blood-brain barrier exemplifies the paradoxical role of microglia post-ischemic stroke.

4. Microglial-Targeted Treatment and Intervention

As microglia have been found to hold both beneficial and detrimental effects following neuronal injury, they are of great interest in the treatment of damaged tissue, especially in the recovery process of ischemic stroke. As summarized previously, the paradoxical effects of microglia appear to prevail mainly when overactivation of microglia or the release of neurotoxic agents occur [19, 20]. Though studies involving drugs and antibiotics such as minocycline have established that they are capable of fully inhibiting

microglia activation to alleviate the tissue damage resulting from ischemic stroke, many researchers oppose the use of abolishing microglia activation [15, 16]. Block et al., [17] suggest that early attenuation of microglial response to non-deleterious levels would be the ideal therapeutic approach in the treatment of strokes and neurodegenerative disorders. They hypothesize that given the progressive and cumulative process of microglial activation, intervening early on would allow for an opportunity to ensure that microglia are not overactivated at any point. Gomes-Leal [15] also believes that drug use should be avoided in addressing the microglia overactivation. He states that it is fundamental to identify which microglia receptors contribute to the beneficial or detrimental effects following strokes. By being able to identify these receptors, experimental manipulation or pharmacological applications may be able to enhance the beneficial effects of microglia while diminishing detrimental effects. Guruswamy et al., [7] agree with Gomes-Leal, elaborating further that fine-tuning immunomodulatory interventions while avoiding harmful immunosuppressive effects would be the most effective method in promoting the repair of damaged tissue post-stroke. A consensus among these researchers regarding the modulation of microglia activation levels rather than the total blockage of microglia activation is apparent. These methods of therapeutic remedy can and should be explored in the future through experimental design to analyze the effectiveness of modulating microglial activation post-ischemic stroke.

Recent studies have utilized these ideas to develop methods of intervention targeting microglia in ischemic stroke therapy [22, 23]. As suggested, modulation of microglial activation using pharmacological methods can improve the recovery process post-stroke [22]. Aside from minocycline, other treatments that modulate the effects of microglia rather than inhibit them such as noggin, which modulates microglial phenotypes, and tumour necrosis factor (TNF), which modulates microglial activation, can also be used to assist in post-stroke recovery in animal models [18]. Though these are promising steps toward creating the most optimal method of microglial intervention, nothing has been clinically approved for use in humans yet [22]. Other non-pharmaceutical methods utilizing cellular therapies in animal models that involve direct administration of microglia have also been found to yield improved axonal outgrowth and reduced tissue damage [23, 24]. Other animal studies using non-medical interventions such as exercise and environmental enrichment can also aid in stroke-recovery for older mice as the activity can modify age-related microglial dysfunction [25, 26].

5. Challenges of Treatment and Intervention

Despite these promising techniques, research on model systems is more extensive than humans as we do not perform these types of experiments on humans [22]. Human research comes with complications given the challenges of applying experimental and laboratory techniques from animal studies to human patients. This may be due to practical differences between lab studies and real stroke victims. Even if treatments are found to work in animals, they may only work in a brief window of time post-stroke when the individual may not even be aware that they are experiencing a stroke, leading to decreased efficacy if used [6]. These treatments may also work differently in animal models as for example, rats have three times the glucose, oxygen metabolism, and

blood flow as humans, and effects of treatment may be species dependent [6]. These studies are conducted in laboratories, using special equipment in 'ideal environments', while also often using young and healthy mice while stroke victims are often older human adults [6]. In addition, other reasons concern the approach of studying strokes, as every stroke is different and therefore not as heterogeneous and predictable as those studied in the lab [6]. Though it is useful studying animal models, the generalizability in some cases is questionable.

Treatments for ischemic stroke cannot be optimized using the findings of the current literature, likely due to a lack of understanding of the modulation of microglia [22]. The complexity that comes with attempting to selectively target the deleterious effects of microglia without impacting the beneficial effects also contributes to this difficulty in identifying treatment methods [22, 27]. Animal models may further complicate this problem as drug concentrations and limits of tolerated dosages vary between, for example, rodent models and humans which may exacerbate side effects 6. Even if methods targeting microglia are found to be effective in improving post-stroke symptoms, due to its paradoxical effects, side effects could potentially further decrease the quality of life in these individuals who already face many daily struggles as a result of their injury. Drug side effects can be monitored in animal models, but side effects may be missed or more complicated than can be observed with laboratory tools. Not only do researchers have to keep in mind the paradoxical effects but also the psychosocial impacts on the individuals that they are trying to help since inevitably these humans are more complex than animal models.

6. Conclusion

Researchers hold consensus that microglia play a large role in the neuroimmune system, possessing healthy inflammatory, and debris clearing properties as well as destructive neurotoxic, and disruptive properties. Microglia are vital in the immune response following stroke, however the paradoxical effects make these cells complex targets for treatment and intervention. Due to this reason, the progress research has made toward developing clinically safe therapeutic methods of intervention targeting microglia has been overall met with limited success. In attempting to yield the most beneficial effects of microglia, deleterious effects may result instead. Though it has been established that the selective modulation of microglia yields the most optimal improvements in stroke symptoms, research from animal models has not yet been able to be replicated in humans, resulting in this stand still in the literature. This finding prompts the need to explore the modulation of this activation and experimentally test if it is a feasible intervention method while being aware of its potentially harmful effects. Microglia hold great potential as a treatment target for ischemic stroke, therefore if selective modulation of microglia is able to be applied to humans, while yielding minimal deleterious or harmful effects, perhaps science may someday significantly change the outcome for stroke victims.

References

[1] Jeffrey L Frost and Dorothy P Schafer. Microglia: Architects of the developing nervous system. *Trends Cell Biol*, 26(8):587–597, March 2016.

[2] Manuel B Graeber. Changing face of microglia. *Science*, 330(6005):783–788, November 2010.

[3] Public Health Agency of Canada. Government of canada, Dec 2019. URL https://www.canada.ca/en/public-health/services/publications/diseases-conditions/stroke-canada-fact-sheet.html#shr-pg0.

[4] Heart and Stroke Foundation of Canada. 2017 stroke report. URL https://www.heartandstroke.ca/-/media/pdf-files/canada/stroke-report/strokereport2017en.ashx.

[5] Emelia J Benjamin, Michael J Blaha, Stephanie E Chiuve, Mary Cushman, Sandeep R Das, Rajat Deo, Sarah D de Ferranti, James Floyd, Myriam Fornage, Cathleen Gillespie, Carmen R Isasi, Monik C Jiménez, Lori Chaffin Jordan, Suzanne E Judd, Daniel Lackland, Judith H Lichtman, Lynda Lisabeth, Simin Liu, Chris T Longenecker, Rachel H Mackey, Kunihiro Matsushita, Dariush Mozaffarian, Michael E Mussolino, Khurram Nasir, Robert W Neumar, Latha Palaniappan, Dilip K Pandey, Ravi R Thiagarajan, Mathew J Reeves, Matthew Ritchey, Carlos J Rodriguez, Gregory A Roth, Wayne D Rosamond, Comilla Sasson, Amytis Towfighi, Connie W Tsao, Melanie B Turner, Salim S Virani, Jenifer H Voeks, Joshua Z Willey, John T Wilkins, Jason Hy Wu, Heather M Alger, Sally S Wong, Paul Muntner, and American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics-2017 update: A report from the american heart association. *Circulation*, 135(10):e146–e603, January 2017.

[6] U Dirnagl, C Iadecola, and M A Moskowitz. Pathobiology of ischaemic stroke: an integrated view. *Trends Neurosci*, 22(9):391–397, September 1999.

[7] Revathy Guruswamy and Ayman ElAli. Complex roles of microglial cells in ischemic stroke pathobiology: New insights and future directions. *Int J Mol Sci*, 18 (3), February 2017.

[8] Harold P Adams, Jr, Gregory del Zoppo, Mark J Alberts, Deepak L Bhatt, Lawrence Brass, Anthony Furlan, Robert L Grubb, Randall T Higashida, Edward C Jauch, Chelsea Kidwell, Patrick D Lyden, Lewis B Morgenstern, Adnan I Qureshi, Robert H Rosenwasser, Phillip A Scott, Eelco F M Wijdicks, American Heart Association, American Stroke Association Stroke Council, Clinical Cardiology Council, Cardiovascular Radiology and Intervention Council, and Atherosclerotic Peripheral Vascular Disease and Quality of Care Outcomes in Research Interdisciplinary Working Groups. Guidelines for the early management of adults with ischemic stroke: a guideline from the american heart Association/American stroke association stroke council, clinical cardiology council, cardiovascular radiology and intervention council, and the atherosclerotic peripheral vascular disease and

quality of care outcomes in research interdisciplinary working groups: the american academy of neurology affirms the value of this guideline as an educational tool for neurologists. *Stroke*, 38(5):1655–1711, April 2007.

[9] Axel Nimmerjahn, Frank Kirchhoff, and Fritjof Helmchen. Resting microglial cells are highly dynamic surveillants of brain parenchyma in vivo. *Science*, 308(5726): 1314–1318, April 2005.

[10] Mélanie Lalancette-Hébert, Geneviève Gowing, Alain Simard, Yuan Cheng Weng, and Jasna Kriz. Selective ablation of proliferating microglial cells exacerbates ischemic injury in the brain. *J Neurosci*, 27(10):2596–2605, March 2007.

[11] David P Stirling, Kourosh Khodarahmi, Jie Liu, Lowell T McPhail, Christopher B McBride, John D Steeves, Matt S Ramer, and Wolfram Tetzlaff. Minocycline treatment reduces delayed oligodendrocyte death, attenuates axonal dieback, and improves functional outcome after spinal cord injury. *J Neurosci*, 24(9):2182–2190, March 2004.

[12] Cheng-Ting Jiang, Wan-Feng Wu, Yi-Hui Deng, and Jin-Wen Ge. Modulators of microglia activation and polarization in ischemic stroke (review). *Mol Med Rep*, 21 (5):2006–2018, February 2020.

[13] Yu Tang and Weidong Le. Differential roles of M1 and M2 microglia in neurodegenerative diseases. *Mol Neurobiol*, 53(2):1181–1194, January 2015.

[14] I Glezer, A R Simard, and S Rivest. Neuroprotective role of the innate immune system by microglia. *Neuroscience*, 147(4):867–883, April 2007.

[15] Walace Gomes-Leal. Microglial physiopathology: how to explain the dual role of microglia after acute neural disorders? *Brain Behav*, 2(3):345–356, May 2012.

[16] Kazuhide Hayakawa, Kenichi Mishima, Masanori Nozako, Mai Hazekawa, Shohei Mishima, Masayuki Fujioka, Kensuke Orito, Nobuaki Egashira, Katsunori Iwasaki, and Michihiro Fujiwara. Delayed treatment with minocycline ameliorates neurologic impairment through activated microglia expressing a high-mobility group box1-inhibiting mechanism. *Stroke*, 39(3):951–958, February 2008.

[17] Michelle L Block, Luigi Zecca, and Jau-Shyong Hong. Microglia-mediated neurotoxicity: uncovering the molecular mechanisms. *Nat Rev Neurosci*, 8(1):57–69, January 2007.

[18] Michelle L Block and Jau-Shyong Hong. Microglia and inflammation-mediated neurodegeneration: multiple triggers with a common mechanism. *Prog Neurobiol*, 76(2):77–98, June 2005.

[19] M Griffiths, J W Neal, and P Gasque. Innate immunity and protective neuroinflammation: new emphasis on the role of neuroimmune regulatory proteins. *Int Rev Neurobiol*, 82:29–55, 2007.

[20] Birgit Obermeier, Richard Daneman, and Richard M Ransohoff. Development, maintenance and disruption of the blood-brain barrier. *Nat Med*, 19(12):1584–1596, December 2013.

[21] Anna Carolina Carvalho da Fonseca, Diana Matias, Celina Garcia, Rackele Amaral, Luiz Henrique Geraldo, Catarina Freitas, and Flavia Regina Souza Lima. The impact of microglial activation on blood-brain barrier in brain diseases. *Front Cell Neurosci*, 8:362, November 2014.

[22] Charlotte Rawlinson, Stuart Jenkins, Laura Thei, Mark L Dallas, and Ruoli Chen. Post-Ischaemic immunological response in the brain: Targeting microglia in ischaemic stroke therapy. *Brain Sci*, 10(3), March 2020.

[23] Fumihiro Imai, Hiromi Suzuki, Jumpei Oda, Takashi Ninomiya, Kenji Ono, Hirotoshi Sano, and Makoto Sawada. Neuroprotective effect of exogenous microglia in global brain ischemia. *J Cereb Blood Flow Metab*, 27(3):488–500, July 2006.

[24] Masato Kanazawa, Minami Miura, Masafumi Toriyabe, Misaki Koyama, Masahiro Hatakeyama, Masanori Ishikawa, Takashi Nakajima, Osamu Onodera, Tetsuya Takahashi, Masatoyo Nishizawa, and Takayoshi Shimohata. Microglia preconditioned by oxygen-glucose deprivation promote functional recovery in ischemic rats. *Sci Rep*, 7:42582, February 2017.

[25] Seemaab Ali, Xianglan Liu, Nicholas J Queen, Ripal S Patel, Ryan K Wilkins, Xiaokui Mo, and Lei Cao. Long-term environmental enrichment affects microglial morphology in middle age mice. *Aging (Albany NY)*, 11(8):2388–2402, April 2019.

[26] Rachel A Kohman, Tushar K Bhattacharya, Elzbieta Wojcik, and Justin S Rhodes. Exercise reduces activation of microglia isolated from hippocampus and brain of aged mice. *J Neuroinflammation*, 10:114, September 2013.

[27] Midori A Yenari, Tiina M Kauppinen, and Raymond A Swanson. Microglial activation in stroke: therapeutic targets. *Neurotherapeutics*, 7(4):378–391, October 2010.

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Asynchronous and Virtual Mindfulness-Based Treatments for Chronic Pain

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Abstract

Chronic pain conditions affect a significant proportion of Canadian and U.S. citizens and is a leading driver in the opioid crisis. They are usually non-life threatening and debilitating; however, most healthcare professionals opt to prescribe pain-relief drugs despite evidence showing pharmacological treatments often cause lower mental wellbeing and more functional limitations. Non-pharmacological treatments, such as mindfulness-based treatments (MBTs), are a fairly new approach that have been proven to be better at long-term pain management for chronic pain conditions. MBTs also provide opportunities for creating asynchronous and virtual delivery methods of treatment for chronic pain. This study seeks to synthesize research conducted on the delivery of MBTs through virtual and asynchronous methods. Five studies were used in this review from which seven themes emerged: motivation, patient empowerment, reduced medication overuse, accessibility, increased life skills, technological difficulties, and consistency. Virtual MBTs can greatly improve the quality, efficiency and accessibility of chronic pain treatment services through reducing healthcare expenditures, removing transportation barriers and providing immediate access to care. Although MBTs are a powerful pain management tool, there is still a lack of research in the field, especially concerning remote methods of delivery. Additional large-scale studies and standardization of MBTs are needed to improve the efficacy and delivery of services.

Keywords — Chronic pain, Mindfulness-based treatments, Opioids, E-health

1. Introduction

Chronic Chronic pain is the leading cause of disability in Canada and the U.S. In 2012, 19% of the Canadian population was estimated to have a chronic pain condition and, in the U.S., 8.0% reported persistent chronic pain that restricted daily activities for six months or more [1, 2]. Additionally, individuals with severe cases of chronic pain were found to be frequent visitors to hospitals, which resulted in increased healthcare expenditures [3]. In 2008, the total cost of healthcare expenditures from chronic pain and losses due to worker productivity resulted in losses ranging from $560 to $635 billion for the U.S. [3].

Many healthcare professionals often opt to prescribe opioids to chronic pain patients, which can lead to opioid misuse disorders and overdoses [4]. However, recent research has shown the long-term use of opioids may result in significant health concerns due to fear, distress and avoidance of activities that may cause pain. This, in turn, can lead to the disuse and decreased functioning of muscles [5, 6]. There is a growing need

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in healthcare to find evidence-based alternatives that allow chronic pain patients to manage pain effectively and in a dignified manner. With the rising rates of prescription opioid-related deaths, more patients and healthcare professionals are being cautious of the use of opioids in treating chronic pain long-term. The Center for Disease Control and Prevention (CDC) recently published a set of guidelines for chronic pain that recommended exploring non-opioid treatments first and only using opioids if benefits outweigh the risks [7]. Even non-opioids can cause health problems, such as ulcers and internal bleeding, depending on the dosage, patient's age, and how long the patient has been taking them [8].

Chronic pain conditions can be treated through three different types of treatments: opioids, non-opioids, and non-pharmacological treatments. Several studies have shown non-pharmacological treatments, such as mindfulness-based treatments (MBTs), are often more effective in long-term pain management. MBTs focus on building awareness and target psychosocial factors that may influence the trajectory and severity of chronic pain conditions [9, 10]. MBTs also seek to increase patients' self-efficacy during flare-ups or difficult times by providing them with effective coping skills [9]. This allows patients to feel more confident in their ability to handle long-term pain and reduce their reliance on short-term fixes, such as opioids. Pharmacological treatments do not cure chronic pain but decrease pain and inflammation, and often require physical rehabilitation as well to ensure full function [10].

Due to the pandemic, there has been a proliferation and increased demand and acceptability for remote health services in an effort to stem the transmission of COVID-19 [11]. Due to the rise of technology, an increasing number of households have access to at least one digital device with which they can connect remotely to others, making remote delivery of services more feasible and acceptable [12]. Moreover, technology provides many benefits, such as better patient outcomes and reduced demands on resources and wait times in hospitals as patients can be connected to a healthcare professional quicker and more easily [11, 13]. As MBTs do not require prescriptions or in-person care, they provide opportunities for virtual and asynchronous methods of delivery that can help reduce barriers to access and wait times. In this paper, I will be investigating whether MBTs are an acceptable non-pharmacological treatment for chronic pain patients that can be delivered through virtual and asynchronous means.

2. Materials and Methods

A scan of the literature on PubMed was conducted using the search terms "chronic pain", "mindfulness", and "ehealth", with the date of publication restricted to 2010 to 2021. Qualitative and quantitative data were included to gather insight on users' experience and the success of the program based on the study's outcomes. Studies needed to have an intervention targeting chronic pain that included an element of mindfulness.

3. Results

3.1. Description of Included Studies

The study selection process is summarized in Fig. 1. A total of 561 eligible studies were gathered; however, based on the titles and abstracts, only 17 were found to be relevant to the study and were considered original research. After reviewing the abstracts of the articles for relevance to the research question, a further 12 studies were eliminated as they were not related to chronic pain or did not contain results of a completed study. Three studies were not related to virtual care delivery methods, but, as their intervention could be translated to a virtual platform or delivered asynchronously, they were retained.

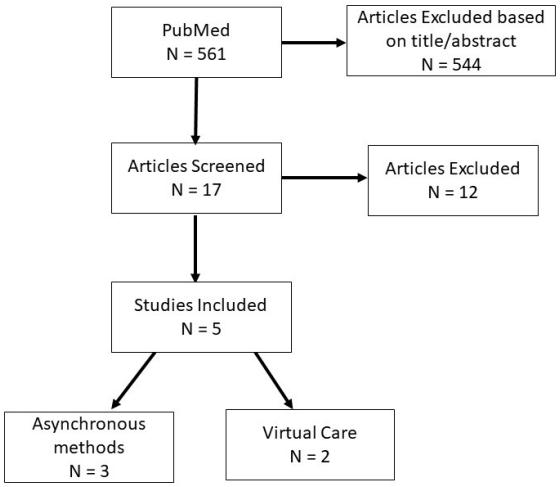

Figure 1: *Flowchart of systematic review. Shows the exclusion and inclusion processes.*

Studies used in the review were from the United States [14, 15, 16], the United Kingdom [17], and Italy [18]. The studies were a blend of randomized control trials and pilot studies with sample sizes varying from 20 to 206 participants. All of the studies aimed to examine the effectiveness and adherence rate of a mindfulness-based program targeting chronic pain. Some of the studies focused on a general chronic pain population [14, 15], while others focussed on more specific populations, such as chronic lower back pain [16], chronic pelvic pain [17], and chronic migraines [18]. Study populations were mostly mixed genders and adults of a wide age range and demographic, except for one study that looked exclusively at women and another study that recruited participants from a veteran's clinic. Studies looked at various virtual platforms for MBTs, such as apps [14] and digital monitoring devices [15], as well as hybrid formats that combined in-person and virtual delivery care methods [16**?** , 18]. The studies are summarized in Fi. **??**.

Study	Design	Sample Size and Population	Intervention and Control	Sessions and Duration	Summary of findings
Zgierska et al., 2016	RCT	35 Adults in the US with Chronic Lower Back Pain treated with ‡30 mg of morphine-equivalent dose per day for 3+ months	**Control**: usual care alone **Intervention**: MM-based intervention combined with usual care	8 sessions 2 hours group sessions + 30 minutes/d, 6 days/wk home practice	59% (10/17) reported course was useful for pain management 47% (8/17) reported improved pain coping skills
Cosio & Swaroop, 2016	RCT	96 veterans in the US with chronic, non-cancer pain	**Intervention 1:** Acceptance and Commitment Therapy (ACT) **Intervention 2:** Cognitive Behavioral Therapy (CBT)	N/A (self-help workbook)	**ACT**: decreasing trend for distress with number of sessions **CBT**: quadratic trend (sig increases for certain lessons such as pleasant activity scheduling and activity pacing)
Greenberg et al., 2020	RCT	82 Adults in the US with chronic pain	**Intervention 1:** Mind-body physical activity program (GetActive) **Intervention 2:** GetActive with a digital monitoring device	N/A conducted on their own time	**Program 1**: +41m with effect size of 0.99 SD units for physical function **Program 2**: +50m with effect size of 0.85 SD units for physical function
Ball et al., 2019	RCT	90 patients from two gynaecology clinics within Barts Health NHS, London, UK who have chronic pelvic pain for 6+ months with access to smartphone or computer and understand English	**Control**: waiting list (usual care) **Intervention 1:** MBT + additional pain module delivered by smartphone app **Intervention 2**: muscle relaxation from same app	N/A smartphone app used on their own time	Qualitative data **Patients**: were excited before study, but less positive after **Staff**: expressed concerns of extra workload support due to need to troubleshoot tech problems
Grazzi et al., 2020	RCT	20 patients in Italy with history of chronic migraine ≥ 10 years and overuse of triptans or non-steroidal anti-inflammatory drugs ≥ 5 years	**Intervention 1**: Pharmacological prophylaxis **Intervention 2**: MBT delivered through smartphone	6 weekly-45-min sessions for 12 months + 12 mins long daily asynchronous sessions	Headache frequency decreased significantly ($p<0.001$) for both groups at 6M and 12M

Figure 2: *Summary of Characteristics of Studies Included.*

4. Discussion

With the rising incidence of opioid-related deaths, MBTs provide a powerful tool in combatting this growing issue. MBTs have the ability to reduce healthcare expenditures significantly from reducing unplanned hospital visits to cutting the costs associated with pharmacological treatments. Chronic pain patients are also more likely to see sustainable long-term improvements in their pain resilience and are better able to perform daily activities of living through MBTs. MBTs can also improve the quality of life and wellbeing of chronic pain patients by increasing an individual's self-efficacy and providing them with the skills needed to manage their pain effectively without medications. Virtual and asynchronous delivery methods of MBTs, such as through apps, CDs, booklets, and other virtual platforms, are a fairly new field in research. However, through further research and quality improvement, they have the ability to provide people with tools to manage pain on their own after an MBT program has ended and to decrease the burden on the healthcare system. Results from the systematic review have been summarized into seven themes concerning the benefits and barriers to implementing virtual and asynchronous MBTs, as well as the limitations of the review.

4.1. Motivation

The effectiveness and usefulness of MBTs are often underestimated and discounted, leading to low adherence rates. One study found providing staff with training on how to introduce MBTs, as well as information about the link between psychology and pain management, was extremely important in translating the importance of MBTs to participants [17]. It is also important to remember that MBTs require a significant time

commitment from participants to regularly practice these skills, especially during pain flare-ups. Therefore, programs must be accessible to allow participants to recognize the objectives are achievable. Greenberg et al. [14] found personalized goal-setting also helped motivate and empower participants. In this study, participants set physical activity goals; however, if they missed a weekly goal, they were given the opportunity to decrease their goals or set a more realistic one based on their weekly activity. This allowed participants to stay in control of their goals and to ensure that the goals matched their lifestyle and capabilities. It is important that the goals and layout of the program are easily understood and tailored to participants.

4.2. Patient Empowerment

Participants all enrolled in the studies due to an interest in learning new coping skills and tools for pain management. Pharmacological treatments often have accompanying side effects and may not be as effective in all situations [5]. Cosio & Swaroop [17] found participants reported more interest in the programs after they learned more about the link between psychology and pain maintenance. Throughout the program, participants were also taught cognitive defusion techniques to help them identify their values and relinquish pain anxiety, which allowed participants to feel more in control during flare-ups. Greenberg et al. [15] also reported significant reductions in catastrophizing and kinesiophobia, as well as improvements in pain resilience. Ball et al. [14] found participants reported that, after a while, they were able to use MBT skills on their own to manage their pain. Although all the programs provided different curriculums featuring different mind-body skills, they all provided participants with new skills that helped them with pain management.

4.3. Reduced Medicine Overuse

Prior to the start of one of the studies, participants were enrolled into a medication withdrawal program [18]. Throughout the MBT program portion, staff would reinforce the mindfulness-based practices and discourage participants from reverting back to pharmacological treatments. This led to higher adherence to treatment than usual in-person clinic visits and a very low drop-out rate (5% at 6M and 14% at 12M). This shows that patients receiving MBTs were able to successfully maintain the transition away from opioid treatments to mindfulness-based practices. Zgierska et al.'s [16] study also focussed on a sample who used opioids. They found only three participants reported that the program was not helpful. This was due to many reporting it was not tailored enough for their population, chronic lower back pain, or that talking about pain caused an increase in their pain levels. However, treatment groups in both studies showed high adherence rate to MBTs. Thus, MBTs provide a non-pharmacological alternative to pain management that can reduce opioid-related mortality and morbidity amongst chronic pain patients.

4.4. Accessibility

Transportation and getting to chronic pain services create barriers to chronic pain patients who may experience high pain severity and frequency of flare-ups. Virtual and asynchronous methods of delivery help remedy this by allowing services to be accessed at a convenient time for patients. It also provides access to high-quality services for those living in areas where chronic pain services or culturally-appropriate services may not be easily accessible for them. Asynchronous programs provide flexibility and portability for those who may also experience chronic fatigue or have a busy schedule [17]. They also allow services to be accessed as a preventative method and on an as-needed basis. Some studies have also found that, over time, participants became self-sufficient and no longer needed resources (18). Asynchronous programs can also reduce wait times and other barriers to enrollment into programs, such as anxiety towards group therapy programs [19]. MBTs provide alternatives to pharmacological treatments that can be delivered efficiently and are effective at pain management.

4.5. Increased Life Skills

MBTs provide skills that can be used in other areas of life. In Greenberg et al.'s [15] study, participants reported significant improvement in their performance-based and self-reported physical function. Participants in Zgierska et al.'s [16] study noted the skills they learned could be used in other aspects of life, such as stopping arguments, improving sleep and keeping a positive mindset. Many of the studies also found participants reported general improvement in their mental health [14, 15, 16, 17, 18]. MBTs were also reported to help participants relax and destress [17]. The skills gained from MBTs can be applied to many other aspects of life outside of pain management and, in turn, significantly improve quality of life.

4.6. Technological Difficulties

All virtual platforms of delivering healthcare services come with inherent technological difficulties and barriers to access. Ball et al. [14] reported participants who had difficulties or were not comfortable with technology were less likely to stick with the program, restrict the functionality of the program or refuse to start the program. To remedy this, participants suggested creating infographics and video tutorials to help orient first-time users to virtual platforms. Ball et al. [14] also recognized there may be barriers to technology, such as not having a smartphone or storage space on a device for downloading an app. Components that require Wi-Fi connectivity may also create problems with accessibility. Staff recommended lending devices, creating desktop versions, and allowing for download capabilities for when access to internet is not possible. Staff also expressed concern at the additional workload it would place on them to orient patients to apps and technology. When designing virtual methods of delivery, it is important to consider the barriers that may be presented through this method and the steps needed to address them.

4.7. Consistency

Studies that did not have weekly check-ins found participants were less likely to adhere to the program. Ball et al. (15) found withdrawal by participants was mostly caused by lack of time by participants, as well as lack of motivation to try out mindfulness-based practices. Ball et al.'s (15) program was designed to be part of a routine that was meant to be practiced regularly in order to see benefits. However, some participants reported using it intermittently due to missed reminders and not being able to fit it into their routine or devote adequate time to it. In Greenberg et al.'s (16) study, participants' progress was constantly monitored throughout the duration of the program. If they missed a goal, staff members would check up on them to take steps towards meeting the next goal. They also had weekly group sessions where they reviewed the weekly lessons and solved barriers to adherence. This forced participants to stick with the program and provided support and solutions, so participants felt motivated to persevere through the program.

Virtual platforms can also be seen as impersonal and less favourable by participants in comparison to face-to-face contact. Greenberg et al. [15] remedied technological difficulties and provided social connection through conducting weekly check-ins with participants to troubleshoot barriers to adherence and review the lessons for that week. These check-ins assisted with adherence and provided a layer of accountability for participants. Additionally, Zgierska et al.'s [16] study found peer support increased motivation and adherence to the program. Although asynchronous programs increase accessibility, they may also create barriers to services for others and should not replace face-to-face services entirely. Hybrid programs that have a synchronous option and opportunities for peer support and social connection should be further explored. The biggest barrier to adherence for participants was motivation, which can be targeted by adding accountability measures for participants and providing support from check-ins by staff members and/or peer support.

4.8. Limitations of this Review

This review had several limitations. MBTs and e-health are both new fields in research and, thus, have little research conducted. Therefore, the studies used in this review were mostly pilot studies with small sample sizes. MBTs also currently have no standardized guidelines on how they are delivered and what should be included in the different sessions. Due to the lack of consistency in the programming between the different studies, comparing the different studies' effectiveness may not be feasible. Chronic pain conditions also vary. Two studies looked at general chronic pain conditions and three studies looked at specific conditions. Further research is needed to truly investigate the effects MBTs can have on specific conditions to see if an all-size-fits approach is applicable for chronic pain conditions.

5. Conclusion

Studies have shown us that future virtual and remote delivery of MBTs must have certain requirements and considerations. Programs must be patient-centred by fitting

the needs and lifestyle of participants. MBTs must also be accompanied with education in order for programs to have high adherence. The science of how MBTs work is not well understood by participants and, thus, can lead to misinformation. Proper education about the importance and impact mindfulness-based treatments can have on chronic pain in combination with the program can greatly increase motivation. As chronic pain can be an isolating experience, providing opportunities for peer support allow for participants to build relationships and support each other through their journey. Apps and other asynchronous methods of delivery should look at ways to build in social connection into their programs, as this will also provide alternatives to individuals that are not keen on group therapies but are still looking for ways to connect with others. Participants need accountability from a staff person to meet their goals and stick with the program, as asynchronous programs can be impersonal and lead to high drop-out rates. Staff can also troubleshoot any technological problems and barriers to adherence for participants as they arise. Although many studies have been successful in showing the benefits over usual care, there is still more research needed to understand the costs and benefits of MBTs and to refine the design of virtual and remote MBTs. MBTs have the power to revolutionize pain management and inspire future innovation in the field of chronic pain of MBTs. However, there is still a long way to go in terms of research and providing high quality MBTs to patients.

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References

[1] Statistics Canada. Prevalence of chronic pain among individuals with neurological conditions, 2018.

[2] Michael Von Korff, Ann I Scher, Charles Helmick, Olivia Carter-Pokras, David W Dodick, Joseph Goulet, Robin Hamill-Ruth, Linda LeResche, Linda Porter, Raymond Tait, Gregory Terman, Christin Veasley, and Sean Mackey. United states national pain strategy for population research: Concepts, definitions, and pilot data. *J Pain*, 17(10):1068–1080, July 2016.

[3] Darrell J Gaskin and Patrick Richard. The economic costs of pain in the united states. *J Pain*, 13(8):715–724, May 2012.

[4] Kurt Kroenke and Andrea Cheville. Management of chronic pain in the aftermath of the opioid backlash. *JAMA*, 317(23):2365–2366, June 2017.

[5] Denise Boudreau, Michael Von Korff, Carolyn M Rutter, Kathleen Saunders, G Thomas Ray, Mark D Sullivan, Cynthia I Campbell, Joseph O Merrill, Michael J

Silverberg, Caleb Banta-Green, and Constance Weisner. Trends in long-term opioid therapy for chronic non-cancer pain. *Pharmacoepidemiol Drug Saf*, 18(12):1166–1175, December 2009.

[6] Anne Schuchat, Debra Houry, and Gery P Guy, Jr. New data on opioid use and prescribing in the united states. *JAMA*, 318(5):425–426, August 2017.

[7] Deborah Dowell, Tamara M Haegerich, and Roger Chou. CDC guideline for prescribing opioids for chronic Pain–United states, 2016. *JAMA*, 315(15):1624–1645, April 2016.

[8] Home, 2015. URL https://www.hamiltonhealthsciences.ca/wp-content/uploads/2019/08/PainClinicChronicPainMeds-th.pdf.

[9] Robert R Edwards, Robert H Dworkin, Mark D Sullivan, Dennis C Turk, and Ajay D Wasan. The role of psychosocial processes in the development and maintenance of chronic pain. *J Pain*, 17(9 Suppl):T70–92, September 2016.

[10] Fadel Zeidan and David R Vago. Mindfulness meditation-based pain relief: a mechanistic account. *Ann N Y Acad Sci*, 1373(1):114–127, June 2016.

[11] Elham Monaghesh and Alireza Hajizadeh. The role of telehealth during COVID-19 outbreak: a systematic review based on current evidence. *BMC Public Health*, 20 (1):1193, August 2020.

[12] Jazmine Valle, Tyler Godby, David P Paul, 3rd, Harlan Smith, and Alberto Coustasse. Use of smartphones for clinical and medical education. *Health Care Manag (Frederick)*, 36(3):293–300, 2017.

[13] Healthcare workers. URL https://www.cdc.gov/coronavirus/2019-ncov/index.html.

[14] Elizabeth Ball, Sian Newton, Frank Rohricht, Liz Steed, Judy Birch, Julie Dodds, Clara Cantalapiedra Calvete, Stephanie Taylor, and Carol Rivas. mhealth: providing a mindfulness app for women with chronic pelvic pain in gynaecology outpatient clinics: qualitative data analysis of user experience and lessons learnt. *BMJ Open*, 10(3):e030711, March 2020.

[15] Jonathan Greenberg, Paula J Popok, Ann Lin, Ronald J Kulich, Peter James, Eric A Macklin, Rachel A Millstein, Robert R Edwards, and Ana-Maria Vranceanu. A Mind-Body physical activity program for chronic pain with or without a digital monitoring device: Proof-of-Concept feasibility randomized controlled trial. *JMIR Form Res*, 4(6):e18703, June 2020.

[16] Aleksandra E Zgierska, Cindy A Burzinski, Jennifer Cox, John Kloke, Janice Singles, Shilagh Mirgain, Aaron Stegner, Dane B Cook, and Miroslav Bačkonja. Mindfulness Meditation-Based intervention is feasible, acceptable, and safe for chronic low back pain requiring Long-Term daily opioid therapy. *J Altern Complement Med*, 22 (8):610–620, June 2016.

[17] David Cosio and Sujata Swaroop. The use of mind-body medicine in chronic pain management: Differential trends and Session-by-Session changes in anxiety. *J Pain Manag Med*, 2(2), March 2016.

[18] Licia Grazzi, Paul Rizzoli, and Frank Andrasik. Effectiveness of mindfulness by smartphone, for patients with chronic migraine and medication overuse during the covid-19 emergency. *Neurol Sci*, 41(Suppl 2):461–462, December 2020.

[19] Diana J Burgess, Roni Evans, Kelli D Allen, Ann Bangerter, Gert Bronfort, Lee J Cross, John E Ferguson, Alex Haley, Emily M Hagel Campbell, Mallory R Mahaffey, Marianne S Matthias, Laura A Meis, Melissa A Polusny, J Greg Serpa, Stephanie L Taylor, and Brent C Taylor. Learning to apply mindfulness to pain (LAMP): Design for a pragmatic clinical trial of two Mindfulness-Based interventions for chronic pain. *Pain Med*, 21(Suppl 2):S29–S36, December 2020.

[20] Nicola Torrance, Blair H Smith, Margaret C Watson, and Michael I Bennett. Medication and treatment use in primary care patients with chronic pain of predominantly neuropathic origin. *Fam Pract*, 24(5):481–485, August 2007.

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Savasana and Staph Infections: An examination of the effectiveness of 'natural' and commercial cleaners against *Staphylococcus carnosus* on yoga mats

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Abstract

Staphylococcus aureus is one of the most common bacterial strains found in community fitness centres in the United States. Recent studies have found a link between methicillin-resistant *S. aureus* (MRSA) infections and improperly sanitized fitness equipment, such as yoga mats. Therefore, effective disinfectant methods are crucial for the prevention of bacterial transmission. As opposed to commercial cleaners, 'all-natural' or 'organic' cleaners have been favoured by the yoga community. However, there is very little information on their effectiveness as disinfectants against various bacteria. The goal of this study was to examine the effectiveness of different 'natural' and commercial cleaning products in inhibiting the growth of *Staphylococcus carnosus* when disinfecting yoga mats infected with *S. carnosus*. All cleaners were compared to Lysol® All-Purpose Cleaner, a Health Canada certified disinfectant. We hypothesized that the 'natural' cleaners used on the yoga mats would not be as effective at inhibiting the bacterial growth of *S. carnosus* in comparison to the two commercial cleaners tested. It was found that the commercial cleaner containing sodium hypochlorite (bleach) was significantly more effective than all of the natural cleaning products.

Keywords — Fitness, Yoga Equipment, Cleaners, Disinfectants, Staphylococcus

1. Introduction

Antibiotic resistance in *Staphylococcus aureus* is a major health concern worldwide [1]. In the United States alone, methicillin-resistant *S. aureus* (MRSA) causes over 80,000 infections and 11,000 deaths per year [1]. MRSA can be transmitted via skin contact and through the touching of contaminated surfaces. Roughly one-third of the world's total population carries MRSA on their skin and in their nose [1, 2]. *S. aureus* becomes a threat when it enters the body, as it has the capacity to cause mild to life-threatening diseases and is resistant to most commercially available antibiotics [3]. *S. aureus* is one of the most common bacterial strains found in community fitness centres, and recent studies have found a link between MRSA infections and improperly sanitized yoga mats [1, 2]. Yoga mats are often shared within fitness facilities and between individuals, especially in highly trafficked recreational centers [1]. For most

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athletes, a yoga mat is essential, and usage involves intimate and prolonged mat contact, particularly with the hands and feet, during sweat-inducing activities that contaminate yoga mats and provide a viable mechanism for bacterial transmission [1].

In an attempt to bypass the use of toxic chemicals, 'all-natural' or 'organic' cleaners made with a number of different ingredients including essential oils have been favoured by the yoga community. However, there is insufficient information on their effectiveness as disinfectants [4]. Our study examined the efficacy of two 'natural' cleaners on a yoga mat infected with *Staphylococcus carnosus* in comparison to two commercial cleaners. To our knowledge, no prior studies have investigated bacterial adhesion and 'natural' cleaner efficacy on yoga mats made of polyvinyl chloride (PVC). The first chosen 'natural' cleaner was lemongrass essential oil. Previous studies have demonstrated it has general antibacterial properties [4]. The second was B CLEAN, a 'natural' antibacterial yoga mat spray. The 'natural' disinfectants were tested against Lysol® All-Purpose Cleaner, a Health Canada certified disinfectant [5], and Vim® Power and Shine™ Multi-Purpose Cleaner, a commercial disinfectant containing bleach that is used at Simon Fraser University's Fitness Centre.

Due to its prevalence on most gym surfaces, the genus *Staphylococcus* was selected [6]. We used the *S. carnosus* species, a Biosafety Level 1 classified bacteria. *S. carnosus* was selected because it belongs to the same genus as *S. aureus* but lacks the virulence genes, making it safer to work with for this study. Considering that *S. carnosus* is non-pathogenic, it makes for a suitable model organism to study pathogenic bacterial strains like *S. aureus* [7].

Based on the absence of common disinfectant chemicals present in lemongrass essential oil and B CLEAN [4], our hypothesis was that the effectiveness of the 'natural' cleaners on the yoga mat would not be as successful at inhibiting the bacterial growth of *S. carnosus* in comparison to both commercial cleaners.

2. Materials and Methods

Disinfectants*:

- Lysol® All-Purpose Cleaner (positive control)
- Water (negative control)
- Sage 100% lemongrass pure essential oil
- Vim® Power and Shine™ Multi-Purpose Cleaner
- B CLEAN Mat Spray

The disinfectants were tested at full concentrations because when tested on *S. aureus* they were less effective at diluted concentrations [4], and none of the directions found on any of the product's packaging instructs users to dilute the products. Lysol® was used as a positive control as it is a phenolic compound, which has repeatedly shown to inhibit the growth of many strains of bacteria, including *S. aureus* [8]. Water was used as a negative control.

A diagram of the methods is shown in Fig. 1. To begin, we pipetted 50 µl of *S. carnosus* onto the center of a 5 cm by 5 cm piece of sterile Athletic Works Yoga Mat (3 mm thick, made of PVC) which was placed in a sterile petri dish, and spread the bacterial broth using aseptic technique. We let the piece incubate for 30 minutes at 37°C, to imitate core body temperature and because this is the optimal inoculation temperature for the genus *Staphylococcus* [9]. Afterwards, we placed the mat piece in a petri dish and pipetted 1 mL of disinfectant from a sterile Erlenmeyer flask onto the center of the piece and spread it using aseptic technique. Based on our preliminary experiments, 1 mL was proven to be a sufficient amount to completely cover the surface of the mat. After 30 seconds, a 500 g weight was placed onto the center of a pre-autoclaved 15 cm by 15 cm Mainstays Bar Mop Dishcloth cotton towel and was used to wipe the yoga mat piece in a consistent manner 4 times. Next, we cut the mat piece, with sterilized scissors and forceps, into 9 squares to increase surface area exposure and to allow the remaining *S. carnosus* bacteria on both the surface and absorbed into the mat to be released when placed into a 50 mL falcon tube filled with 15 mL of Trypticase Soy Broth (TSB). We determined that 15-35 mL of TSB would be required for each replicate, as preliminary tests determined that the yoga mat piece displaced 6 mL of solution. We then manually shook the tube for 30 seconds to ensure full surface coverage of the mat pieces. The same person shook the tube each time to ensure consistency. We then performed several serial dilutions on the TSB and mat solution by transferring 0.1 mL of the 1/10 dilution from the falcon tube onto Trypticase Soy Agar (TSA) and spread it using aseptic technique. The whole procedure: Infect/Disinfect/Cut/Serial Dilute/Plate, was replicated 13 times for each disinfectant for a total of 65 replications. The plates were placed in the incubator at 37°C for 2 hours. The number of bacterial colonies were then counted, and the number of colony-forming units per mL (CFU/mL) were calculated. One limitation of this study was that we did not have the ability to confirm that all bacterial colonies found on the PVC yoga mats after incubation were *S. carnosus*. For the purpose of this study, all bacterial colonies found on the PVC yoga mats were assumed to be *S. carnosus*.

The statistical analysis was done using JMP® (Ver. 14. SAS Institute Inc., Cary, NC). We graphed the mean number of recovered bacteria *S. carnosus* with 95% confidence intervals for each disinfectant. We then ran a one-way analysis of variance (ANOVA) test to get the p-value. Lastly, we ran a post-hoc Tukey-Kramer HSD multiple-comparison test (MCT) to get the Connecting Letters Report.

3. Results

The mean number of bacteria present on the yoga mat pieces after disinfection varied between the disinfectants (Fig. 2; $F(4, 55) = 7.1648$, $p = 0.0001$). Vim® Power and Shine™ Cleaner was significantly more effective than lemongrass oil, B CLEAN, and water. It was not significantly more effective than Lysol® All-Purpose Cleaner. Thus, both commercial cleaners did not significantly differ in their ability to inhibit the growth of *S. carnosus*. No significant difference was observed between Lysol® All-Purpose Cleaner and lemongrass oil, nor between lemongrass oil, B CLEAN, and water. There was a significant difference observed between Lysol® All-Purpose Cleaner, B CLEAN,

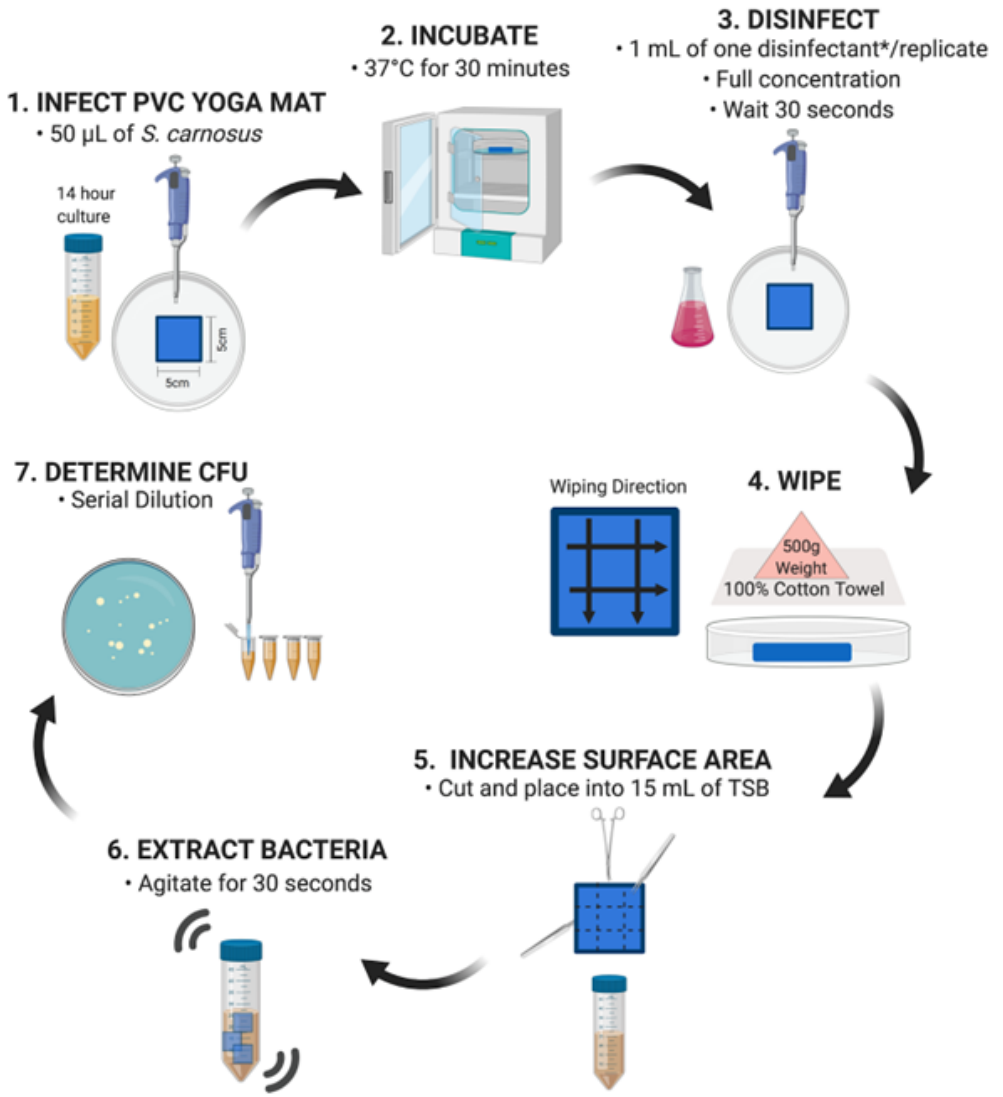

Figure 1: ***Diagram of Methods.*** *1. Infect 5 cm by 5 cm PVC yoga mat with 50 µl of S. carnosus broth. 2. Incubate the infected mat piece. 3. Disinfect with 1 mL of cleaner. 4. Wipe with a flat-bottom 500 g weight placed on a sterile cotton cloth. 5. Cut mat 4 times into 9 pieces. 6. Place pieces into Trypticase Soy Broth and shake. 7. Perform serial dilutions and plate on Trypticase Soy Agar plates. Image created with BioRender.com.*

and water. Water, the negative control, allowed for the most growth of *S. carnosus*. The cleaning agent that claimed to disinfect surfaces that allowed for the most growth of *S. carnosus* was B CLEAN. Vim® Power and Shine™ Cleaner was the most effective at inhibiting the growth of *S. carnosus* on PVC yoga mat (Fig. 2).

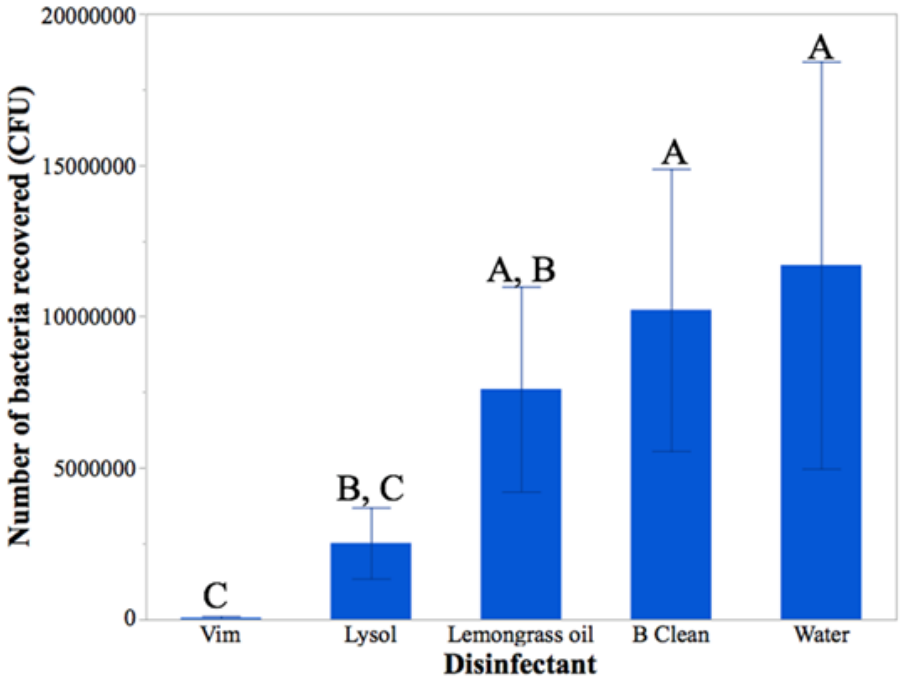

Figure 2: *Mean number of Staphylococcus carnosus present (CFU) on yoga mat after incubation for 30 minutes at 37°C and disinfection with Vim Power and Shine, Lysol All Purpose Cleaner, Saje Lemongrass Oil, B Clean Mat Spray, and Water. Mean disinfectant bars that do not share a letter significantly differ in disinfecting ability according to Tukey's HSD. Error bars represent 95% confidence intervals,* $\alpha = 0.05$.

4. Discussion

Our hypothesis was that the effectiveness of the 'natural' cleaners on the yoga mat would not be as successful at inhibiting the bacterial growth of *S. carnosus* in comparison to both commercial cleaners. The results differed from what we anticipated and contrast with the findings of relevant past studies. For instance, a previous study investigating the general effectiveness of 'natural' cleaners against *S. aureus* found no 'natural' cleaner to be more effective than Lysol® All-Purpose Cleaner [4]. Again, we hypothesized that the 'natural' cleaners would be less effective than the commercial cleaners due to their lack of common disinfectant chemicals [4]. Lysol® All-Purpose Cleaner contains phenolic compounds and ammonium chlorides, such as benzalkonium chloride, which are responsible for its strong disinfecting abilities [4, 5, 6, 7, 8, 9, 10]. However, our results suggest that Lysol was equally effective as lemongrass oil.

The disinfectant properties in Cymbopogon citratus (lemongrass) can be attributed to its chemical makeup [11]. A past study determined that the main components present in the leaves of lemongrass were hexadecenoic acid (Palmitoleic acid), hepta-9,10,11-trienioc acid, octadecenoic acid (Stearic acid), 2-ethenyltradecan-1-ol, eicosane aldehyde and 1-ethoxyoctadecane [11]. These phytocompounds are believed to exhibit

a wide range of functions including antibacterial, antiviral, and antifungal abilities [11]. Lemongrass oil should be further studied with regards to its ability to inhibit the growth of bacteria, including *S. carnosus* and *S. aureus*.

We were surprised to find that Lysol® All-Purpose Cleaner, our positive control, was equally as effective as Vim® Power and Shine™ Cleaner. This could be a result of Vim's primary active ingredient, sodium hypochlorite (bleach), which is commonly known for its antibacterial properties [12]. B CLEAN was found to be equally as effective as water, despite claiming to prevent bacterial growth, and it is significantly more expensive than water [13].

Overall, our data suggests that either of the commercial cleaners tested in this study could be effective at inhibiting the bacterial growth of *S. carnosus* on yoga mats. However, further research is needed to determine how variables such as contact times for the disinfectants, incubation times and temperatures, humidity levels, types of bacteria, and different mat materials can affect the cleaners' ability to eliminate pathogens. From this list, the further testing of disinfectant contact time could be particularly important. We speculated that most people spray and then immediately wipe their mats, so even our contact time of 30 seconds could be seen as generous if trying to mimic real life. Studies should also perform Minimum Inhibitory Concentration tests and determine the exact composition of each disinfectant – the precise concentrations of each ingredient contained within each bottle and each droplet – and explore the different combinations of essential oils and other natural ingredients in order to achieve maximum effectiveness against *S. carnosus* [4].

Although the results from this experiment did not support our hypothesis, in combination with results of previous external experiments, it revealed that these natural products do possess some potential to function as antibacterial disinfectants for yoga mats. As fitness becomes more popular, especially in the community setting, a need for effective sanitizing agents for yoga mats and fitness equipment will be in higher demand. Accordingly, the demand will also increase the production of alternative 'all natural' products because their nature suits the practice and lifestyle of yoga well. Future studies must be conducted to determine whether a 'natural' disinfectant, as successful as a chemical agent like Lysol® All-Purpose Cleaner or Vim® Power and Shine™ Cleaner, can be created for safe and effective use on yoga mats in gyms and in yoga studios.

5. Conclusion

This study yielded results consistent with other studies that have evaluated the antimicrobial activity of natural ingredients, but to our knowledge, this study was the first to test various disinfectants on PVC yoga mats [14]. Further research is needed to better comprehend how disinfectants work on PVC yoga mats. Different concentrations and combinations of essential oils and natural ingredients, as well as contact time before wiping, could all be investigated more extensively [4]. Further research on the antibacterial properties of essential oils, such as lemongrass oil, should also be carried out in order to appeal to the fitness community with regards to surface cleaners. Equipment specific studies, such as this one, are important to help determine the most

effective ways to reduce bacterial transmission in fitness facilities.

6. Acknowledgments

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References

[1] Mark Dalman, Sabana Bhatta, Nagashreyaa Nagajothi, Dipendra Thapaliya, Hailee Olson, Haji Mohammad Naimi, and Tara C Smith. Characterizing the molecular epidemiology of staphylococcus aureus across and within fitness facility types. *BMC Infect Dis*, 19(1):69, January 2019.

[2] Nabanita Mukherjee, Scot E Dowd, Andy Wise, Sapna Kedia, Varun Vohra, and Pratik Banerjee. Diversity of bacterial communities of fitness center surfaces in a U.S. metropolitan area. *Int J Environ Res Public Health*, 11(12):12544–12561, December 2014.

[3] R Monina Klevens, Melissa A Morrison, Joelle Nadle, Susan Petit, Ken Gershman, Susan Ray, Lee H Harrison, Ruth Lynfield, Ghinwa Dumyati, John M Townes, Allen S Craig, Elizabeth R Zell, Gregory E Fosheim, Linda K McDougal, Roberta B Carey, Scott K Fridkin, and Active Bacterial Core surveillance (ABCs) MRSA Investigators. Invasive methicillin-resistant staphylococcus aureus infections in the united states. *JAMA*, 298(15):1763–1771, October 2007.

[4] Laura B Johnston, Gabriel M Cox, Neil M Skov, and Kelsi L Anderson. Preliminary report: Evaluation of the effectiveness of essential oil-based cleaners against staphylococcus aureus. *Bios*, 87(3):110–116, 2016.

[5] Faqs | lysol® canada. URL https://www.lysol.ca/en/faqs/.

[6] Kathleen A Ryan, Cristos Ifantides, Christopher Bucciarelli, Heidi Saliba, Sanjeev Tuli, Erik Black, and Lindsay A Thompson. Are gymnasium equipment surfaces a source of staphylococcal infections in the community? *Am J Infect Control*, 39(2): 148–150, March 2011.

[7] John Löfblom, Ralf Rosenstein, Minh-Thu Nguyen, Stefan Ståhl, and Friedrich Götz. Staphylococcus carnosus: from starter culture to protein engineering platform. *Appl Microbiol Biotechnol*, 101(23-24):8293–8307, October 2017.

[8] Iu A Nikolaev, I A Borzenkov, M V Kalinin, N G Loĭko, A L Tarasov, V K Plakunov, S S Beliaev, N V Voronina, V F Gal'chenko, and G I El'-Registan. [antimicrobic features of phenolic lipids]. *Prikl Biokhim Mikrobiol*, 46(2):172–179, March 2010.

[9] Dominique M Missiakas and Olaf Schneewind. Growth and laboratory maintenance of staphylococcus aureus. *Curr Protoc Microbiol*, Chapter 9:Unit 9C.1, February 2013.

[10] Jeffrey K Aronson. *Meyler's side effects of drugs: the international encyclopedia of adverse drug reactions and interactions*. Elsevier, 2015.

[11] E O Ajayi, A P Sadimenko, and A J Afolayan. GC-MS evaluation of cymbopogon citratus (DC) stapf oil obtained using modified hydrodistillation and microwave extraction methods. *Food Chem*, 209:262–266, April 2016.

[12] Randy Schueller. *Sodium Hypochlorite*, volume 7, pages 4022–4023. Gale, Farmington Hills, MI, 5th ed. edition, 2022/8/5/ 2014. URL https://link.gale.com/apps/doc/CX3727802234/GVRL?u=sfu_z39&sid=bookmark-GVRL&xid=c28bc535. Topic overview.

[13] Mat cleansers: Props & accessories: B yoga canada. URL https://byoganow.com/products/b-clean-250ml.

[14] Bronagh Blackwood, Gillian Thompson, Ronan McMullan, Michael Stevenson, Thomas V Riley, Fiona A Alderdice, T John Trinder, Gavin G Lavery, and Danny F McAuley. Tea tree oil (5%) body wash versus standard care (johnson's baby softwash) to prevent colonization with methicillin-resistant staphylococcus aureus in critically ill adults: a randomized controlled trial. *J Antimicrob Chemother*, 68(5): 1193–1199, January 2013.

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The Ergonomics of Perry Chairs: Fit for Canadian University Students

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Abstract

The purpose of this study was to determine whether student seating (Perry chairs) are objectively and subjectively comfortable for Simon Fraser University students. Purposeful sampling occurred within an undergraduate Kinesiology class (BPK 303) to ensure students from both ends of the height range of university students were captured. Students were asked to rate their subjective comfort after sitting in Perry chairs for two hours. Subsequently, six key anthropometric measures were taken (hip breadth, buttock-to-scapula height, lumbar support height, hip angle, buttock-to-popliteal length and popliteal height) and compared to Perry chair dimensions to determine ergonomic fit. 25 BPK 303 students' anthropometrics were collected but only 16 had completed a subjective survey evaluating comfort during a two-hour lecture. Overall mean comfort ratings had a decreasing trend from 5.1/7 at the beginning of lecture to 3.1/7 after lecture. Results showed that only the seat breadth was found to provide adequate ergonomic fit. None of the participants were accommodated by all six of the chair dimensions. However, participants reported no significant change in their subjective comfort ratings before and after the lecture and participants' change in subjective comfort ratings were found to not be correlated to their anthropometric measures ($r = 0.1$; $p = 0.84$). In order to adequately assess the benefits of adjustable chairs and their ability to accommodate university students, future studies should increase the duration students are seated for and sample size, as well as make subjective comfort ratings more specific to the different affected body parts

Keywords — Ergonomics, Perry Chairs, Students, University, Anthropometry

1. Introduction

University students often sit for prolonged periods of time at school hence it is crucial that school furniture accommodate their wide range of anthropometrics. Sitting in inadequate furniture for extended amounts of time could lead to harmful sitting postures and result in poor health outcomes such as musculoskeletal disorders [1, 2, 3]. It has been found that musculoskeletal discomfort earlier in life is a significant risk factor of serious joint problems later in life [4]. Several studies have found linkages between prolonged sitting and back pain as well as a strong relationship between backrest height, chair to ground height and presence of lordosis in female students [5, 6, 7]. A study conducted in 2017 found that most seat heights in university settings were only optimal for 19.6% of participants and were often too low

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for participants causing an increase in kyphotic posture when writing [8]. This lack of good ergonomic fit is a significant concern for students' wellbeing.

Chairs have certain dimensions and ranges that must be satisfied in order to accommodate the diverse SFU student population. The literature identifies four chair dimensions which are critical in assessing the ergonomics of chair design. Seat pan width helps to provide stability for the legs, feet, and back for long periods of time [9]. To be ergonomically fit, the width of the seat pan is dependent on the largest individual so that it can accommodate the majority of the populations' hip breadth [10]. As females tend to have wider hip breadths, chairs are often based on the 95th percentile of female hip breadths [11]. Backrest height provides users support for their lumbar spine and reduces paraspinal muscle activation and muscle fatigue [12, 13]. Carcone and Keir [14] found that backrests can decrease the peak pressure on the back by 35% and lower the average pressure on the back by 20% when sitting on a chair with a backrest than without. It is believed that the height of the backrest should be below the scapula to allow arm and trunk movements and must fit the 5th percentile of females to be classified as ergonomically correct [15]. Lumbar support height (the point on the back that curves in the most) is believed to provide the most support when the height and the shape resembles the height and the curve of the user [16, 17, 18]. Lumbar support height has been discovered to reduce both the sitting load on the lumbar spine and the lumbar muscular activity [19]. Moreover, ergonomically correct lumbar support height reduces lower back and referred leg pain when compared to an unsupported backward slouching posture [18]. Seat pan angle between 90° to 110° is believed to result in a healthier retracted head and neck posture of individuals, improving the alignment of the upper body [10, 20]. As the hip flexion angle decreases, the greater the chances of developing hip abnormalities in the joints [20]. Hip angle is also dependent on popliteal height and buttock-to-popliteal length matching up with the chair's seat pan height and length. An ergonomically adequate hip angle is necessary to maintain and protect the natural curvatures of the spine and reduce the incidence of lower back pain. Although, there are various chair dimensions that must be accounted for, these are the most commonly researched measures in the literature and the biggest contributors to students' wellbeing.

Perry chairs are a type of chair commonly offered on university campuses in study areas, libraries, classrooms, etc. (Fig. 1). Due to their high prevalence on site, they are used regularly and for long periods of time by students. Unfortunately, there is a lack of literature available on whether these chairs are ergonomically fit for university students' anthropometry. In this study, we examined whether Perry chairs are subjectively and objectively ergonomically adequate for university students at SFU based on the seat pan width, backrest height, lumbar support height, and hip angle when seated. We gathered anthropometric measures of students and compared them to the dimensions of the Perry chair. We hypothesized that the seat pan width would be ergonomically adequate, but backrest height, lumbar support height, and height and length of seat pan would not be. We also compared students' objective measures and subjective comfort ratings to Perry chairs, to determine whether the ergonomics of chair dimensions can influence the comfort ratings of the user. We hypothesized that SFU students will report lower comfort ratings as class progresses, especially for individuals who are less

ergonomically fit for the chair.

2. Materials and Methods

2.1. Study Population

SFU students enrolled in BPK 303 class from January 2020 to April 2020 were recruited for the study. They ranged from 18 to 30 years of age which was consistent with the demographics of university students attending SFU. 25 subjects were purposely selected to ensure at least 10(3/25) of the sample consisted of tall individuals and another 10% (3/25) consisted of shorter individuals. The remaining 19 individuals consisted of individuals in the middle to ensure a normal distribution. Unfortunately, due to the COVID-19 pandemic, our data collection was interrupted, causing some participants to have incomplete data for subjective measures.

2.2. Procedures

A survey was created to determine whether students subjectively perceived Perry chairs as comfortable. Students were asked to fill out a quick survey throughout a BPK 303 lecture to rate how comfortable they felt sitting in Perry chairs before the lecture, during the break, and after the lecture. The rating was done on a seven-point Likert scale with one representing very uncomfortable, four representing neutral, and seven representing very comfortable. Change in comfort ratings over time were calculated per person and for the overall population.

Participants were able to get up and leave the chair during the mid-lecture break, which was 10-minutes long. Students who did stand up during the break had to report how long they left their seat for. Participants' anthropometric measures were collected to evaluate the ergonomic fit of the Perry chairs. The chosen anthropometric measures were based on the landmarks endorsed by the International Society for the Advancement of Kinanthropometry and previous research studies to ensure quality and uniformity [21]. Six anthropometric measures were taken: hip breadth, buttock-to-scapula height, lumbar support height, hip angle, buttock-to-popliteal length and popliteal height. Each of the measurements were taken three times and the median value was used for data analysis. All six measurements, except for the hip angle, were taken on a seating surface that allowed the participants' knees to be at 90°. Hip angle was measured when participants sat on a Perry chair. When collecting the data, participants were asked to wear loose fitting clothing and remove their shoes to provide access to essential landmarks used in measurements and increase accuracy. Perry chair measurements and the corresponding sample anthropometrics were compared to determine whether the Perry chairs are ergonomically fit for students (Table 3). Based on the optimal seat dimensions, the proportion of students that fit the criteria was assessed to determine if at least 95% of the sample was accommodated by the Perry chairs.

2.3. Statistical Analysis

Descriptives were taken for objective and subjective measures and a statistical analysis was conducted to determine whether there was a correlation between subjective and objective measures. Histograms were made to examine the trend in the change in comfort ratings over time for all participants and within participants. The mean and standard deviation (sd) were reported. For the objective measures, Perry chair measurements were compared against anthropometric measures to determine whether Perry chairs were ergonomically adequate or objectively comfortable for the 95th to 5th percentile of BPK 303 students. The mean, sd, 5th and 95th percentiles were reported for hip breadth, buttock-to-scapula height, lumbar support height, hip breadth, hip angle, popliteal height and buttock-to-popliteal length. Histograms were also made to examine where the distribution of anthropometrics fell. An alpha level of $p \leq 0.05$ was used as the criterion for statistical significance. Data analysis was conducted using IBM SPSS statistics (version 25.0) and Microsoft Excel 2019.

3. Results

Overall, there were eight males and 17 females that had anthropometric data collected. However, due to missing data, there were only four males and 12 females who had their anthropometric measures linked with their subjective comfort ratings. Participants all ranged from 20 to 25 years of age. Age distribution amongst the total number of participants and linked participants were similar. Females tended to be younger, while males tended to be slightly older. Overall, the age of participants fell into a normal distribution with a mean of 22.3 years ± 1.3 for the total number of participants and 22.4 years ± 1.0 for linked participants (Tab. 1).

Table 1: *Age and gender distribution of sample population. Linked participants are the participants whose anthropometric measures were able to be linked to their subjective measures from the in-class survey.*

Total Number of Participants (N = 95)	**Age (Female)**		**Age (Male)**		**Age (Mixed)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
	22	1.13	23.2	1.37	22.4	1.3
Linked Participants	**Age (Female)**		**Age (Male)**		**Age (Mixed)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
	22.1	1.12	22.6	0.78	22.3	1.04

Participants were asked to rate their comfort on a scale of one (very uncomfortable) to seven (very comfortable) at three separate times during the lecture (at the beginning, during the break and after the lecture). Before the lecture, most participants reported high comfort ratings (75%) with a mean of 5.1 ± 0.9 and range of 3 to 6 (Tab. 2). For those who stood during the break, participants reported high comfort ratings with a mean of 4.8 and those who did not stand had a mean of 4.5. During the lecture, most participants reported a comfort rating of three or four (81%) with a mean of 3.4 ± 0.8 and a range of two to five (Tab. 3). For those who stood during the break, participants reported a mean comfort rating of 3.2 and 3.7 for those who did not stand. After the

Table 2: *Mean and standard deviation of subjects' comfort rating at different times of the lecture.*

Time Measure Was Taken:	Mean Comfort Rating		
	Total (N=16)	Standing (N=9)	Not Standing (N=7)
Before Lecture	5.1	4.8	5.4
During Lecture	3.4	3.2	3.7
After Lecture	3.1	2.7	3.7

lecture, most participants reported a comfort rating of three or four (69%) with a mean of 3.1 ± 1.2 and a range of one to five (Tab. 2). For those who stood during the break, participants reported a mean comfort rating of 2.7 and 3.7 for those who did not stand. Overall, thedistribution for after lecture is very similar to the distribution of comfort ratings taken during the lecture.

For the overall sample, on average, the change in comfort ratings over time was -2.0 for after lecture to before lecture. However, there was only a -0.3 decrease between after lecture and during lecture and a -1.7 decrease in comfort ratings between during and before lecture. Over time, participants showed an overall decreasing trend in comfort ratings throughout the duration of the lecture. Students were also provided a ten minute break during the halfway mark and students had the option to remain in their seats or stand up. 43% (7/16) of participants did not stand up during the break. Three individuals stood up for five minutes, three individuals stood up for seven minutes and three individuals stood up for ten minutes. A Spearman's rank-order correlation was calculated to determine whether there was a significant difference for changes in comfort rating within individuals and how long individuals stood up during the break. Results showed a correlation of $r = 0.38$ ($p = 0.15$) which was deemed non-significant.

The Perry chair has a backrest height of 40.2cm. Participants' buttock-to-scapula height had a mean of 44.5cm ± 4.3. The 5th percentile of the buttock-to-scapula height distribution was 33.5cm and the 95th percentile was 50.9cm (Tab. 3). The Perry chair was found to not be ergonomically adequate as it did not accommodate the 5th percentile. However, it accommodated 96% of the sample. In terms of lumbar support height, the sample had a mean height of 29.9cm ± 3.7 (Fig. G-7). The 5th percentile of the lumbar support height distribution was 23.1cm and the 95th percentile was 38.4cm (Tab. 3). Lumbar support height of the chair was 26.3cm and matched up with 12% of the sample (3/25). The Perry chair was found to not be ergonomically adequate for the 5th to 95th percentile.

Three measurements were taken to assess the seat pan: hip breadth, buttock-to-popliteal length, and popliteal height. The sample had a mean hip breadth of 28.5cm ± 4.0. The 5th percentile of the hip breadth distribution was 22.5cm and the 95th percentile was 37.5cm (Tab. 3). After adding an additional 10% for thigh width to the sample's hip breadth measures, Perry chairs were found to be ergonomically adequate for all participants in terms of seat width. For popliteal height, the sample had a mean of 43.1cm ± 3.0. The 5th percentile of the distribution was 38.6cm and the 95th percentile was 49.4cm (Tab. 3). The seat pan height was 45.6cm. Therefore, the Perry chair was found to not be ergonomically adequate as it accommodated only 40% of the sample and not the 5th percentile (10/25) in terms of seat height. Buttock-to-popliteal length

of the sample had a mean length of 47.2cm ± 5.5. The 5th percentile of the buttock-to-popliteal length distribution was 32.9cm and the 95th percentile was 54.1cm (Table 3). The seat pan length of the Perry chair was 45.6cm. Therefore, the Perry chair was found to not be ergonomically adequate as it did not accommodate the 5th percentile for seat pan length. Buttock-to-popliteal length only accommodated 72% of the sample (18/25). The final measure, hip angle, was determined by measuring participants' natural hip angle when seated. The 5th percentile of the hip angle distribution was 88° and the 90th percentile was 116°. The mean of 104° ± 7.7, the chair's seat angle only accommodated 64% of the sample (16/25) (Tab. 3). Thus, the seat pan was found to be ergonomically inadequate in all dimensions except for seat pan width.

Table 3: *Descriptive Statistics for Anthropometric Measurements.*

Chair Dimensions	Anthropomorphic Measure	Mean	SD	5th Percentile	95th Percentile	Chair Dimension	Optimal Chair Dimension	Fit (Y/N)
Chair Seat Pan Width	Hip Breadth	28.5 cm	4.0 cm	22.5 cm	37.5 cm	46.4 cm	41.25 cm	Y
Chair Backrest Height	Buttock-to-Scapular Height	44.5 cm	4.3 cm	33.5 cm	50.9 cm	40.2 cm	<33.5 cm	N
Chair Lumbar Support Height	Lumbar Support Height	29.9 cm	3.7 cm	33.5 cm	38.4 cm	26.3 cm	Same as participants	N
Chair Angle	Measured Hip Angle	104°	7.7°	88°	116°	100°	90-100°	N
Chair Seat Pan Length	Buttock-to-Popliteal Length	47.2 cm	5.5 cm	32.9 cm	54.1 cm	45.6 cm	32.9 cm	N
Chair Seat Height	Popliteal Height	43.1 cm	3.0 cm	38.6 cm	49.4 cm	45.6 cm	36.67 cm	N

Several Spearman's rank-order correlations were calculated to determine whether there was a correlation between comfort rating changes within individuals and the number of anthropometric measures that were ergonomically fit for the Perry chair. Participants' anthropometric measures that fell in the ergonomically adequate range for the Perry chair dimensions were coded as 1, and those who fell outside of the range were classified as 0. Change in comfort ratings were based on the change in comfort rating from after lecture and right before lecture began. A correlation of $r = 0.1$ ($p = 0.8$) was found for all six anthropometric measures. The change in reported comfort ratings and how ergonomically fit participants were, was found to be non-significant for both. Seven independent Spearman's rank-order correlations were calculated to determine whether there was a significant difference between comfort rating changes for individuals and their specific anthropometric measures. Analysis obtained correlations ranging from $0.01 \leq r \leq 0.3$ ($0.67 \leq p \leq 0.2$) (Tab. 4). Although none of the anthropometric measures were found to be significantly correlated to comfort ratings, there was a moderate correlation for lumbar support height ($r = 0.3$, $p = 0.3$) and buttock-to-popliteal length ($r = 0.3$, $p = 0.2$) (Tab. 4). Popliteal height was also found to have a weak correlation to comfort ratings ($r = 0.13$, $p = 0.63$) (Ta. 4). Additional Spearman's rank-order correlations were calculated to determine whether there was a significant difference between comfort rating changes and demographics. Analysis obtained for gender found a correlation of -0.46 ($p = 0.07$) which was moderate but non-significant. Analysis obtained for age found a correlation of -0.06 ($p = 0.84$) which was non-significant.

4. Discussion

The aim of this study was to determine whether Perry chairs are ergonomically fit for students both objectively and subjectively. The results of this study show that when sitting on a Perry chair for over a two-hour period, there was no significant change in

Table 4: *Results of Spearman's Rank Order Correlation Coefficients for the change in comfort and anthropometric measures.*

Anthropomorphic Measure	Spearman's Rank Order Correlation Coefficients	P-Value
Buttock-to-Scapula Height	0.059	0.827
Lumbar Support Height	0.297	0.265
Hip Angle	-00116	0.669
Popliteal Height	0.130	0.631
Buttock-to-Popliteal Length	-0.331	0.210

terms of subjective comfort for participants. However, in terms of anthropometric measures, students were only adequately accommodated by seat pan width. Furthermore, the ergonomics of chair design were not correlated to the subjective comfort ratings. Due to the COVID-19 pandemic that unexpectedly interrupted our data collection, we could not collect survey responses concerning subjective comfort levels from all participants that provided us with anthropometric measures. Additionally, we couldn't achieve a normal distribution with our data set due to the participants with missing anthropometric and subjective measures being taller individuals. Change in subjective comfort ratings and demographics was found to be non-significant, while there was a moderate correlation for gender. Male participants reported a minor change while females tended to report a greater change in their comfort ratings. However, our sample may not be representative of males due to the small sample size. Nevertheless, future analysis should consider gender as a possible confounding factor in subjective comfort ratings.

4.1. Subjective Comfort Ratings

The results of this study show that there was a decrease in participants' overall and individual comfort ratings throughout the lecture, although this decrease was not significant. However, it is important to consider potential for biases from participants when collecting subjective measures. For example, there may be human error in participants self-reporting their comfort ratings, such as forgetting to record the comfort rating or the length of time they spent standing during the break. Additionally, individuals may unintentionally record a trend in their comfort rating since they are informed of the aims of the study prior to their participation. There may be other factors that hinder the accuracy of the comfort rating such as the desk height and the eye height when sitting on the Perry chair. As our survey only asked students for comfort ratings of the chair, it fails to address other elements of the classroom as well as the specificity of the chair. Future research is recommended to identify Perry chairs' compatibility to other university furniture as well as include a section where participants can record their comfort ratings for certain body parts to allow for more specificity.

4.2. Anthropomorphic Measures

The results of this study show that the Perry chair was not ergonomically fit for most of the dimensions that we measured students for. Perry chair seat pan width can

accommodate the 100th percentile of participants' hip breadth, however, the other dimensions measured in this study were not able to accommodate students. Hip angle is highly dependent on how the subject sits and if they are able to reach the backrest comfortably. It is also possible that there might have been some bias due to the Hawthorne Effect as individuals may exhibit better posture in the lab than in real world settings [22]. Shoes were also asked to be taken off to allow accurate measurements however, this may imply that our results are not representative of real-world applications as students typically wear shoes when seated in Perry chairs. Participants may have even bigger differences in their hip angle, than what is observed, outside of a lab setting. Majority of participants were also not accommodated by the popliteal height and the buttock-to-popliteal length which can affect hip angle. When the popliteal height is smaller than the height of the seat pan, the subject will have a hip angle that is greater than 90°. Additionally, participants will have hip angles significantly greater than 90° if they are sitting at the front of the chair as they tend to lean towards the backrest. As Perry chairs implement a sloped edge seat pan, it allows a natural increase in hip angle for those who do not fulfill the popliteal height requirement [23]. However, this sloped edge still is not able to accommodate the majority of students. In terms of the seat backing of the chair, the results of this study show that the Perry chair backrest height does not meet the ergonomic standard for accommodating the sample's buttock-to-scapula height and lumbar support height. Many studies have identified the backrest height of university furniture to not be ergonomically fit for university students [15, 24]. Backrest as part of a chair design is considered appropriate when it is below the scapula because it allows the movement of arms and trunk [15]. Failure to accommodate the smallest individual, or the 5th percentile, may result in decreased effects on both student performance and physical responses [1]. Another key aspect of the backrest is lumbar support height which has been shown to reduce both the sitting load on the lumbar spine and the lumbar muscular activity when lumbar support height matches the chairs' lumbar support height [19]. It is recommended that chairs should allow for adjustability in the lumbar support depth and height to allow the sitter to match it to their lumbar curves. However, lumbar support height is something that is hard to accommodate everyone with through non-adjustable equipment hence, our results show that no one was accommodated by the chairs' lumbar support height. As students in university range in heights and distributions, exploration of adjustable chairs prior to future furniture decisions should be made to reflect the need for back support that is adjustable for the diverse body types of SFU students.

5. Conclusion

Overall, our study showed that Perry chairs may not be ergonomically adequate for SFU university students as hip breadth was the only measure considered to have adequate ergonomically fit. Buttock-to-popliteal length and buttock-to-scapula height were found to be ergonomically adequate for 96% of all participants in the study. However, none of the participants were accommodated by all of the Perry chair dimensions investigated in the study. Furthermore, we found that participants' subjective comfort ratings were

not correlated to anthropometric measures and there was no specific anthropometric measure that had a higher impact on subjective ratings of comfort. Future studies may wish to examine the change in comfort ratings between various chair types or examine the impact of various chair materials on subjective comfort ratings, as well as other furniture such as desks and tables. Future studies should also look at a larger and more representative sample with a longer sitting period when investigating trends in subjective comfort ratings. Additionally, adjustable seating in universities should be investigated as it has the potential to accommodate the diverse student population [14, 16, 17, 19]. Measures like lumbar support height are not easily accommodated in static chair designs. Wang et al. [16] found that adjustment functions of chairs can enhance comfort and decrease risk of musculoskeletal injuries. Similarly, Coleman et al. [17] found that a significant number of participants would adjust the lumbar support height to meet the ergonomic recommendations when the option was provided. They also advised that the adjustment tool should be made accessible and user-friendly for the sitter. Overall, our study found that Perry chairs at SFU may not ergonomically accommodate the majority of students and that further research should be done to ensure better health outcomes and satisfaction for students.

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References

[1] H I Castellucci, P M Arezes, J F M Molenbroek, R de Bruin, and C Viviani. The influence of school furniture on students' performance and physical responses: results of a systematic review. *Ergonomics*, 60(1):93–110, April 2016.

[2] Morgana Mongraw-Chaffin, Alka M Kanaya, Namratha R Kandula, Arti Shah, and Cheryl A M Anderson. The relationship between anthropometry and body composition from computed tomography: The mediators of atherosclerosis in south asians living in america study. *Ethn Health*, 22(6):565–574, October 2016.

[3] Valerie Rice, Hal Hendrick, Karen Jacobs, Rani Lueder, Jake Pauls, Michael Wogalter, and ConneMara Bazley. Ergonomics for children: Forward directions. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 52, pages 758–762. SAGE Publications Sage CA: Los Angeles, CA, 2008.

[4] C Parcells, M Stommel, and R P Hubbard. Mismatch of classroom furniture and student body dimensions: empirical findings and health implications. *J Adolesc Health*, 24(4):265–273, April 1999.

[5] Samira Baharampour, Jalil Nazari, Iman Dianat, and Mohamad Asgharijafarabadi. Student's body dimensions in relation to classroom furniture. *Health Promot Perspect*, 3(2):165–174, December 2013.

[6] Kath D Watson, Ann C Papageorgiou, Gareth T Jones, Stewart Taylor, Deborah P M Symmons, Alan J Silman, and Gary J Macfarlane. Low back pain in schoolchildren: occurrence and characteristics. *Pain*, 97(1-2):87–92, May 2002.

[7] M Shariati and A and Naderi. The relationship between chair dimensions and musculoskeletal disorders among female students in one academic branch. *Journal of Occupational Health and Epidemiology*, 5(2), 2016. doi:10.18869/acadpub.johe.5.2.63. URL http://johe.rums.ac.ir/article-1-200-en.html.

[8] J Van Houcke, A Schouten, G Steenackers, D Vandermeulen, C Pattyn, and E A Audenaert. Computer-based estimation of the hip joint reaction force and hip flexion angle in three different sitting configurations. *Appl Ergon*, 63:99–105, April 2017.

[9] Yolandi Brink, Quinette Louw, Karen Grimmer, and Esmè Jordaan. The spinal posture of computing adolescents in a real-life setting. *BMC Musculoskelet Disord*, 15:212, June 2014.

[10] Chanda Nelofer Khanam, Mahalakshmi V Reddy, and A Mrunalini. Designing student's seating furniture for classroom environment. *Journal of Human Ecology*, 20(4):241–248, 2006.

[11] Ismail Wilson Taifa and Darshak A. Desai. Anthropometric measurements for ergonomic design of students' furniture in india. *Engineering Science and Technology, an International Journal*, 20(1):232–239, 2017. ISSN 2215-0986. doi:https://doi.org/10.1016/j.jestch.2016.08.004. URL https://www.sciencedirect.com/science/article/pii/S2215098616304578.

[12] T Bendix, V Poulsen, K Klausen, and C V Jensen. What does a backrest actually do to the lumbar spine? *Ergonomics*, 39(4):533–542, April 1996.

[13] Máire Curran, Leonard O'Sullivan, Peter O'Sullivan, Wim Dankaerts, and Kieran O'Sullivan. Does using a chair backrest or reducing seated hip flexion influence trunk muscle activity and discomfort? a systematic review. *Hum Factors*, 57(7): 1115–1148, July 2015.

[14] Steven M Carcone and Peter J Keir. Effects of backrest design on biomechanics and comfort during seated work. *Appl Ergon*, 38(6):755–764, February 2007.

[15] M K Gouvali and K Boudolos. Match between school furniture dimensions and children's anthropometry. *Appl Ergon*, 37(6):765–773, January 2006.

[16] Bo Wang, Xiaopin Jin, Bo Cheng, and Zhenshuo Fang. Optimal lumbar support prediction using intereface pressure. In *2011 International Conference on Electric Information and Control Engineering*, pages 2433–2436. IEEE, 2011.

[17] Anne L Coleman, Katie Stone, Susan K Ewing, Michael Nevitt, Steven Cummings, Jane A Cauley, Kristine E Ensrud, Emily L Harris, Marc C Hochberg, and Carol M Mangione. Higher risk of multiple falls among elderly women who lose visual acuity. *Ophthalmology*, 111(5):857–862, May 2004.

[18] E N Corlett. Background to sitting at work: research-based requirements for the design of work seats. *Ergonomics*, 49(14):1538–1546, November 2006.

[19] Mohsen Makhsous, Fang Lin, James Bankard, Ronald W Hendrix, Matthew Hepler, and Press, Joel. Biomechanical effects of sitting with adjustable ischial and lumbar support on occupational low back pain: evaluation of sitting load and back muscle activity. *BMC Musculoskelet Disord*, 10:17, February 2009.

[20] Stuart J Horton, Gillian M Johnson, and Margot A Skinner. Changes in head and neck posture using an office chair with and without lumbar roll support. *Spine (Phila Pa 1976)*, 35(12):E542–8, May 2010.

[21] Ward R. Kinanthropometry, 2013.

[22] Philip Sedgwick and Nan Greenwood. Understanding the hawthorne effect. *BMJ*, 351:h4672, September 2015.

[23] Nse A Odunaiya, Dolapo D Owonuwa, and Oluwafemi O Oguntibeju. Ergonomic suitability of educational furniture and possible health implications in a university setting. *Adv Med Educ Pract*, 5:1–14, January 2014.

[24] A. S. M. Hoque, M. S. Parvez, P. K. Halder, and Tamas Szecsi. Ergonomic design of classroom furniture for university students of bangladesh. *Journal of Industrial and Production Engineering*, 31:239 – 252, 2014.

[25] I Hapsari Susilowati and C Satrya. The comparison of anthropometry data of undergraduate students and desk chairs in the faculty of public health, universitas indonesia. *KnE Life Sciences*, 4(4):483–491, May 2018. doi:10.18502/kls.v4i4.2310. URL https://knepublishing.com/index.php/KnE-Life/article/view/2310.

7. Appendix

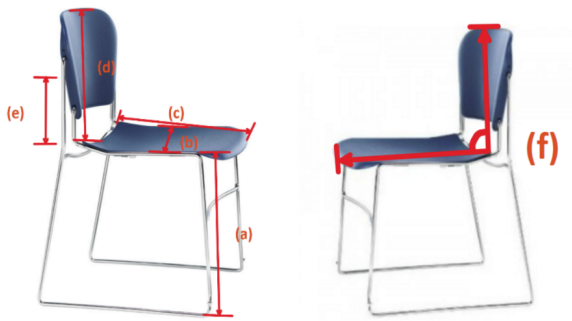

Figure 1: *Visual representation of: (a) Chair Seat Height, (b) Chair Seat Pan Width, (c) Chair Seat Pan Length, (d) Chair Backrest Height, (e) Chair Lumbar Support Height, (f) Chair Angle.*