EMBRACING INNOVATION: EMPOWERING OCCUPATIONAL THERAPY POST-STROKE REHABILITATION WITH EXOSKELETONS

A Thesis submitted to the faculty at Stanbridge University in partial fulfilment of the requirements for the degree of Master of Science in Occupational Therapy

by

Rachel Glozman, Casey Hayes, and Haley Michaels

Thesis advisor: Lena Huang, OTD, OTR/L

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Certification of Approval

I certify that I have read *Embracing Innovation: Empowering Occupational Therapy Post Stroke Rehabilitation with Exoskeletons* by Rachel Glozman, Casey Hayes, and Haley Michaels, and in my opinion, this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Occupational Therapy at Stanbridge University.

Lena Huang, OTD, OTR/L

Instructor of Occupational Therapy

ACCEPTED 

Myka Persson, OTD, OTR/L

Program Director, Master of Science in Occupational Therapy

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Abstract

Stroke, a leading cause of disability in the United States, significantly impacts patients' quality of life by inducing physical, economic, and social challenges. Many stroke survivors suffer residual deficits, notably in their arms and hands, which reduces their independence and overall quality of life. With a growing aging population, there is an urgent need to broaden neurorehabilitation strategies addressing stroke impacts. Upper extremity exoskeletons are an emerging technology with promising implications for post-stroke rehabilitation programs. When integrated with EMG sensors, they can detect muscle activation patterns and provide assistive movement (Trigili et al., 2019). A more profound comprehension of exoskeletons among occupational therapy practitioners (OTPs) is fundamental to enhancing their use in neurorehabilitation and promoting functional mobility and patient engagement in daily activities. Our study provides insights into perceptions surrounding exoskeleton use in post-stroke occupational therapy practices. We contribute to the growing body of literature on this topic and propose strategies for integrating exoskeleton technology. We uncovered a notable gap in knowledge and training among OTPs concerning exoskeleton technology. Our research revealed that an increased familiarity with exoskeleton technology in occupational therapy practice is associated with a growing awareness of its potential benefits and limitations. We found that the cost of exoskeleton technology, current designs, and usability, along with the lack of training opportunities for OTPs to learn how to incorporate them into practice were identified as major barriers to their adoption. Our research shows that increases in familiarity with the current research landscape are associated with increased willingness to incorporate this technology into practice. This

uncovers a knowledge gap that underscores the necessity for enriched educational resources and training. We suggest specialized training programs, workshops, and online resources to enhance therapists' expertise and confidence in employing exoskeletons. We consider financial challenges and advocate for policies favoring the inclusion of exoskeleton technology in rehabilitation plans. We also highlight the need for a diverse research approach towards exoskeletons in post-stroke intervention and encourage collaborations and funding opportunities for exoskeleton-centric research. This initiative aims to enhance the acceptance and implementation of this technology in occupational therapy practice, thereby improving post-stroke patient outcomes.

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Embracing Innovation: Empowering Occupational Therapy Post-Stroke Rehabilitation with Exoskeletons

Stroke survivors often suffer from upper extremity impairments that impact their functional independence and quality of life (Baby et al., 2021). Traditional rehabilitation approaches have shown efficacy but may not provide the targeted and intensive therapy needed for optimal recovery (Ambrosini et al., 2019). Recent advancements in exoskeleton technology offer a promising solution to address the limitations of traditional therapy. Exoskeletons are wearable devices designed to assist and augment a person's movements, allowing for repetitive and task-oriented therapy. Perry et al. (2021) demonstrated that exoskeleton-assisted therapy improves shoulder flexion performance after stroke. Similarly, studies conducted by Hung et al. (2019) and Lee et al. (2021) support the positive effects of robot-assisted therapy in improving upper extremity functioning in individuals with chronic stroke. When integrated with EMG sensors, they can detect muscle activation patterns and provide assistive movement (Trigili et al., 2019). Despite the promising evidence from research studies, adopting exoskeleton technology in routine clinical practice still needs improvement. Occupational therapy practitioners (OTPs) face a significant challenge in effectively integrating exoskeleton technology into post-stroke rehabilitation; one significant barrier is the cost associated with acquiring and maintaining exoskeleton devices, as highlighted in the study by Gorgey (2018). The high initial investment and ongoing maintenance expenses associated with these devices may pose financial constraints for healthcare facilities.

In addition to cost concerns, OTPs may need help with usability, design limitations, and the lack of training opportunities for incorporating exoskeletons into practice. Mendonca et al. (2022) emphasize the importance of providing adequate training and support to therapists to integrate exoskeleton technology into their rehabilitation programs successfully. The study's emphasis on evaluating the effectiveness and dosage of robotic interventions for adults with chronic stroke indicates the need for OTPs to be well-trained on this topic.

The American Occupational Therapy Association (AOTA) and the American Occupational Therapy Foundation (AOTF) Research Agenda highlights the need for evidence-based practices to optimize client outcomes, underscoring the need for further research around the use of exoskeleton technology in stroke rehabilitation contexts. The research agenda emphasizes the importance of translational research, including research relating to the implications of novel developments in sciences related to occupational therapy (OT) for the science and practice of OT (AOTF & AOTA, 2018). Our findings can provide valuable insights for OTPs, enabling them to incorporate exoskeleton technology into their post-stroke rehabilitation programs effectively.

To bridge the gap between research findings and clinical practice, our thesis explores the factors contributing to the underutilization of exoskeleton technology in OT for post-stroke rehabilitation. By surveying OTPs, we have gained insights into their familiarity with exoskeleton technology, their knowledge of ongoing research, and their perspectives on potential barriers hindering its implementation. By synthesizing the findings from our survey with existing literature, our thesis provides evidence-based strategies for OTPs to integrate exoskeleton therapy into their treatment plans effectively. This integration will ultimately facilitate better patient outcomes and advance the field of OT by embracing technologically advanced approaches to post-stroke rehabilitation.

Statement of the Problem

Stroke accounted for nearly one in every six deaths from cardiovascular disease in 2020, with a stroke-related death occurring approximately every four minutes (Centers for Disease Control and Prevention, 2022). Survivors of a stroke are often left with chronic debilitating symptoms. Post-stroke disability impacts patients' quality of life, leading to socioeconomic and social challenges. Among survivors, 50-70% experience residual deficits, particularly affecting their upper extremities, leading to reduced independence and quality of life (Aydilek et al., 2022). The International Classification of Functioning, Disability, and Health for Stroke provides a framework for assessing stroke survivors that encompasses body structures, body functions, activities and participation, and environmental factors (Geyh et al., 2004). OT plays a crucial role in stroke rehabilitation by addressing activities of daily living (ADLs) and instrumental ADLs, enabling post-stroke patients to maintain self-sufficiency in various environments (Aydilek et al., 2022).

Upper limb exoskeletons are being explored as potential solutions for post-stroke deficits, such as increased joint range of motion, mobility, function, and spasticity reduction. While there is limited evidence on the efficacy of exoskeletons from studies conducted by Singh et al. (2021), Taravati et al. (2021), and Lee et al. (2021), patients who have used upper limb exoskeletons as adjuncts to rehabilitation have demonstrated positive results. A study by Frisoli et al. (2012) showed that rehabilitation treatment in the chronic phase after stroke improved motor performance, reduced spasticity, enhanced movement execution, and indicated potential muscle plasticity even years after the stroke event, highlighting the importance of multi-joint and 3D spatial movements in upper-limb stroke rehabilitation. Flynn et al. (2019) demonstrated optimistic perceptions among clinical professionals regarding exoskeleton use in stroke survivors. However, more research is needed on proactive solutions to enhance the implementation of this technology into OT practice.

The significance of this problem for OT lies in its potential to address function, adaptation, and occupational performance for stroke survivors. The OT practice framework emphasizes addressing clients' occupational needs to promote meaningful participation in ADLs (AOTA, 2020). Integrating upper limb exoskeletons into post-stroke rehabilitation allows therapists to target functional goals, helping clients regain motor control and strength for performing ADLs and instrumental ADLs (Geyh et al., 2004). The need for research on this topic is evident from the limited availability of comprehensive studies on integrating exoskeleton technology into OT practice.

The existing gap in the literature underscores the imperative of investigating strategies to facilitate the integration of exoskeleton technology into OT practice. To address this, our research employs a survey of OTPs to understand their level of familiarity with exoskeleton technology, assess their perceptions regarding its potential advantages and constraints, and formulate strategic recommendations for the effective adoption of exoskeletons in contemporary and future OT practice.

Literature Review

The adoption of robotic technology in post-stroke rehabilitation, particularly upper limb exoskeletons, has emerged as a promising avenue for enhancing motor functions and quality of life for stroke survivors. Understanding the current state of knowledge in this area sheds light on the effectiveness of robotic interventions and informs strategies for enhancing their implementation, ultimately improving outcomes for stroke survivors. Two themes emerge in the literature, the first regarding the effectiveness of exoskeletons and robotic technology in stroke rehabilitation and the second regarding OTPs' perceptions of exoskeletons and robotic technology in stroke care.

Effectiveness

Several studies detail various aspects of upper limb robotic rehabilitation for stroke survivors. Taravati et al. (2021) conducted a randomized controlled study emphasizing a rigorous experimental design that employed random assignment to minimize bias and establish causal relationships between robotic therapy and improvements in post-stroke impact areas. Their study evaluated the effects of an upper limb robotic rehabilitation program on motor functions, quality of life, cognition, and emotional status. While the findings demonstrated improvements across these dimensions, the limitations of a small sample size and a four-week intervention period raised questions about the long-term sustainability of these gains. Nevertheless, Taravati et al.'s study underscores the importance of addressing quality of life, cognition, and emotional well-being alongside motor functions in post-stroke interventions.

Lee et al. (2021) performed a randomized, crossover-controlled study that showcased significant improvements in upper extremity motor control and ADLs in stroke survivors undergoing robot-assisted therapy. Although their study's design and objective outcome measures added strength to their findings, the absence of a comparison group receiving conventional therapy left the question of efficacy over traditional rehabilitation methods unanswered. Lambercy et al. (2011) conducted a study that explored robot-assisted grasp and pronation/supination training in chronic stroke survivors, which revealed promising results in improved hand and arm motor functions. Their focus on functional training and standardized motor assessment scales strengthened their findings. However, the absence of a comparison group and a relatively small sample size posed potential limitations and an increased margin of error.

In a systematic review, Grefkes and Fink (2020) examined stroke recovery concepts and future perspectives. The strengths of this review lie in its extensive coverage of the topic and its implications for rehabilitation strategies. It provides a valuable context for understanding the potential role of robotic technology in post-stroke rehabilitation. Singh et al. (2021) conducted a systematic review and meta-analysis highlighting the overall positive effects of upper limb robotic-assisted therapy on motor functions and ADLs. Their systematic approach and robust analysis added credibility, though variations in study designs and outcome measures among the included studies introduced heterogeneity, limiting its generalizability.

Perceptions

Flynn et al. (2019) delved into the perceptions of physical therapists and OTPs regarding using robotic exoskeletons in stroke rehabilitation. Their study revealed an optimistic attitude among therapists toward adopting exoskeletons, indicating an acceptance of robotic technology among OTPs. The article exposed a need for further insights into therapists' specific challenges when integrating robotic interventions into their practice.

Mashizume et al. (2021) conducted a qualitative study investigating OTPs' perceptions of using robotics in occupational therapy for chronic stroke patients. The research included semi-structured focus group interviews with 27 OTPs in Japan who had experience in using robotics with chronic stroke patients as a self-training method that involved repetitive movements of a paralyzed upper extremity. These OTPs viewed robotics as an adjunct to other therapies. They felt the technology could enhance patient body function and foster their desire for independence. They reported that their patients demonstrated improved upper extremity function, pain reduction, and trunk. This success in therapy further motivated them to engage in activities that were previously disrupted by stroke-related complications. The study highlighted how improved body function and a sense of agency gained through robotics training enhanced occupational performance and increased participation in desired occupations. OTPs tailored robotics to individual patient needs and goals, promoting improved body function, enhanced occupational performance, and greater participation in meaningful activities.

Flynn et al. (2019) and Mashizume et al.'s (2021) research underline robotics' potential as a valuable tool in occupational therapy, contributing to optimized patient outcomes and highlighting the profession's adaptability in embracing technological advancements. When applying these findings, it is crucial to consider the specific context and limitations. Generalizing results beyond Japan or the specific robotic systems used in their interventions should be done cautiously. Further research involving diverse samples and various robotic systems is necessary to comprehensively understand the applicability and effectiveness of robotic therapy in different cultural and healthcare settings.

Statement of Purpose, Research Questions, Hypothesis

The main objective of our study is to investigate OTP's perceptions of exoskeleton use as a post-stroke intervention and to develop strategies to promote their use. In order to accomplish this, we conducted a survey to collect insight from 18 OTPs on various related concerns. One of our key research questions focused on exploring the educational resources and training opportunities available to OTPs regarding exoskeleton technology. By gaining insights into the current state of educational support, we were able to propose strategies to enhance the availability and quality of resources for therapists. We also examined the financial implications of adopting this technology. By analyzing responses to our survey questions, we could identify challenges related to insurance coverage. In addition to educational and financial-related strategies, we aim to examine the perceptions of existing research. By assessing OTPs' perspectives on the availability and quality of research in this area, we were able to propose strategies to encourage more robust and diverse research efforts.

We hypothesized that OTPs' perspectives and experiences would provide valuable insights into practical strategies for enhancing the adoption of exoskeleton technology in post-stroke rehabilitation. The findings from our study contribute to a growing body of research devoted to advancing stroke rehabilitation practices, hopefully translating into clinical practice that results in improved functional outcomes and overall well-being for stroke survivors.

Theoretical Framework

We used the Model of Human Occupation (MOHO) as our frame of reference for this study because it emphasizes how the relationship between a person’s volition, habits, and performance capacity impacts their occupational performance (Forsyth et al., 2019). MOHO is a widely recognized theoretical framework in the OT community because it comprehensively understands how individuals engage in meaningful occupation. MOHO explains how occupations are chosen, patterned, and performed. MOHO examines how participation in occupations contributes to one's sense of identity and competency. MOHO suggests that when someone is engaging in an occupation, that person's characteristics are interacting with the environment. This dynamic interplay between person, environment, and occupation is crucial for understanding OT's role in a client's life.

As conceptualized by MOHO, three critical elements of the person are volition, habituation, and performance capacity (Forsyth et al., 2019). Volition, as defined within the MOHO frame of reference, refers to the motivational elements that guide one's exploration of one's environment and interests. The concept of volition assumes that all people desire to participate in occupations, this desire being shaped by their previous experiences. The cycle of volition—anticipating the possibilities for doing, deciding what to do, the experience of doing, and the later interpretation of the experience—is shaped by personal factors, including personal causation, the individual's values, and their interests.

Habituation refers to the roles, routines, and habits of an individual (Forsyth et al., 2019). An individual's roles are a crucial element of their identity, as they show the lens through which one sees oneself (as a teacher, student, mother, computer analyst, etc.). Along with habits, a person's roles largely dictate how they regularly interact with their physical and social environments. As an OTP, it is essential to note that when a person's habitation is disrupted or impacted by a medical event or illness, they can perceive a significant loss of what gave their life stability and meaning. Individual performance capacity refers to one's physical and mental abilities, which underlie one's occupational performance. While this aspect is considered in all theoretical frameworks, MOHO emphasizes how people perceive their bodies and the world around them concerning their impairment.

The MOHO framework broadly conceptualizes OT as a "process in which practitioners support client engagement in occupations to shape the clients' choices, their routine ways of doing things, and their skills" (Forsyth et al., 2019). This applies to exoskeleton use in post-stroke rehabilitation. Implementing the technology in a client's recovery plan allows individuals to exercise their volition, maintain their habits, and improve their changed performance capacity through rehabilitative and adaptive uses. When determining if an individual is a good fit for exoskeleton use, the OTP should assess the individual's motivation and personal matters related to regaining independence and mobility and participating in meaningful activities. This can help the OTP formulate a plan that aligns with the individual's goals and desires and ensure that using an exoskeleton in rehabilitation will enhance the client's ability to exercise their volition.

An OTP should also evaluate an individual's daily patterns and habits as impacted by a stroke. By understanding the disruptions caused by the stroke and considering the use of exoskeletons as a potential intervention, the therapist can formulate a plan that integrates the exoskeleton into the individual's daily activities, roles, and routines, allowing the patient to maintain their sense of identity. Increasing an OTP's awareness of the exoskeleton technology's rehabilitative and adaptive capacities could help promote efficient practice. An OTP should also assess the individual's physical capabilities when considering exoskeleton use as a potential therapy modality. This includes strength, balance, coordination, and endurance. This evaluation helps determine the suitability of exoskeleton use. It guides the development of an intervention plan considering the individual's performance capacity, which aligns with the patient-centered care that OTPs offer.

Methodology

Design

Our study used a mixed-methods design in the form of an online survey. Participants were recruited using social media platforms, discussion forums, and personal connections with colleagues and peers. All participants provided written informed consent.

Participants

Participants were recruited between September 9, 2023, and October 4, 2023. To participate in our study, all participants were required to be either a licensed and registered occupational therapist or certified occupational therapy assistant and have access to the internet. All other allied health professionals were excluded, as were occupational therapy students, unless they were simultaneously currently practicing OTPs and attending school. A total of 18 OTPs completed the survey.

Procedure

The data instrument for this study was a survey created using Google Forms. Participants were provided with a survey link and asked to complete it online. The survey consisted of questions related to using exoskeletons in OT practice, including strategies used and challenges faced. The survey contained 11 questions and took approximately 10-15 minutes to complete.

We composed a list of survey questions that included a combination of Likert-scale scoring and an open-ended question, creating a mixed-methods research design.

The Likert-scoring portion of the survey provided quantitative data that allowed us to identify patterns and visualize the findings. The open-ended question gave us valuable qualitative data for a comprehensive and in-depth understanding of the participant's answers. The survey questions targeted OTPs' current perceptions of exoskeleton use, limitations, perceived barriers, and strategies for its implementation into practice. A survey was chosen as the research instrument to increase the sample size. This form of data collection is less invasive and time-consuming, imposing minimal inconvenience to participants' schedules. Upon the determined closing date of the survey, we identified common themes in the results.

Outcome Measures

The survey outcomes were focused on the strategies developed for implementing exoskeleton use in OT practice and the burdens that OTPs face when using exoskeletons. They explored the potential effectiveness of different implementation strategies and identified challenges and barriers encountered by OTPs.

The survey outcomes included quantitative and qualitative data on using exoskeletons in OT practice. The survey questions were designed to capture various aspects of this topic, allowing for a comprehensive analysis. For the quantitative outcomes, a rating scale ranging from 1 to 10 was used to gather data. The numerical data obtained from the rating scale responses allowed for quantitative analysis, including calculations of mean and statistical comparisons. In addition to the quantitative outcomes, the survey included an open-ended question to gather qualitative data. This open-ended question allowed OTPs to provide detailed responses and insights regarding their experiences with exoskeleton implementation. The qualitative data captured rich and nuanced information about OTPs' challenges, successes, and specific strategies.

Data Analysis

For quantitative data (i.e., Likert-scale scoring), the Stanbridge University statistician assisted us in the computation of inferential and descriptive statistics and charts and graphs that helped us identify commonalities in answers. These statistics are a powerful tool to gauge the sentiments and preferences of our respondents. From understanding the average inclinations to identifying patterns, these numbers paint a vivid picture of the contributors' perspective.

Figure 1 shows the chart used to represent our descriptive statistics derived from our quantitative survey data, focusing on various aspects of exoskeleton technology in OT practice settings. Each bar represents the average response score to a particular survey question, giving us a clear insight into participants' perceptions and knowledge about the technology. The survey revealed that participants are moderately familiar with exoskeletons. There is a concern about the lack of training opportunities for exoskeleton usage, which aligns with our qualitative findings. The highest average score relates to respondents' willingness to incorporate exoskeleton technology if available, suggesting an overall positive outlook despite the existing challenges or concerns.

We utilized the Dedoose qualitative analysis tool to identify key themes in answers for the qualitative data. We created parent codes by identifying common themes among the open-ended answers in the survey. Specific concepts and examples called child codes fall under each parent code. This method of data organization helped us gain insight into the more prominent themes. Our team was divided into pairs to review all survey responses and compare data collected to ensure inter-rater reliability. Open-ended survey responses were converted into numerical values to form a statistical analysis using charts. Each node in the chart represents a parent or child code.

Figure 2 shows the Dedoose Code Co-Occurrence Table, helping us understand the code representation and connections within our qualitative data set. This also allowed us to view patterns within the answers we received. Answer frequency was matched to a color spectrum, with red being the most frequent and blue being the least frequent. We gathered that training and setup, especially OTP training, was amongst the most popular codes, repeated six times throughout the eleven answers we received. By looking at the data, we can infer that the most significant perceptual barrier within exoskeleton use in OT practice settings is the need for more training. It is important to note that the codes that touch edges or link together indicate instances where they appear together in the same short answer response, suggesting a strong relationship between codes. From this, we could infer that if a participant lacked interest, it was most likely because they also needed more knowledge about exoskeletons. We also determined that exoskeleton use in different practice settings depended on the technology levels and cost of the machine.

Figure 3 shows the Dedoose Code Application Chart, which lets us visualize the code occurrence by media experts from our survey. This chart helped us visualize the gaps within our parent and child codes compared to the responses we got in the survey. The red nodes indicate at least one code per media expert. Survey participants 9 and 18 had the most in-depth answers, giving them each 10 codes per answer.

Ethical and Legal Considerations

To safeguard the integrity of our study, we took several measures to ensure its ethical and legal reliability. Before their involvement, prospective participants were provided with comprehensive information about the purpose, procedures, potential risks, and benefits and their right to withdraw from the study without any adverse consequences. Before participating in the survey, the OTP participants were provided an informed consent form via Google Forms with an electronic signature or agreement. Participation in the survey was voluntary, and participants could withdraw from the study at any time.

We obtained site agreements from each facility to get permission from facilities to send them our survey. These agreements detailed the program director’s consent to be sent our survey at the designated time and their agreement to distribute it to the OTPs at that site. These agreements can be found in Appendix B.

All data was handled in compliance with relevant data protection regulations. Our survey was designed to be completed in 10-15 minutes in an effort to minimize time burdens on our participants. We emphasized the voluntary nature of participation and reassured participants that their involvement would not result in any negative consequences. The survey could be completed at their convenience within a designated time frame to accommodate their schedules and commitments. To mitigate emotional risks, we carefully constructed survey questions to be sensitive and respectful. Participants had the option to skip any question they found uncomfortable.

To safeguard the privacy and confidentiality of participants, we implemented the following measures: We de-identified the data collected during the study to ensure that participants' information remained confidential. Personally identifiable information, such as names, contact details, or any other identifying information, was removed or replaced with pseudonyms. Participants' responses were not linked to any specific participant. To protect confidentiality, we kept identifying information separate from the research data. For example, signed consent forms containing participants' personal details were stored separately from the survey data. This separation ensured no direct connection between participants' identities and survey responses. Access to the data was restricted to us and our advisor. Sensitive data was stored securely on password-protected computers. The survey was conducted and stored securely on Google Forms, a cloud-based platform provided by Google. Google Forms employs robust security measures to protect data, including encryption during transit and at rest. We anticipated that participation in this survey presented no greater risk than everyday internet use. The data will be stored until November 26, 2023. After the designated period, the data will be securely deleted to ensure compliance with data retention guidelines. The data collected through Google Forms may be analyzed and summarized for presentation purposes. However, when presenting the data, it will be aggregated and presented in a manner that ensures participant confidentiality. Individual responses will not be identifiable in any presentations or publications resulting from the study.

Results

In the survey, participants were first questioned about their familiarity with exoskeleton technology in occupational therapy. A Likert scale was used with responses ranging from 1-10, where 1 indicates not familiar at all, and 10 indicates extremely familiar. For the question, "How familiar are you with exoskeleton technology in occupational therapy practice?" the average response score was 3.3. When asked, "How familiar are you with the current landscape of RESEARCH taking place regarding exoskeleton use in occupational therapy?" the average response score was 2.1. This trend continued with the question, "How familiar are you with exoskeleton technology's potential benefits and limitations in occupational therapy practice?" which received an average score of 3.5. Shifting to barriers, participants strongly agreed that "The cost of exoskeleton technology is a significant barrier to its adoption," with an average score of 7.7. Feedback on "Current designs, technology, and usability are significant barriers to its adoption" yielded an average score of 5. The statement "The lack of training opportunities for occupational therapists to learn how to incorporate exoskeletons into practice is a barrier to its adoption" had an average score of 7.6. In contrast, the sentiment "The perception that exoskeletons may replace the need for human therapists is a barrier to its adoption" garnered a 3.3 average. Participants also responded to "Concerns about patient acceptance and comfort with exoskeleton technology are barriers to its adoption," averaging a score of 4.9. Lastly, when considering the implementation of this technology, respondents broadly agreed with the statement, "If this technology were available, I would incorporate it into my practice," which had an average score of 7.4.

Spearman's rank correlation (r_s) was computed to assess the relationship between variables pertaining to potential barriers and challenges that potentially hinder the widespread adoption of exoskeletons in post-stroke intervention. Strong positive correlations were found between familiarity with exoskeleton technology in occupational therapy practice and familiarity in current landscape of research taking place regarding exoskeleton use in occupational therapy with a p value of $<.001$; familiarity with exoskeleton technology in occupational therapy practice and familiarity in exoskeleton technology's potential benefits and limitations in occupational therapy practice with a p value of <.001; familiarity with exoskeleton technology in occupational therapy and willingness to incorporate this technology into practice, if available with a p value of <.004; familiarity in current landscape of research taking place regarding exoskeleton use in occupational therapy and familiarity in exoskeleton technology's potential benefits and limitations in occupational therapy practice with a p value of <.001; familiarity in current landscape of research taking place regarding exoskeleton use in occupational therapy and willingness to incorporate this technology into practice, if available with a p value of <.002; familiarity in exoskeleton technology's potential benefits and limitations in occupational therapy practice and willingness to incorporate this technology into practice, if available with a p value of <.009; the belief that the cost of exoskeleton technology is a significant barrier to its adoption and the belief that current designs, technology, and usability are significant barriers to its adoption with a p value of <.004; and the belief that current designs, technology, and usability are significant barriers to its adoption and the belief that the lack of training opportunities for occupational therapists to learn how to incorporate exoskeletons into practice is a barrier to its adoption with a p value of <.032.

A positive correlation was also found between familiarity with exoskeleton technology in occupational therapy practice and the belief that the cost of exoskeleton technology is a significant barrier to its adoption, with a p-value of <.048. A strong negative correlation was found between the perception that exoskeletons may replace the need for human therapists and the willingness to incorporate this technology into practice, if available, with a p-value of <.001.

The qualitative data was analyzed using the Dedoose qualitative analysis tool. The results showed recurrent themes surrounding the use of exoskeleton technology in OT practice. A prominent theme was the need for more training. This emerged as a significant barrier to exoskeleton adoption, as shown by six mentions across the eleven responses received. The Dedoose Code Co-Occurrence Chart and Code Application Chart were used to visualize the frequency and relationships between the identified themes. There was a notable correlation between a lack of knowledge about exoskeletons and a lack of interest in the technology, meaning that those who knew less about it showed less interest in using it. This suggests enhancing knowledge and training among OTPs could create a heightened interest. Other common themes among the OTPs who responded to the survey were technological challenges and financial considerations. This suggests a lack of knowledge regarding how an OTP could feasibly obtain and use this technology.

Discussion

Our quantitative analysis offers insights into OTPs perceptions surrounding exoskeleton technology. Concerning familiarity, respondents demonstrated a moderate acquaintance with the technology itself (3.3) and its potential benefits and limitations (3.5). A gap was apparent in the awareness of the current research landscape, reflected in the score of 2.1. While therapists may be aware of the technology's presence, many may not be up to date with recent research findings, a pivotal factor for integrating innovative tools into practice.

A significant barrier highlighted was the perceived high cost of exoskeleton technology, receiving a score of 7.7. Steep initial costs can deter the incorporation of groundbreaking healthcare technologies. This brings forth an important consideration: the role of health insurance. A potential strategy to address the cost barrier could involve educating OTPs on devices covered by various health insurance companies and the specific diagnoses they cater to. This knowledge could empower therapists, making the technology seem more accessible and feasible for incorporation into their practices. Another barrier identified was the absence of training opportunities, with a score of 7.6. It underscores the quintessential role training plays in technological adoption. Collaborations between device manufacturers and training institutions could facilitate workshops, webinars, or certification programs, ensuring therapists are proficient and confident in using exoskeletons.

While some therapists may hold reservations about technology potentially replacing human touch, as evidenced by a score of 3.3, it was not a universally shared sentiment. This technology aims to augment, not replace. Despite the barriers, there is an enthusiasm for integration, demonstrated by the score of 7.4 when asked whether or not they would incorporate this technology if available. This suggests that once barriers like cost and training are addressed, therapists exhibit a solid propensity to employ exoskeletons. Given these findings, the call to action is on stakeholders—technology developers, research entities, and training institutions—to prioritize accessibility, training, and awareness. Advocating for insurance coverage, comprehensive training programs, and public-private partnerships might prove instrumental in expediting the adoption of this technology in OT. Further studies can investigate these solutions and evaluate their efficacy in real-world scenarios.

Our research found that the more familiar an OTP was with exoskeleton technology, the more likely they were to be familiar with the current research landscape. We discovered that individuals who answered that they were familiar with the technology, the current landscape of research, and exoskeleton technology's potential benefits and limitations also answered that they were highly likely to incorporate exoskeletons into their practice if given the opportunity. Another key finding was that individuals who answered that current designs, technology, and usability are significant barriers to exoskeleton adoption were more likely to answer that the lack of training opportunities for OTPs to learn how to incorporate exoskeletons into practice was also a barrier to the technology's adoption. This indicates that individuals who see current exoskeleton technology as complicated or unwieldy have lower confidence in using and teaching clients how to operate them.

Our finding that there is a perceptual training deficit among OTPs aligns with the barriers highlighted in the literature review, showcasing a gap that needs to be addressed. The lack of interest and knowledge underscores a critical area for intervention: bolstering educational resources and training avenues for OTPs. This could include creating specialized training programs, workshops, and online resources to hone therapists' skills in using exoskeletons. This could increase their confidence in integrating this technology into their practice. Bridging this educational gap could spark interest, expand knowledge, and ultimately pave the way for adopting exoskeleton technology in post-stroke rehabilitation.

The role of insurance coverage in either facilitating or posing hurdles calls for a deeper investigation. OTPs cited financial challenges as a perceived barrier. Advocating for policies that promote the inclusion of exoskeleton technology in rehabilitation plans through dialogues with insurance firms and policymakers can elevate awareness about the merits of exoskeletons and their potential to improve patient outcomes and decrease long-term healthcare costs.

Beyond the educational and financial-related facets, looking at the existing research landscape is imperative. By gauging OTPs' viewpoints on the availability and quality of research in this realm, we can see that there is a need to encourage more robust and varied research endeavors. This might include nurturing collaboration among researchers, therapists, and healthcare institutions.

Our dive into the possibilities of exoskeleton technology in stroke rehabilitation brings us closer to the aspirations detailed in the AOTA and AOTF research agenda, particularly when bolstering evidence-based practices and navigating translational research (AOTA, 2018). The training gap among OTPs shows the need to craft educational pathways that are both practical and accessible. Our advocacy for dialogue between policy, practice, and financial gateways, such as insurance, aligns with the translational research agenda of the AOTA and AOTF. We strive to weave scientific advancements into everyday OT practice. We find ourselves at an exciting crossroad, where our findings and professional knowledge echo the AOTA and AOTF's vision of an ever-evolving, collaborative, and scientifically robust OT field.

Limitations

Sampling bias is possible because the participants were recruited from social media platforms, personal networks, and discussion forums, which may represent only part of the OTP population. The reliance on self-reported data in the survey may be subject to response or recall bias, which could have led to over-reporting or exaggerated reporting. Technological advancements or changes in clinical practices may influence our research findings' relevance and applicability over time. The Dedoose software used to analyze the qualitative data may have limitations and technological lags, contributing to a weakened study.

There were 18 participants in our survey, and only 11 opted into the long answer portion. The small sample size of 11 for the qualitative data analysis could be a potential limitation, as it does not accurately convey all the participants' thoughts and feelings. This might not hold enough statistical power to have an effect. The short timeframe over which the study took place may also have contributed to the small number of responses we received.

Conclusion

Traditional post-stroke rehabilitation interventions are effective but often fail to restore optimal functional independence and quality of life to stroke survivors. Exoskeleton use addresses upper limb functional mobility, a specific area of impairment for most stroke survivors. While current literature supports the effectiveness of exoskeleton use in post-stroke rehabilitation, it is not widely adopted among OTPs in practice. Our research provides insight into OTPs' perceptions regarding exoskeleton use and identifies strategies to promote its wider use as a post-stroke rehabilitation intervention. We discovered that individuals who answered that they were familiar with the technology, the current landscape of research, and the technology's potential benefits and limitations also answered that they were highly likely to incorporate them into their practice if given the opportunity. Another key finding was that individuals who answered that current designs, technology, and usability are significant barriers to adoption were more likely to answer that the lack of training opportunities for OTPs to learn how to incorporate exoskeletons into practice was also a barrier to its adoption. This indicates that individuals who see current exoskeleton technology as complicated or unwieldy have lower confidence in using and teaching clients how to operate them.

Awareness surrounding insurance coverages for specific exoskeleton devices and their applicability for certain diagnoses could pave the way to surmount financial barriers. Collaborative efforts between device manufacturers and training institutions, manifesting as hands-on workshops or certification programs, could bridge the knowledge and training gap. This could make the technology more accessible to OTPs.

We recommend further research comparing the effectiveness of different strategies for implementing exoskeleton use in OT post-stroke rehabilitation to determine which avenue would be most successful. A more in-depth study addressing differences in various generational or cultural perceptions regarding this technology and how it should be used would also be beneficial. Our research supports the field of OT's advancement by contributing to a body of literature that aims to improve the quality of OT services, promote evidence-based practice, and enhance client outcomes.

This study supports the AOTA "Vision 2025" of ensuring everyone's health, well-being, and improved quality of life (AOTA, 2017). By highlighting the potential of exoskeleton technology for post-stroke rehabilitation, we are pushing for more effective, innovative solutions that can help people actively engage in their daily lives. By embracing new technologies and addressing these challenges, we are taking steps to fulfill the promises of AOTA's Centennial Vision.

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Table 1

Spearman Correlations of Exoskeleton Technology in Occupational Therapy Practice

N = 18		1	2	3	4	5	6	7	8	9
1. How familiar are you with exoskeleton technology in occupational therapy practice?	r_s	--								
	p									
2. How familiar are you with the current landscape of RESEARCH taking place regarding exoskeleton use in occupational therapy?	r_s	.794	--							
	p	<.001								
3. How familiar are you with exoskeleton technology's potential benefits and limitations in occupational therapy practice?	r_s	.992	.765	--						
	p	<.001	<.001							
4. The cost of exoskeleton technology is a significant barrier to its adoption.	r_s	.471	.318	.457	--					
	p	.048	.199	.057						
5. Current designs, technology, and usability are significant barriers to its adoption.	r_s	.214	.286	.207	.643	--				
	p	.394	.250	.410	.004					
6. The lack of training opportunities for occupational therapists to learn how to incorporate exoskeletons into practice is a barrier to its adoption.	r_s	-.296	-.113	-.329	.254	.506	--			
	p	.233	.655	.182	.309	.032				
7. The perception that exoskeletons may replace the need for human therapists is a barrier to its adoption.	r_s	-.278	-.094	-.228	-.123	.276	-.002	--		
	p	.264	.711	.363	.626	.267	.993			
8. Concerns about patient acceptance and comfort with exoskeleton technology are barriers to its adoption.	r_s	-.051	-.011	-.040	.371	.352	.358	.207	--	
	p	.839	.964	.875	.130	.152	.144	.409		
9. If this technology were available, I would incorporate it into my practice.	r_s	.647	.676	.595	.330	.054	.053	-.702	-.152	--
	p	.004	.002	.009	.180	.831	.834	.001	.548	

Note. r_s, Spearman correlation. p, p-value.

Figure 1

Descriptive Statistics

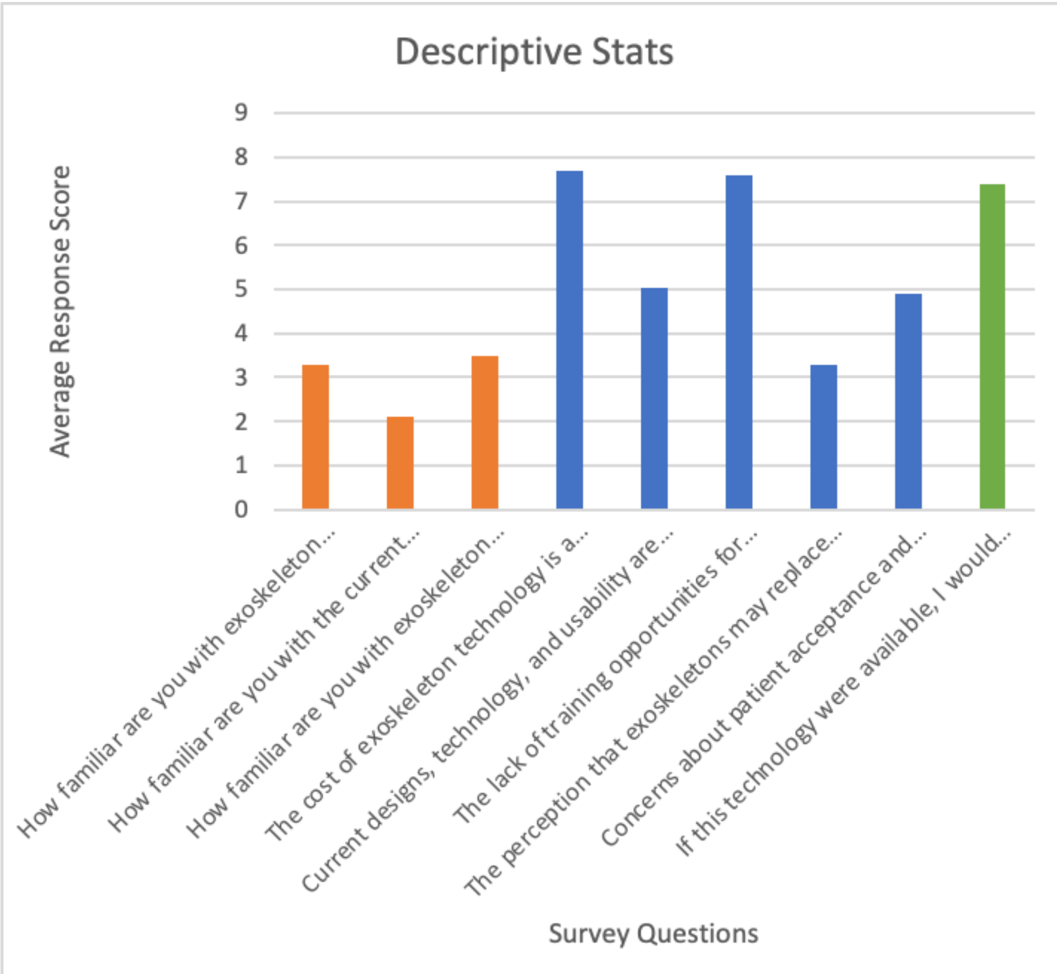
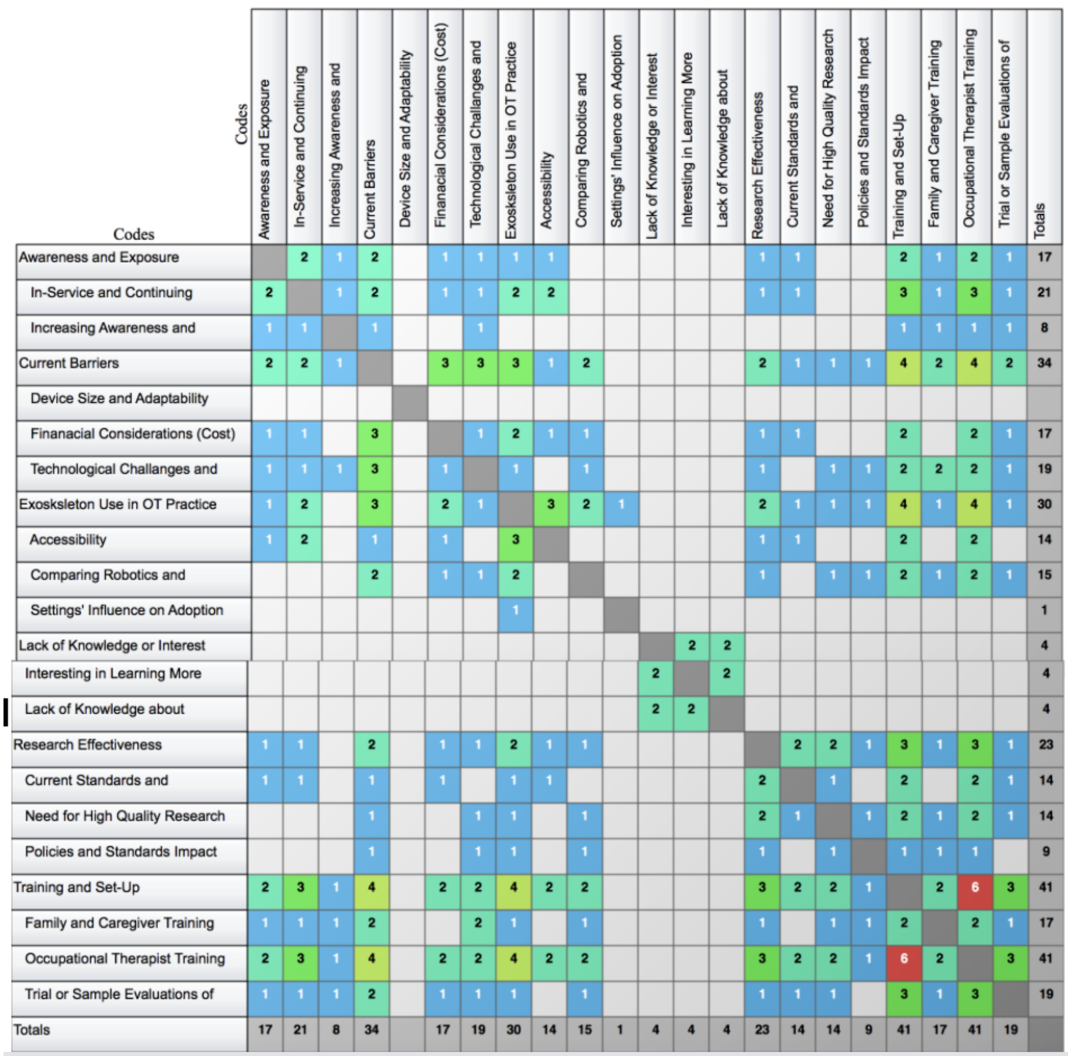


Figure 2

Code Co-Occurrence



Codes	Awareness and Exposure	In-Service and Continuing	Increasing Awareness and	Current Barriers	Device Size and Adaptability	Finanacial Considerations (Cost)	Technological Challanges and	Exosksleton Use in OT Practice	Accessibility	Comparing Robotics and	Settings' Influence on Adoption	Lack of Knowledge or Interest	Interesting in Learning More	Lack of Knowledge about	Research Effectiveness	Current Standards and	Need for High Quality Research	Policies and Standards Impact	Training and Set-Up	Family and Caregiver Training	Occupational Therapist Training	Trial or Sample Evaluations of	Totals
Awareness and Exposure		2	1	2		1	1	1	1						1	1			2	1	2	1	17
In-Service and Continuing	2		1	2		1	1	2	2						1	1			3	1	3	1	21
Increasing Awareness and	1	1		1			1												1	1	1	1	8
Current Barriers	2	2	1			3	3	3	1	2					2	1	1	1	4	2	4	2	34
Device Size and Adaptability																							
Finanacial Considerations (Cost)	1	1		3			1	2	1	1					1	1			2		2	1	17
Technological Challanges and	1	1	1	3		1		1		1					1		1	1	2	2	2	1	19
Exosksleton Use in OT Practice	1	2		3		2	1		3	2	1				2	1	1	1	4	1	4	1	30
Accessibility	1	2		1		1		3							1	1			2		2		14
Comparing Robotics and				2		1	1	2							1		1	1	2	1	2	1	15
Settings' Influence on Adoption								1															1
Lack of Knowledge or Interest													2	2									4
Interesting in Learning More												2		2									4
Lack of Knowledge about												2	2										4
Research Effectiveness	1	1		2		1	1	2	1	1						2	2	1	3	1	3	1	23
Current Standards and	1	1		1		1		1	1						2		1		2		2	1	14
Need for High Quality Research				1			1	1		1					2	1		1	2	1	2	1	14
Policies and Standards Impact				1			1	1		1					1		1		1	1	1		9
Training and Set-Up	2	3	1	4		2	2	4	2	2					3	2	2	1		2	6	3	41
Family and Caregiver Training	1	1	1	2			2	1		1					1		1	1	2		2	1	17
Occupational Therapist Training	2	3	1	4		2	2	4	2	2					3	2	2	1	6	2		3	41
Trial or Sample Evaluations of	1	1	1	2		1	1	1		1					1	1	1		3	1	3		19
Totals	17	21	8	34		17	19	30	14	15	1	4	4	4	23	14	14	9	41	17	41	19	

Note. This figure tells us which codes repeat and how many times they repeat, giving us valuable information on the patterns within the survey responses.

Figure 3

Code Application

Media \ Codes	Awareness and Exposure	In-Service and Continuing	Increasing Awareness and	Current Barriers	Device Size and Adaptability	Finanacial Considerations (Cost)	Technological Challanges and	Exoksleton Use in OT Practice	Accessibility	Comparing Robotics and	Settings' Influence on Adoption	Lack of Knowledge or Interest	Interesting in Learning More	Lack of Knowledge about	Research Effectiveness	Current Standards and	Need for High Quality Research	Policies and Standards Impact	Training and Set-Up	Family and Caregiver Training	Occupational Therapist Training	Trial or Sample Evaluations of	Totals
9				1			1	1		1					1		1	1	1	1	1		10
7												1	1	1									3
5				1		1	1																3
3															1	1	1		1		1	1	6
18	1	1		1		1		1	1						1	1			1		1		10
17				1		1		1		1									1		1	1	7
14		1						1	1										1		1		5
13								1			1												2
12	1	1	1	1			1												1	1	1	1	9
10												1	1	1									3
1								1	1														2
Totals	2	3	1	5		3	3	6	3	2	1	2	2	2	3	2	2	1	6	2	6	3	

Note: The Code Application figure shows the parent and child codes organized by participants.

Appendix A

Institutional Review Board Approval

Dear Dr. Lena Huang and Students,

The Stanbridge University Institutional Review Board has completed the review of your application entitled, "Exoskeleton Use in Post CVA Survey." Your application (#08MSOT012) is approved and categorized as Expedited.

IRB Application Number	#08MSOT012
Date	09/14/2023
Level of Review	**Expedited**
Application Approved	X
Conditional Approval	
Disapproved	
Comments	The requested Minor changes have been reviewed and confirmed as completed by the IRB. (09/14/2023)
Signature of IRB Chair	

Please note that any anticipated changes to this approved protocol requires submission of an IRB Modification application with IRB approval confirmed prior to their implementation.

Sincerely,
Julie Grace, M.S., M.A.
IRB Chair

Appendix B: Site Approval Forms

Stanbridge Master's Thesis Research project: OTs and exoskeletons

You forwarded this message on Wed 6/21/2023 4:42 PM

Seto, Jones
To: Huang, Lena; Whelton, Melissa
Tue 6/20/2023 10:43 AM

Hi Lena,
I would love to support the having our OT department participate in things to support OT in research, but I would first need to see the survey. If things look ok, I can help forward it along, you would need to provide the introductory information and be clear that the survey is not part of UCI and is completely voluntary.

I will let you know if barriers arise that would prevent me from helping.

Have a good day,
Jones

...

Huang, Lena
Hi Jones & Melissa! I'm working with a thesis group at Stanbridge. My group is conducting resear...
Sun 6/18/2023 8:24 PM

Haley Michaels Mon, Jun 19, 1:58 PM (5 days ago)
Hello Kelsie! I graduated from Calvin University and got your email address from my friend, who …

Lewis, Kelsie L. Wed, Jun 21, 6:16 AM (3 days ago)
to Haley

Haley,

I unfortunately do not work with the stroke population, so I don't think I would be the best individual to complete your survey. I would be happy to share the survey with our OT team who work in inpatient rehab and may encounter patients with strokes.

Kelsie Lewis, MS OTRL
Occupational Therapist
Inpatient/Home Care OT Clinical Education Coordinator
Rehabilitation Services – Corewell Health West
corewellhealth.org

Corewell Health

100 Michigan St | MC010
Grand Rapids, MI 49503

T-Mobile LTE 9:28 AM 88%

Cheri Teranishi 9:20 AM

to me

Hi Casey,

Hope all is well with you & school! Things here are rolling right along. Yes, please send the link to your survey and I will distribute it to our OT team. When do you graduate? When are you thinking of coming back home? Do you know what setting you'd like to practice in? Have a wonderful day!

Thank you,

Cheri Teranishi-Hashimoto, PT, DPT, MS, MSPT

Therapy Director

Program Director--Women's Health & Cancer Rehabilitation

REHAB Hospital of the Pacific

226 North Kuakini Street | Honolulu, Hawaii 96817

Direct: (808) 566-3428

Fax: (808) 535-2018

cheri.teranishi@rehabhospital.org

www.rehabhospital.org

REHAB Hospital of the Pacific

Dedicated to Rebuilding Lives

T-Mobile LTE 3:16 PM 55%

RE: New Message (sent by contact form at Palm Terrace Healthcare and Rehabilitation Center) Inbox

Nguyen, Elaine 1:47 PM

to Kristine, me, Karen

Good Afternoon Casey,

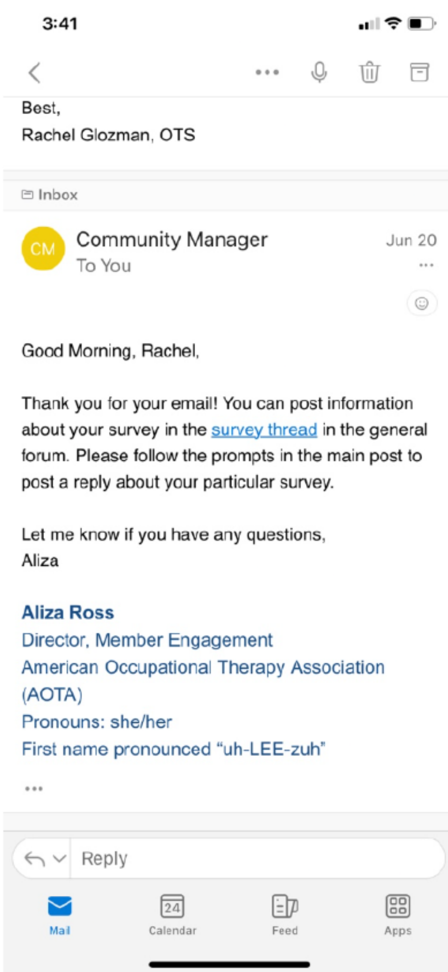
I'd love to help with your research.

Please kindly send us the survey once it's completed.

Thanks,
Elaine Nguyen, OTR/L

Director of Rehab

Palm Terrace Healthcare and Rehabilitation Center


3:41

Best,
Rachel Glozman, OTS

Inbox

Community Manager
To You
Jun 20

Good Morning, Rachel,

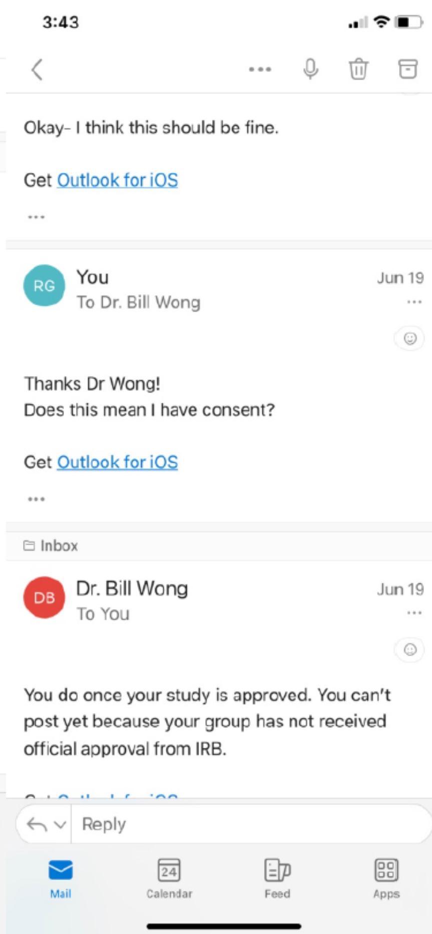
Thank you for your email! You can post information about your survey in the survey thread in the general forum. Please follow the prompts in the main post to post a reply about your particular survey.

Let me know if you have any questions,
Aliza

Aliza Ross
Director, Member Engagement
American Occupational Therapy Association (AOTA)
Pronouns: she/her
First name pronounced "uh-LEE-zuh"

Reply

Mail Calendar Feed Apps


3:43

Okay- I think this should be fine.

Get Outlook for iOS

You
To Dr. Bill Wong
Jun 19

Thanks Dr Wong!
Does this mean I have consent?

Get Outlook for iOS

Inbox

Dr. Bill Wong
To You
Jun 19

You do once your study is approved. You can't post yet because your group has not received official approval from IRB.

Reply

Mail Calendar Feed Apps