Trust and Pediatric Exoskeletons: A Comparative Study of Clinician and Parental Perspectives

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***Abstract*— The purpose of this study was to survey the perspectives of clinicians regarding pediatric robotic exoskeletons and compare their views with the views of parents of children with disabilities. A total of 78 clinicians completed the survey; they were contacted through Children's Healthcare of Atlanta, the American Academy for Cerebral Palsy and Developmental Medicine, and group pages on Facebook. Most of the clinicians were somewhat concerned to very concerned that a child might not use the device safely outside of the clinical setting. Most clinicians reported that the child would try to walk, run, and climb using the exoskeleton. The parents reported higher trust (i.e., lower concern) in the child using an exoskeleton outside of the clinical setting, compared to the clinician group. Prior experience with robotic exoskeletons can have an important impact on each group's expectations and self-reported level of trust in the technology.**

***Index Terms*—Ethics; Exoskeletons; Rehabilitation; Robots; Trust**

I. Introduction

CLINICIANS, patients, and patient families may soon be interacting with a wide variety of robotic devices because of the technology's potential to assist with the healthcare needs of children [1] and older adults [2]. An important facet of such interactions is the possibility that they might overtrust these devices. Overtrust, in this context, refers to a user believing that a technological device can perform a specific function or mitigate a risk when it actually cannot [3]. The authors recently surveyed parents who have a child with a movement disability to determine their views and concerns related to their child's use of robotic exoskeletons [3]. Here, the authors discuss the second phase of this research; it examines whether clinicians might overtrust exoskeletons and their views about how exoskeletons should respond to risky situations. Current models of exoskeletons do not have the capacity to enable users to perform tasks such as running, climbing, or jumping, but the concern is that users might think that they can attempt such tasks anyway and potentially experience an injury.

The use of robots as therapy tools raises difficult ethical challenges. Parents, wanting to help their child, may wishfully view the technology as offering a significant change in prognosis. Clinicians, perhaps unsure what the risks are with using robots, may be concerned about how the technology's adoption might change patient outcomes. For example, the clinician may have to consider that if a child has difficulty using an exoskeleton or feels uncomfortable wearing it, this could potentially interfere with the child's willingness to try other treatment protocols. On the other hand, the child might simply want to participate in activities like any other child. Each stakeholder may thus have different perspectives on the same technology.

The hope for an improvement in their child's health might influence parents to overtrust robotic technology, potentially placing their child at risk. The authors' previous paper provided some evidence in support of that hypothesis [3]. In the parental study, "over 62% of respondents indicated they would typically or completely trust their child to handle risky situations with an exoskeleton even though the technology may not be designed for such situations" [3]. It is possible that parents might generate too much enthusiasm for the technology, perhaps even as the clinician attempts to moderate their expectations. Of course, reality depends on the individual situation, personalities, and experiences of the patients involved.

This paper describes an exploratory study that examined the perspective of clinicians who have experience providing care for children with disabilities and compared it to that of the parents of children with disabilities. Although the terms do not always mean the same thing, the authors use "healthcare provider" and "clinician" interchangeably for the purposes of

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this paper. The use of surveys to measure attitudes and beliefs may only reveal a limited picture of one's actual underlying perspective and future behavior. Nevertheless, the findings could provide insight into viewpoints of parents and clinicians, and more importantly, whether their viewpoints diverge.

II. Background

Overtrust is the central concern of this project. A widely referenced definition in the field of computing is as follows: "Overtrust is poor calibration in which trust exceeds system capabilities" [4]. Yet drawing on Parasuraman and Riley [5], the authors defined overtrust of robots in prior work as "a situation in which (I) a person accepts risk because it is believed that a robot can perform a function that it cannot or (II) the person accepts too much risk because the expectation is that the robot will mitigate the risk" [3]. In this context, the authors investigated whether and to what degree clinicians may overtrust robotic exoskeletons.

A robotic exoskeleton externally attaches to a human body. They can be used to assist with upper and/or lower body movement. Key aims behind the technology's development are to improve the effectiveness of rehabilitation and to enable those with physical disabilities or impairments to have greater freedom of movement [6, 7, 8]. With some exceptions [9], exoskeletons would usually have to be used on flat surfaces in controlled environments under the supervision of another person. Although exoskeletons are typically used in clinical settings, some companies have already marketed the technology for in-home use [10, 11, 12]. Many exoskeletons are commercially available, and among the most common ones are the ReWalk [13], the Ekso GT [14], and Cyberdyne's HAL [15]. While exoskeletons are gaining popularity as independent gait assistive devices in adults, this work is motivated by the fact that companies have been developing exoskeletons for pediatric populations [16, 17]. These pediatric-focused exoskeleton devices are typically being used to provide clinic-based gait therapy to children with movement disabilities or impairments [18, 19]. As such, the goal of this study was to investigate clinician perceptions of how a child would interact with an exoskeleton and compare those perceptions to the views of parents. This information could eventually assist in informing certain performance and safety guidelines for manufacturers. Moreover, if clinicians and parents have a fuller understanding of the risks, such as bone fractures [20, 21], and benefits of exoskeletons, it will not only help educate them on how to ensure a child's safety, but it may increase the likelihood that an exoskeleton is not abandoned after initial use.

III. Methods

The authors administered an online survey to clinicians who treat children with any form of disability that affects movement, muscle control, and/or balance. The intent was to examine the perspective of clinicians with respect to the risks, such as falling and bone fractures, that pediatric patients with lower extremity mobility disorders may experience while wearing a robotic exoskeleton. While exoskeletons are in the process of being adopted for use in rehabilitation clinics, patients, and their families, may expect to be able to use the technology in the home and other settings. By better understanding how users and others may interact with robotic exoskeletons, this study may shed light on trust-related issues with healthcare robots more generally.

A participation request was sent by a trusted colleague to Children's Healthcare of Atlanta and to the American Academy for Cerebral Palsy and Developmental Medicine. The request was also sent to group pages on Facebook, which is similar to the method used to recruit parents for the authors' prior survey. After clicking on a survey link, potential subjects were asked to review a consent form. The survey took approximately 10 minutes to complete. It consisted of 30 questions and participants could skip any question they did not want to answer. The survey contained a combination of multiple-choice questions (some of which were on a five-point Likert-scale), and demographic questions (see Appendix 1). The survey also contained a series of open answer questions, but those results will not be reported in this paper. An attention check question ("Please mark "B" if you are reading this question") was included to ensure participants were actively engaged. Data collection took place between October 11 and December 14, 2017 using the Qualtrics platform and participants received a $20 gift card for completing the survey. The study was approved by Georgia Tech's Institutional Review Board (IRB).

A. Data Analysis

The authors performed descriptive analysis of demographics and survey responses from the clinicians. The Mann-Whitney U (MW-U) test was used to compare the trust self-reported by the parent group to the self-reported trust of the clinician group regarding children using exoskeletons. This test was selected because 1) the survey response scales were ordinal, 2) this test does not require normal data distributions, and 3) this test can handle varying sample sizes. Spearman Rho correlations were performed between the level of trust that parents and clinicians showed in a child wearing exoskeletons to other self-reported measures such as level of comfort with computing technology and robots, and prior exposure to robotic exoskeletons. Bonferroni corrections in level of significant α were made where necessary to account for type I errors. The trust ratings of participants (parents and clinicians) who had prior exposure to exoskeletons were also compared to those who did not.

IV. Results

A. Demographics of Survey Respondents

A total of 98 participants clicked on the survey link. A participant's responses were excluded if the survey's "attention check" question was not answered or answered incorrectly. Twenty individuals fell into this category. Thus, 78 respondents completed the survey; demographic information for this group is as follows: Age = 46.6±12.5 years, 58 female and 20 male, 88.3% white, 7.8% Asian, 2.6% Hispanic or Latino, and 1.3% Black or African American.

Regarding the educational qualifications of the respondents, 48% had a professional degree such as MD or DPT, 32.5% had a doctoral degree, and the rest had a bachelors or master's degree; 40% were from the U.S. South, 16% were from the U.S. West and Northeast each, and 14.7% from the U.S. Midwest, while 13.3% were from outside the USA.

Responses to "How often have you interacted with robots (for example, a robotic vacuum)?" were slightly skewed towards frequent interaction with robots. About 13% of the participants reported daily interaction, 25.9% reported interaction many times a week, 44.2% reported interactions once or twice to few times a week, and 16.9% reported no interaction at all. For the question "How comfortable would you be with using a new advanced technology, such as a robotic device, that you have not used before?", 29.9% reported that they were very comfortable, 49.4% were somewhat comfortable, 16.9% were neutral, and 3.9% were somewhat uncomfortable. All clinicians reported that they had used some form of computing technology or mobile phone several times a day. About 88.3% of clinicians indicated that they were very comfortable, and 10.4% were somewhat comfortable with computing technologies. Only one participant indicated being very uncomfortable with these technologies.

B. Clinician Perceptions of Child-Robot Interaction

The clinicians reported the mean age of the children they worked with as being 6.8 ± 3.1 years old. All of the clinicians reported working with children who have disabilities that affect movement, muscle control, and/or balance, and about 83% of them indicated having daily interaction with such children. However, only about 25.6% reported working with children who use robotic exoskeletons. A potential limitation with the relevant question is an error in its wording (the phrase "How often" at the beginning was mistakenly included when a binary "yes or no" answer was being sought to the intended prompt "do you work with children that use a robotic exoskeleton?").

When asked "In your professional opinion, if a child encounters a risky situation (for example, trying to climb stairs without supervision) while wearing a robotic exoskeleton outside of the clinical setting, who should be notified first?", 71.8% of the clinicians reported that the child's parent or guardian should be notified first, while 16.7% reported the child should be notified first. Only 3.8% clinicians stated that it was important for both the parent and the child to be notified, depending on the type of risky situation. For the question "If a child encounters a risky situation while wearing a robotic exoskeleton outside of the clinical setting, what would be the best way for the device to notify or protect the child?", 36.4% of the clinicians said that the device should stop working and 5.2% said the device should slow down. Other clinicians indicated that some type of warning prompt would be the best way to address a risky situation. Approximately 28.6% preferred an audio warning (for example, a beeping sound), 9.1% preferred a vibration prompt and, surprisingly, none preferred a visual warning (for example, flashing light). Four clinicians (5.2%) preferred a combination of several prompts and nine clinicians (11.7%), using the comments box connected to the "Other" option, suggested having an ability to customize the prompts to the child's abilities and situations.

When asked "How much do you trust a child wearing a robotic exoskeleton to use the device safely outside of the clinical setting?" about 7.5% clinicians "somewhat" to "completely" trust the child and 35.1% clinicians had some concern but also trusted the child to use the device safely. Most of the clinicians were somewhat (42.9%) to very concerned (14.3%) that the child might not use the device safely outside of the clinical setting. It is important to note that there may have been some ambiguity in the question because it was not directly specified whether the child would be under an adult's supervision. Regarding "How much do you trust a parent to monitor a child wearing a robotic exoskeleton outside of the clinical setting?", 10.3% said they would completely trust the parent, 39.7% suggested they would somewhat trust the parent, 30.8% said they would trust the parent but also have some concern, and 19.2% said they would be concerned that the parent might not monitor the child outside of the clinical setting.

Regarding "Which types of activities do you think your child would try to perform while using a robotic exoskeleton? (check all that apply)", the most commonly reported activities were walking (71 respondents, 91%), running (51, 65.4%), climbing (48, 61.5%), and jumping (36, 46.2%). Thirteen clinicians selected the "Other" option; four of these clinicians suggested that the child would try all possible activities allowed by the exoskeleton. Four others suggested that the activities would significantly vary depending on the child's age, developmental level, personality/temperament, and the use setting. One clinician stated that "Children want to be children, I think the child would try anything that the exoskeleton allowed especially if it meant keeping up with peers."

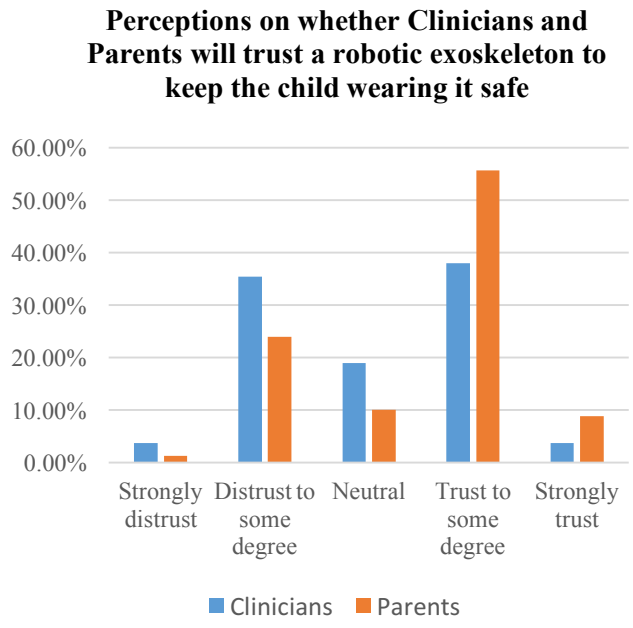

Fig. 1. The level of trust (reported in percentages) that clinicians think other healthcare providers and parents "will trust a robotic exoskeleton to keep [the/their] child wearing it safe."

Responses to "In your professional opinion, how much do you think healthcare providers will trust a robotic exoskeleton to keep the child wearing it safe?" were spread out across the trust/distrust scale. Approximately 3.8% said they would strongly trust the device, 37.2% said they would trust it to some degree, 19.2% were neutral, 35.9% said they would distrust it to some degree, and approximately 3.8% said they would strongly distrust the device. For the question, "In your professional opinion, how much do you think parents or guardians will trust a robotic exoskeleton to keep their child wearing it safe?", 9% of the clinicians reported that parents would strongly trust the device, 55.1% said parents would trust to some degree, 10.3% were neutral, 24.4% said parents would distrust device to some degree while only one clinician said parents will strongly distrust the device. Responses to the two aforementioned questions are reported in Figure 1.

C. Comparison of Perceptions of Parents and Clinicians

The parent survey results were previously reported in [3], but some of that data will be compared with the clinician group below. For the prior parent study, 108 people clicked on the survey link and after applying the exclusion criteria, there were 97 parent respondents. 72 of the parents were male, 24 female, and one did not indicate. The recruitment strategy for that study "involved placing an advertisement on a number of Facebook group pages focused on either assistive technologies, special-education technology, or parent support groups of children with special needs" [3]. Significant differences between the parent and clinician groups were seen. Compared to clinicians, the parents had higher frequency of interaction with robots (MW-U=3111.5 P=0.015), higher level of comfort with using computing technology (MW-U=1582 P<0.001), and lower level of comfort with a new advanced technology (MW-U=1387 P=0.025). The clinician group was significantly (MW-U=2004 P<0.001) older (46.5±12.5) than the parent group (36.3±6.8). The percentage of male participants was significantly (MW-U 2004 P<0.001) higher in the parent group (74.2%) than in the clinician group (25.6%).

The MW-U test revealed a significant difference in the level of trust between parents and clinicians (MW-U = 1535, p<0.001 at level of significant $\alpha \leq 0.05$). Compared to the clinicians, parents overall had higher trust (i.e., lower concern) (mean±sd: 3.5±0.9, median: 4, range: 1-5) with their child using robotic exoskeleton safely outside a clinical setting (2.4±0.9, median: 2, range: 1-5).

For the parent group (level of significant $\alpha \leq 0.01$), a higher level of trust in their child using an exoskeleton and being able to handle risky situations correlated with their higher comfort with using new and advanced technology such as robots (Spearman's ρ= 0.28, p=0.004), with a lower score on how adventurous parents thought their child is (ρ= 0.28, p=0.005), and with prior exposure to robotic exoskeletons (ρ= 0.4, p<0.001). In the clinician group, the level of trust was not significantly correlated with any of the measures evaluated.

Parents whose child had actually used an exoskeleton (75% of the parent sample) reported a higher trust (3.8±0.7, median 4, range 2-5) compared to those whose child had not used an exoskeleton (2.8±1.2, median 3, range 1-5), and this difference was statistically significant (MW-U = 492.5, p<0.001). However, clinicians who had experience working with children who had used exoskeletons did not show a significantly higher level of trust (2.5±0.9, median 2.5, range 1-4) than those clinicians who had not worked with children that had used exoskeletons (2.3±0.8, median 2.0, range 1-5).

TABLE I
SELF-REPORTED TRUST IN THE CHILD WEARING A ROBOTIC EXOSKELETON TO HANDLE RISKY SITUATIONS ENCOUNTERED OUTSIDE OF THE CLINICAL SETTING

	Quantity	Parents	Clinicians
Prior Exposure to Exoskeletons	Mean ± SD	3.77 ± 0.7 (n=72)	2.5 ± 0.95 (n=20)
	Median (range)	4.0 (2-5)	2.5 (1-4)
No Prior Exposure to Exoskeletons	Mean ± SD	2.85 ± 1.19 (n=24)	2.33 ± 0.83 (n=58)
	Median (range)	3.0 (1-5)	2.0 (1-5)

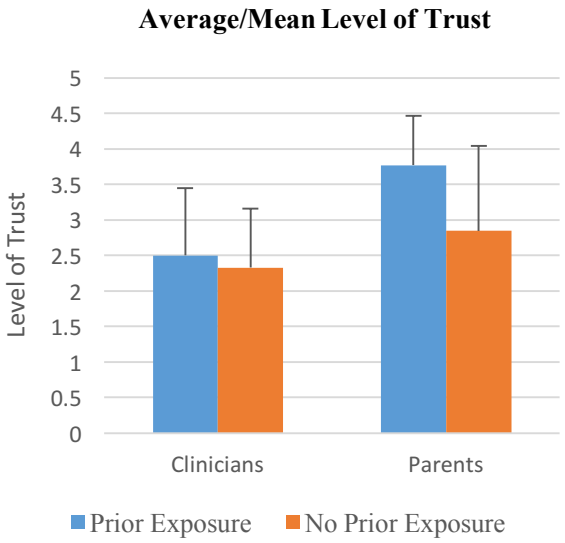

Fig. 2. Average level of trust expressed by clinicians (n=78) and parents (n=96) in the child based on their own prior exposure to exoskeletons.

A higher number of parents had prior exposure to robotic exoskeletons than clinicians (MW-U=2004 P<0.001). Parents with prior exposure to exoskeletons reported a significantly higher level of trust compared to clinicians who had prior experience working with children using exoskeletons (MW-U=227 P<0.001). Prior exposure for parents consists of whether "your child ever used a robotic exoskeleton before" and for clinicians, it refers to whether "you work with children that use a robotic exoskeleton." The clinicians may have been exposed to different amounts and types of information about exoskeletons. Yet these specific details were not collected during this study. It is also difficult to control for this type of background knowledge. Moreover, it is not obvious if or how this exposure might have impacted their clinical

recommendations. For example, statements of support by engineers may lack credibility if the clinician has seen recent injuries using the device. In either case, there was no significant difference in self-reported trust between parents and clinicians who had no prior exposure to children using exoskeletons (see Table 1 and Figure 2).

Regarding the types of activities that the child would try to perform using the exoskeletons, both groups primarily reported walking and running as the most common activities (see Figure 3). Interestingly, compared to parents, a higher proportion of clinicians thought the child would try to climb (27.6% vs 61.5%) and jump (16.3% vs 44.9%).

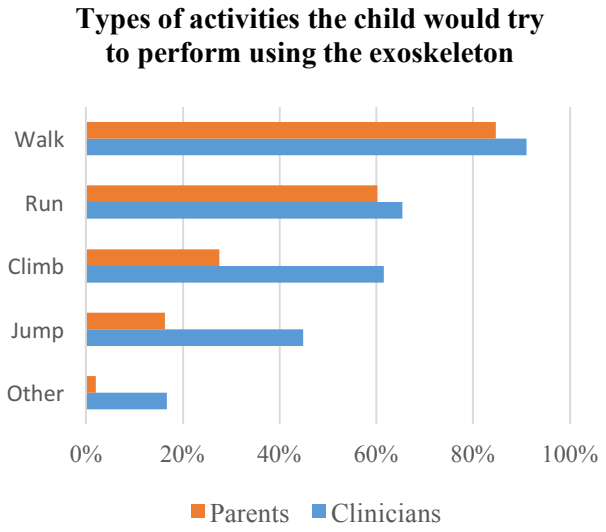

Fig. 3. The types of activities parents (n=94) and clinicians (n=78) thought the child would try to perform while using a robotic exoskeleton (each respondent could select multiple answer options).

V. Discussion

In general, the clinicians did not fully trust that children will use an exoskeleton safely nor did they fully trust parents to monitor a child wearing the device. Moreover, the clinicians indicated that other healthcare professionals would not fully trust an exoskeleton to keep a child safe. Most of the clinicians believe the parent should be warned first instead of the child if a risky situation emerges with the exoskeleton outside of the clinical setting. This could be influenced by the image of the child that the clinician has in mind (i.e., the child's age and whether that child has any physical or mental impairments). Presumably, the clinicians' suggestions would be based on their experience working with a wide variety of children with disabilities. On the other hand, parents would likely select methods and warnings that fit the needs of their own child.

None of the clinicians thought that a visual prompt would be the best way to warn the child. Of course, many of the survey questions required the clinicians to generalize about the pediatric population although children are highly individualistic. Several clinicians pointed out that there is not a singular "best way" to provide warnings. For example, the design of a warning system for a child with cerebral palsy should perhaps differ from the design for a child with a traumatic brain injury.

More parents than clinicians had prior exposure to exoskeletons, which was unexpected. It is not clear why this was the case. Parents and clinicians without prior exposure to exoskeletons tend to report similar levels of trust when the child encounters a risky situation. With prior exposure to exoskeletons, the parents seem more optimistic than clinicians that children can safely use the technology. The parents' higher level of trust in robotic exoskeletons could perhaps be connected to the opportunity that they see in this technology to improve their child's mobility. It is also possible that parents reported a higher level of trust because they are familiar with the abilities of their individual child and have observed the child's interaction with the device. It is important to note that these same parents also indicate that they expect their own children to use the technology to perform risky actions. Moreover, the authors' prior work shows that a significant portion of parents expect their children to supervise themselves or would supervise them remotely via text alerts [3].

Although a significantly higher number of clinicians lacked prior experience with exoskeletons, in general, clinicians seemed more concerned about the technology's risks, perhaps because they encounter children with a wider range of physical disabilities than the parents. As compared to parents, a higher number of clinicians expect the child to attempt to use the robotic exoskeleton to do rigorous, potentially risky, activities like climbing and jumping. This could be connected to the clinician sample population having a relatively low amount of experience with exoskeletons. Another possible factor is that the clinicians have more formal training than parents on medical technology, such as an exoskeleton, and its associated limitations.

VI. Potential Limitations

Given the novelty and limited market penetration of pediatric robotic exoskeletons, a limitation in the study design is that the sample sizes of participants with and without prior exposure vary significantly between the two groups and this could have biased the results. Additional studies are necessary to better understand how prior exposure to exoskeletons affects trust. Along related lines, the level of comfort that respondents indicated that they have in "computing technology" or "a new advanced technology, such as a robotic device" does not necessarily map precisely on to what their level of comfort might be with a robotic exoskeleton. Also, some form of sampling bias may be present since the authors relied on professional networks familiar to them. Because the respondents are anonymous, it is unknown how many of them answered from each recruitment strategy (i.e., from Facebook groups versus professional networks that were contacted). As with the prior parent survey, the possibility of the same person filling out the survey multiple times could not be fully prevented since the survey is anonymous. In addition, although the attention check is a widely-used method to identify respondents that are not carefully reading a survey, there is

some concern that attention check questions may alter respondent behavior. A high number of excluded surveys (20 out of 98), tied to the predetermined exclusion criterion of skipping the attention check question or answering it incorrectly, is another limitation. This could be due in part to the busy schedules of the clinicians; many of them opened the survey but did not complete it.

VII. Conclusion

As robotic technologies are being developed for healthcare settings, it is vital to continue investigating how different stakeholders will interact with the technology. Here, the authors examined clinician perceptions of robotic exoskeletons. This study may help to inform the design of an exoskeleton and the development of protocols focused on helping users to place an appropriate amount of trust in the technology. The study may also reveal insights relevant to other types of human-robot interactions where users may experience significant risk if they place too much trust in a social robot or other robotic device.

In situations where users or others are likely to overtrust robotic technology, such as an exoskeleton, training programs may be needed, which could perhaps be mandated by the FDA, manufacturers, or other entities. For example, educating parents before their child begins wearing an exoskeleton might be a wise step, especially if the technology starts to be used more commonly outside the confines of a clinical setting. Training could include clearly describing the system's limitations, failure modes, and associated risks. Measures could also be implemented to mitigate the chance that clinicians would overtrust the technology. Manufacturers of adult exoskeletons have training certifications that clinicians can complete in order to be eligible to prescribe their devices [22, 23]. Similar certifications can be put in place for pediatric exoskeletons to educate healthcare providers about how children will use the device and how parents will monitor those children. Part of this training program could even allow the children, parents, and clinicians to experience or witness different failure conditions under controlled circumstances.

Future work will consider how a framework might be developed and tested which shows how experiences or evidence about an exoskeleton's limitations might influence the trust parents place in the technology. This framework might be used to characterize particular patients that are at risk of overtrust.

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