Uncovering unexpected impacts: the case of digital manufacturing of wheelchairs in Kenya

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INTRODUCTION

According to the WHO's Guidelines on the Provision of Manual Wheelchairs in Less Resourced Settings a wheelchair must meet the user's individual needs and environmental conditions, provide postural support, and be safe and durable [1]. The wheelchair must be also available and affordable and it must be possible to maintain the product in country through a sustainable system [1]. In Kenya, there are more than 500'000 people with physical disabilities, many of whom are likely to be wheelchair users in need of appropriate wheelchairs [2]. Although there are organisations and institutions in Kenya that have received WHO wheelchair provision training and are committed to providing appropriate wheelchairs, reliance on intermittent supply chains and the continued donor supply of inappropriate wheelchairs remain a very significant problem [3,4].

Currently, wheelchair provision in LMICs follow one of three models: 1) importation, or donation, of complete wheelchairs, new or recycled; 2) importation, or donation, of wheelchair components for local assembly, or; 3) local manufacturing of wheelchairs both at large and small scale. Overall, there is no model which consistently outperforms the others and all of them can be applied to provide good services. However, all of them are affected by unique challenges that can compromise their effectiveness. Models that are heavily reliant on imports are susceptible to supply disruptions which can potentially lead to the provision of intermittent services [5]. Furthermore, imported or donate wheelchairs designed for different environments can be unsuitable to the local conditions [4]. On the other hand, local manufacturing might fail to provide products that consistently meet standards of quality [6].

Leveraging the use of novel digital technologies could help to transform the way in which wheelchairs are designed and manufactured [7]. Through the use of Computer Aided Design (CAD) and 3D printing it is possible to manufacture bespoke assistive products in locum for a relatively contained cost [8]. This de-centralised approach to manufacturing could enable clinicians and technicians in LMICs to take ownership of wheelchair provision, with the potential to tailor appropriate solutions for the end user, manufacturing on demand and within proximity to their point of use. At the same time, the use of CAD software and digital manufacturing technologies would ensure consistent quality standards across different sites, minimising room for error. Such a model also lends itself to sustainability as the expertise for repair would also be locally based.

Over the last three years, Motivation UK has developed a new method to design and produce custom wheelchairs using a parametric model that combines 3D printed nodes and metal tubes. The system enables clinicians to position and take accurate measurements of the client using a wheelchair simulator and input measurements and preferences of the clients in a simple computer interface. The programme feeds the data into a parametric model that creates different geometry of the nodes, constructing the full set of wheelchair joints in a file format suitable for 3D printing. The parametric model also gives the 'blueprint' for the chassis tubes in terms, enabling technicians to fully manufacture a wheelchair chassis locally with the desired specifications (see Figure 1). As the system is still under development, the model is currently only suitable for designing and manufacturing three-wheeled wheelchairs.

We carried out a 5-month research project in collaboration with Bethany Kids (Joytown, Kenya) to explore the acceptability and feasibility of this new wheelchair provision method from the perspective of both users and service providers, and to evaluate the quality of the wheelchairs manufactured with this method. A local team was trained to provide wheelchairs using this innovative model, and 8 local expert wheelchair users evaluated the service provision model alongside the products that were manufactured by the local team.

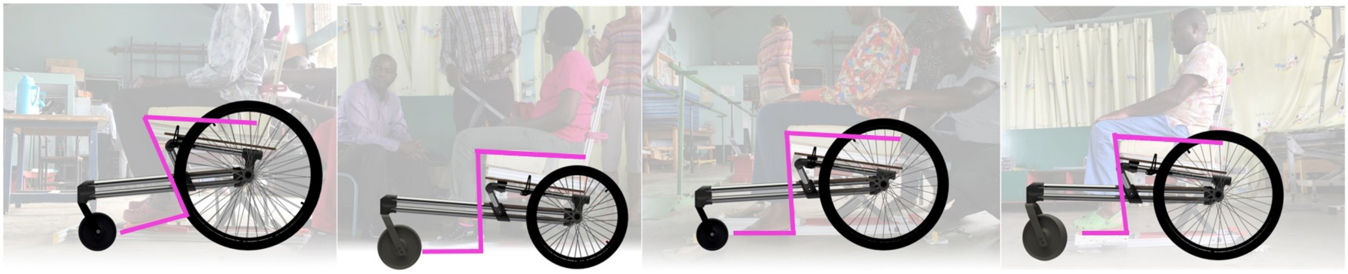

Figure 1 Wheelchair chassis of different configurations made according to the measurements and specifications collected from the clients

METHODS

Training phase

During this phase of the project a clinician and two designers from Motivation UK trained two wheelchair technicians and three clinicians from Bethany Kids. Under trainers' supervision, the trainees first manufactured three initial test wheelchairs using themselves as models to familiarize themselves with the new procedures and technology. Subsequently, two additional wheelchairs were manufactured, also under supervision, for two wheelchair users. Structured observations were conducted during training to document the difficulties encountered by trainees, and semi-structured interviews were carried out after each phase of the training to capture their experiences.

Independent service delivery phase

Throughout this phase the trainees independently manufactured 6 wheelchairs for selected wheelchair users. A technical officer from Motivation Africa was present to observe the process and offer support when required. Furthermore, technical support for any 3D printing or manufacturing issues was provided remotely by the designers in Motivation UK. Interactions between the trainees and the support team were logged to understand the difficulties encountered throughout this phase. Semi-structured interviews were conducted at the end of the study to gather the experience of the trainees and their opinions about future implementations of this model of service provision.

User evaluation

Eight bespoke wheelchairs for were manufactured as part of the project. Users were asked to trial and evaluate the wheelchair according to a set procedure. First, they completed the Wheelchair Skills Test (WST) 5.0 with the new prototype to enable a trial of the wheelchair across different tasks. At the end of the test users filled in the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST) version 2.0 to record their overall satisfaction with the wheelchair. This was followed by a semi-structured interview in which the researcher sought to collect feedback about the wheelchair and the experience of the user throughout the service delivery journey. At the end of the project we carried out a focus group with all the users to enable an open discussion and exchange of opinions about the wheelchair design, potential design improvements and implications of this novel service delivery model.

RESULTS

Performance and satisfaction with the new wheelchair

All users except for one were able to complete the WST. Unfortunately, User 5 was unable to carry out the WST as her wheelchair had some structural issues and the clinicians decided that completing the WST could have put the client at risk. As none of the wheelchair users who were part of the study reported ascending or descending stairs with their wheelchairs normally, we did not include these skills in the WST. Furthermore, as the wheelchair could not be folded, but the seat could be detached from the frame, skill 11 (folds and unfold the wheelchair) was adjusted to reflect the change (see Figure 2).

Overall, scores in the WST were high for all participants with only one user scoring below 60% (50.5% User 6). All participants encountered some difficulties in assembling and disassembling the seat from the wheelchair due to the weight of the seating unit. All users scored highly on basic propulsions skills, transfer skills and advanced propulsions skills, such as negotiating soft surfaces, slopes and gaps. Although four users were unable to complete any wheelie (skills 27-31), three (Users 4,6 and 7) stated they were also unable to do so with their own wheelchairs;

User 2 found it more difficult to perform a wheelie in the new wheelchair as the weight distribution of a that particular three wheeler was different from her usual 4-wheeled chair.

Users scored the prototype wheelchair highly on most of the QUEST 2.0 items. Considering a maximum score of 5, the lowest average score was attributed to "Ease of adjusting parts of the assistive device" (Mean 4 ± .82) and "Weight of the assistive device" (Mean 4.14 ± .69) as most users found the seating unit too heavy. Highest average scores were attributed to "Comfort of the assistive device" (Mean 4.86 ± .38) and "Dimensions of the assistive device" (Mean 4.71 ± .49). When asked about the most important aspects of their assistive device, users most often cited Comfort (6 Users), Durability (6 Users) and Safety (4 Users).

Figure 2 Technician showing the users how to remove and fold the seating unit

Acceptability and feasibility of the provision system for users

Overall, wheelchair users rated the service provision system very highly. What excited the users most was the fact that a service provision model for customized wheelchairs takes into account not only their body dimensions, but also their living environments, lifestyles and mobility goals ("*This model of wheelchair provision is great because the wheelchair is made according to your needs and you have a chance to express what your needs are*" U3). Users acknowledged the fact that this service delivery model could potentially take more time and require multiple visits to the clinic. However, they clearly stated that a wheelchair that could better address their needs would be worth a potentially longer waiting time and the logistical challenges that might be linked to multiple visits. To mitigate difficulties, users proposed having mobile assessment clinics that could travel to the community so that the user would only need to reach the central distribution centre to collect the wheelchair at the fitting appointment ("*You could have, for the measurements stations coming near us, rather than only few of us travelling here you could have many people coming if the station was closer to us. And then you came here to get the wheelchair fitted*" U8). These findings are interesting, however, it is the unexpected outcomes of using a truly user-centered assessment process which we feel are most noteworthy.

First, users stated feeling at the centre of the fitting process – having their opinions listened to by clinicians during assessment in particular gave them an increased sense of confidence and self-worth. Second, learning about how different elements of wheelchair configuration (such as camber and front castor size) might affect their user experience, made them think about their needs, their own wheelchairs and how they could be improved. Third, some users stated that through the assessment process they learned more about their postural and seating requirements potentially affecting their choices around wheelchair setups in the future. Finally, all users stated that interacting with this new service provision model gave them a better understanding of what an appropriate wheelchair really could be; it motivated them to advise their local services and advocates for better provision in their communities ("*I have learned about the project… But I have also learned how appropriate wheelchairs are made and now I know that an appropriate wheelchair is very important. And if someone is asking for one, I'll be very keen to educate them on appropriate wheelchairs*" U1).

Acceptability and feasibility of the provision system for providers

The Bethany Kids staff were initially uncertain about this new service delivery system but, by the end of the project, they unanimously expressed positive opinions about it. The initial concerns about the provision model related to the technological aspects and the increased complexity of the assessment process. In particular, clinicians were worried about the need to take extremely accurate measurements during assessment, with the risk of "ruining" the production of the wheelchair if they were somehow inaccurate. On the other hand, technicians were worried about the dependency on sophisticated and potentially fragile 3D printers and the impact of breakages and likely power cuts on provision. However, throughout the project clinical staff found that taking accurate seating measurements was simplified by the use of the wheelchair simulator (see Figure 3) ("*One thing that I found easy was the measurement on the simulator because there are the arrows and it's just easier than when you have to do it on the person with the blocks or what you have around*" T5). Furthermore, the wheelchair technicians gained increased confidence as they solved (with some remote support from the technical team in the UK) each of the issues that arose during the project, none of which had a severe impact on wheelchair production.

As for the users, the impact of the project on the participating Bethany Kids staff went beyond measurable outcomes. Clinicians stated that the experience gained as part of the project had a direct impact on their everyday practice. Learning about the importance of involving the users in the prescription of customized wheelchairs made them more prone to listen and proactively engage their clients to ensure better outcomes ("*I now know that if I want to give a* *wheelchair for a patient who wants maximum support these are the factors that I consider and if I have a patient with different needs how I can give him a right wheelchair for the situation. I listened and I know what are the important things I need to ask*" T2). The technicians became more aware of how technology could become a part of their everyday work; this motivated them to investigate how similar approaches could be used to provide other customized devices, such as handgrips for crutches or smaller postural support devices. Finally, all participating staff stated that the training received as part of the research had a positive impact on their wheelchair provision skills in general, making them more competent and motivated to provide appropriate wheelchairs for their clients.

DISCUSSION

In keeping with best practice, our team developed a research protocol to evaluate a new model for wheelchair provision according to a series of defined outcomes. The findings that directly related to these pre-selected outcomes helped us to identify flaws in the design of the wheelchairs, improve training content, methodology, and adapt various aspects of this innovative model of wheelchair provision to make it more feasible to this particular context. However, we believe that some of the most important findings originated from this research were "collateral findings" or "spill-over effects" that we did not specifically look for, but that strongly emerged from data collected. When further explored, these findings clearly indicate the value that participants attributed to the goals of the research project and the impact it had on them. Most of these findings could only emerge thanks to the flexibility granted by qualitative methods that enabled us to use a combination of exploratory and confirmatory approaches [9]. Furthermore, the fact that the researchers were not specifically looking for additional indicators of impact from the project likely reduces the chance of confirmation bias. Finally, the delivery of the project also strengthened the resolve of all partners involved to leverage local resources and place extra emphasis on training of clinicians, technicians and users in the quest for providing appropriate wheelchairs to people in LMICs.

Figure 3 Clinicians positioning the client on the wheelchair simulator

CONCLUSION

Novel technologies can help provide appropriate wheelchairs to users living in LMICs. When implementing interventions trying to address these challenges, researchers should use flexible approaches and outcome measures or tools, that enable them to capture the wider impact of a product or service innovation on stakeholders beyond the explicitly stated outcomes of the project.

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