Design and field evaluation of a manual wheelchair seat elevator for throwing events

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INTRODUCTION

Previous studies have demonstrated that participation in exercise and sporting events has many benefits for people with disabilities, including reduced risk of cardiovascular disease, higher satisfaction with life, and greater health related quality of life. [1-3] However, appropriately fitted sporting equipment is still not easily accessible for athletes with disabilities, especially for novice athletes.

Research related to throwing sports such as shot put, discus, and javelin for athletes with disabilities has primarily looked at the biomechanics of the throwing motion. [4-10] While much progress has been made on the biomechanics of the throwing athletes, little research has focused on the design and usability of throwing chairs and performance of athletes in different chairs.

Throwing chairs have little standardization and so the designs vary greatly from chair to chair. In fact, many chairs are custom made by the athletes themselves or by machinists commissioned by the athletes. A few formal manufactures do exist and offer both stock and custom solutions. However, few of these chairs provide the types of postural supports and adjustments typically found in everyday seating and mobility systems for manual wheelchairs.

Figure 1. Adjustable throwing chair.

Grindle et al. developed a highly adjustable throwing chair for athletes with disabilities (see Figure 1). [11] This throwing chair has many adjustable components to accommodate people of different sizes and postures however, the chair does not allow for the athlete's seating system to be replicated. Specifically, with regards to the amount of tilt or "dump" that their own wheelchair seating system has. This throwing chair design could only accommodate a horizontal seat and a vertical backrest which poses a problem for most athletes because they typically practice throwing in their own wheelchair and become comfortable with that seating system. Performing a throwing motion in another device after practicing in their own wheelchair can have a negative effect on throwing performance. [12]

Therefore, the goal of this study is to develop a design that allows an athlete to throw from a seating system similar to their own wheelchair without losing the benefits of a typical throwing chair (i.e. height adjustability and stability).

METHODS

The design had to comply with all rules for international throwing events and allow the athlete to throw from the same posture and position without losing other benefits from a typical throwing chair. The first decision was whether to make a current throwing chair design more adjustable by being able to adjust the seat and backrest angles or to design a way for the athlete to throw from their own chair while not losing the height or stability of a throwing chair. Due to the complexity of manual wheelchair seating systems and effect of minor wheelchair setup differences on the posture of the athletes, developing a manual wheelchair seat elevator design to allow users to throw from their personal wheelchair was decided. An experienced throwing athlete was interviewed to understand additional user needs and develop functional requirements. The following are the functional requirements or design criteria for the manual wheelchair seat elevator:

1. Comply with all national throwing event rules by Wheelchair & Ambulatory Sports, USA. [13]
2. Lift the athlete's manual wheelchair to the maximum allowable height (30in).
3. Accommodate different styles and sizes of wheelchairs.

4. Minimal setup time between throwers.

Based on the functional requirements, three possible design concepts were hand drafted for the manual wheelchair seat elevator. Their advantages and disadvantages were reviewed and discussed by the authors to select an appropriate design. The selected design was drafted in SolidWorks and reviewed by wheelchair experts at the Human Engineering Research Laboratories (HERL). [14,15] Expert suggestions were incorporated in the design, and the manual wheelchair seat elevator was fabricated at the HERL machine shop. Following development, field testing with one user was conducted at the Buckeye Wheelchair Games held by the Paralyzed Veterans of America. [16]

RESULTS

The design essentially consisted of two parts: a motorcycle lift or jack and an adjustable clamp system (see Figure 2) to attach the personal wheelchair to the lift. The jack was a motorcycle lift purchased off the shelf. [17] It has a weight capacity of 300lbs and has a height range of 13in to 35in. Its base dimensions are 13.8in x 16.1in. The clamp attaches to the rear axle and the horizontal frame tube underneath the front of the seat. On the clamp system, two flat plates can be adjusted and locked at a relative angle. The base plate is horizontal and can be secured to the lift while the other one is in the same plane as the clamping mechanism. The total weight of the clamp system is 11lbs.

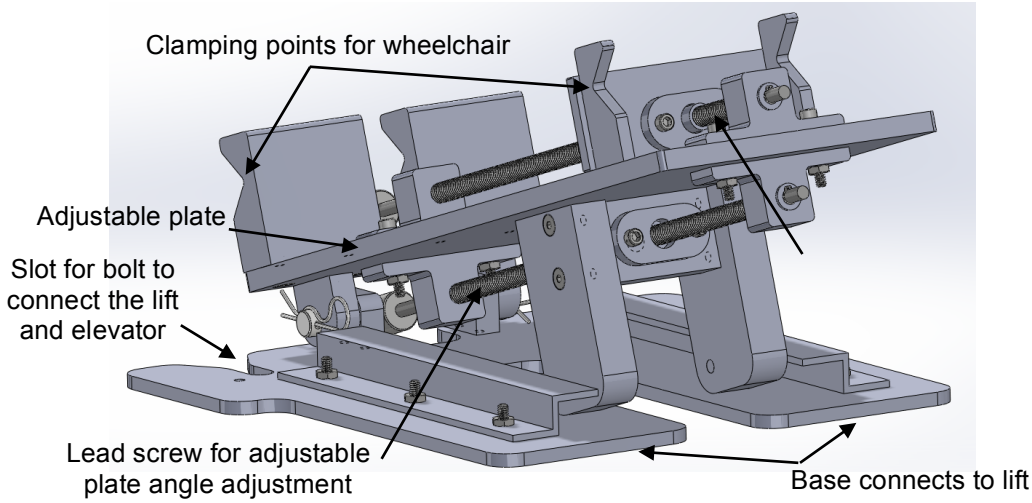

Figure 2. Adjustable clamp system

The clamp can attach to any chair with a rear axle and a horizontal frame bar under the front of the seat. Attaching the clamp to the chair requires running a lead screw so that both bars are in the clamp openings. Then another lead screw will adjust the adjustable plate angle to a horizontal plane. The clamp system attaches to the lift by bolts positioned at the back of the system. The complete manual wheelchair seat elevator assembly is shown in Figure 3.

Figure 3. Manual wheelchair seat elevator (left) and the seat elevator with a mounted wheelchair (right)

User Testing

The design team received favorable design feedback from field testing of the manual wheelchair seat elevator. The user was an experienced throwing athlete and weighed around 250lbs (see Figure 4). The device was trialed during the javelin throw event. The athlete's wheelchair was attached to the seat elevator and the athlete was transferred into the wheelchair afterwards. Straps used to stabilize regular throwing chairs were employed for the same purpose on the seat elevator. The user was able to throw the javelin to a distance equal to what he throws using the regular throwing chair. The user was not comfortable with the sideways stability of the seat elevator. Also, the wheelchair's rear axle could not be tightly secured in the seat elevator clamps. This happened because the lead screw supporting clamp traversal on the adjustable plate lost securement at the end mounts. Wooden sticks were stacked between the two plates of the seat elevator to improve stability during throwing. The user appreciated the seat elevation advantage provided by the new device. The user expressed interest in trying the seat elevator at future wheelchair games once the sideways stability was improved.

Figure 4. Wheelchair athlete throwing javelin in his own wheelchair mounted on the manual wheelchair seat elevator

DISCUSSION

This manual wheelchair seat elevator design is an attempt to allow athletes who participate in throwing events from a seated position to use their personal wheelchairs without losing the height adjustability and stability of a throwing chair. This design will raise a throwers manual wheelchair up to the allowable height of 30in similar to regular throwing chairs. It is feasible to use the manual wheelchair seat elevator for throwing purposes as per user testing but needs few design improvements. Sideways stability was a concern expressed by the user during testing which the design team plans to address by employing supports at edges of clamping system. Loss of the lead screw securement happened because the O-rings employed at the end mounts were not sufficient for holding the screw under user's weight. This requires strengthening the mechanism that holds the lead screw. These design modifications are necessary to improve user safety, performance and satisfaction during throwing.

There can be additional uses for this device as it is essentially a manual wheelchair seat elevator and can be used to allow manual wheelchair user to access items that would ordinarily be out of their reach. These could include kitchen cabinets, shelves, machines, etc. For this application, the lift's height needs to be reduced so that the user can latch the clamp system to the lift independently. Also, the lever to raise and lower the lift needs to be repositioned for easy user access.

The design team plans to conduct further field testing with more users at future wheelchair games following design modifications. Additionally, the team plans to develop an alternate clamping system design for folding wheelchairs with cross-braces.

CONCLUSION

A new manual wheelchair seat elevator design was developed in this study to enable wheelchair users to perform throwing events from their own wheelchair. Based on field testing with an experienced athlete, the seat elevator requires design modifications to improve throwing performance.

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