Making Assistive Technology and Rehabilitation Engineering a Sure Bet

Uniform Throwing Chair for Seated Throwing Sporting Events

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ABSTRACT
The authors collaborated on the design, fabrication, and evaluation of a throwing frame that adjusts to accommodate seated throwing athletes at all classification levels. The benefits of the throwing chair design are that participation will be easier, more standardized, and fair to all competing athletes. The throwing events considered included javelin, discus and shot put events among athletes in fully seated to partially standing positions and various throwing strategies. The throwing chair was designed with input by athletes who are also wheelchair users. Evaluations will be made by competitors at the Warrior Games of the US Paralympics from May 10-14, 2010 at the Olympic training center in Colorado Springs and the National Veteran's Wheelchair Games in July 4-9, 2010, in Denver, CO.

KEYWORDS
Throwing chair; Paralympics; Shot put; Javelin, Discus

BACKGROUND
Physical activity has an important effect in the quality of life for everyone. However, it is more likely that its effects go far beyond in the quality of life of some people with disabilities. Regular exercise is important not only to maintain health but also to reduce the probability to develop secondary health problems as musculoskeletal or cardiovascular problems (1). Additionally, a decline in health status can lead to other psychosocial conditions such as depression, low self-esteem, reduced independence and adaptation.

Within prior studies, there are indications that the percentage of people who practice any kind of physical activity is greater for those without a disability (1). This seems apparent since people with disability may first have physical or mental retraining that hinders activity levels. However, disability itself is not the only factor that hinders the person to do exercise. In the Physical Activity for People with a Disability (PAD) model developed by Hidde P. van der Ploeg et al. (1), environmental barriers have been pointed out as one of the most important factors that discourage people with disabilities from participating in physical activities. Environmental barriers are, as defined by the International Classification of Functioning (ICF), those barriers imposed by the physical place (e.g. home, school and job), society (i.e. social attitudes), institutions, country's laws, regulations, etc. (2). Examples of environmental barriers to physical activity include poor accessibility to physical activity settings and a lack of adaptive equipment and regulations that delay social inclusion. Reducing such environmental barriers can lead to more inclusion of people with disabilities to the sport sphere and thus, to become more physically active.

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In the United States, there is already a positive attitude toward the reduction of those environmental barriers. This spirit is reflected at several national competitions organized to allow people with disabilities to demonstrate their physical capabilities in a wide variety of sports. The impact of these games on people´s life and the true competitive spirit of sports have motivated organizing committees to develop regulations that best diminish unfair competition settings and increase accessibility. As one example, the U.S. Paralympics committee published a discussion paper (3), with a primary goal to discuss reviews and/or implementation of regulations for competitive equipment such as running prosthetics, racing wheelchairs and throwing chairs.

The present design team has responded to work on the US Paralympics recommendations and address other studies carried out to assess the performance of seated throwing athletes (4-6). These studies point out the need of throwing chair designs that allow the participants to perform their best by enhancing their capabilities without providing extra abilities. The equipment should allow a fair competition between athletes in which the winner will be the athlete with the best performance independently of the equipment used. Currently, most athletes create their own custom-made throwing chairs. Time restrictions challenge athletes in their competition setup and organizers when inspecting competition equipment. Additionally, the athletes have to transport their chairs to the competition site, where their participation may be compromised, or in the worst case, disqualified or rejected.

DESIGN OBJECTIVE

While investigating existing throwing chair designs, the team identified several key design goals for improvement. First of all, most throwing chairs have been custom designs for athletes with specific techniques (4-7). This kind of design helps the athletes to execute their best performance; however, limits generalizability for other athletes with different sizes and levels of capability. Second, the athletes with custom chair designs only have three minutes to adjust their seat into desired position with limited assistance (8). Furthermore, these chairs required specific tools for adjustment and differing tie-down methods for securement.

The purpose of this design project was to develop a throwing chair with three main objectives:

1. Incorporate features enabling athletes to perform optimally
2. Design a safe, adjustable throwing chair for fair competition among athletes
3. Manufacture a uniform system to reduce inspection and set-up time

Seeing how throwing chair designs impact competitive performance, several design objectives were defined in addition to the competition rules for seated throwing events.

METHODS/APPROACH

Design

Based on the recommendations of the US Paralympics (3) and the design objective stated above, the team established the following design criteria for a uniform throwing chair shown in Table 1.

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The throwing frame was designed iteratively in SolidWorks Premium 2009, and prototyped in a 1:10 scale using selective laser sintering (SLS) to evaluate the feasibility of the design. The throwing frame consists of a telescopic base with a seat frame to which all seating implements are mounted (Figure 1). The throwing chair subassemblies include the grab bar, tie-down ring, foot plates, knee blocks, thigh strap, lateral supports, backrest, and seat frame rotational adjustment. The telescopic base is height adjustable to accommodate athlete seating at the maximum allowed seat height during competition (including seat cushion). Throwing chair features are all adjustable to support athletes in all classification levels or varied throwing strategies. Additionally, seat frame and pole support subassemblies have a rotational adjustability to allow for different throwing techniques. Figure 1 also shows the rotational subassembly for adjustment of the seat frame orientation.

Category	*Design Criteria*
Modularity and adjustability	Throwing frame has to be divided in different removable modules
	Different seat heights
	Different seat's rotation angles
	Different backrest heights
	Different leg positions
	Different position and orientation of the pole
	Different foot placements
Fast adjustability	One-handed adjustability of all modules
	It can be adjusted in less than 3 minutes
Tie-down method	Accessible tie-down method
	Frame easy to tie
	Tie-down mechanism does not block transfer path
Game rules	Rigid backrest made of non-storing energy material
	Backrest perpendicular to the ground
	Maximum seat height 75cm
	Seat surface parallel to the ground
	Holding bar/pole does not have articulation or joints, does not bend or flex during the throwing action.
	Non-storing energy materials for all components
	Frame footprint dimension is within the field area
	Footrest made of non-storing material

Table 1: Uniform throwing chair design criteria.

Fabrication

Fabrication of the device was completed with laboratory prototyping and machining facilities. Plastic, steel, and aluminum parts were machined using hand tools and manual or computer numeric controlled (CNC) lathes and mills. Clamps and adjustable features were built using electrical discharge machining (EDM) machines. All fabricated parts that were welded together used gas metal arc welding (GMAW) and

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brazing operations. Figure 3 shows the final prototype of the uniform throwing chair.

RESULTS

The throwing chair design incorporated adjustability at all interfaces in order to accommodate the widest range of athletes permitted to participate in seated throwing events for competition. Beyond adjustability, the following user needs drove design decisions and manufacturing efforts.

Figure 1: Uniform throwing chair (design and scale prototype).

Modularity

Modularity provided flexibility and variability of the seating system. Due to unforeseeable differences between athletes with disabilities, accommodation in the seating system allowed for a uniform base to support custom seating needs. Moreover, transferring into and out of the throwing chair was another essential aspect to competition. Thus, removable and modular supporting accessories not only reduced the expected time to change subassemblies, but also increased the possibility to allow custom features inherit to competitive sports. Modularity in the design was reflected in the center post interface to the proposed seat frame subassembly, sleeve interface to the back rest post, and quick-release bracket to the foot plate assembly.

Fast Adjustability

All the parts on the seat could be easily reconfigured by pulling a pin and releasing it in a new orientation. Thus, this quick-release pin design reduces the setup adjustment time between athletes and simplifies the procedures by eliminating the use of special tools.

Fast adjustment of throwing chair features was best reflected by the rotation of the seat frame orientation and

Figure 2: Uniform throwing chair (final prototype)

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grab bar position adjustment. While an athlete would be able to switch throwing orientations between throwing events (ex. front-on to side-on throwing), the seat frame orientation could potentially empower athletes to make minor positioning adjustments when throwing attempts land out of bounds. This reduces the psychological impact of modifying the throwing technique to compensate for improper orientation within the throwing circle. The adjustment would also potentially be independent, where the athlete would lift up on the lever to disengage the brake and use the grab bar to reorient the seat frame incrementally.

Distinguishable Tie-down Ring

The tie-down ring is located in the lower section of the center post, which is a location that could be easily found and accessed. Also, the visual appearance of the ring is strikingly different than other parts on the chair to simplify its identification and proper use.

Game Rules Compliance

The throwing chair fulfilled all requirements specified in the official competition rules of the Paralympics committee. All parts were built of non-energy storing materials such as steel, aluminum, and plastic. The seat and backrest are parallel and perpendicular to the ground, respectively. Finally, the maximum height of the seat can be adjusted to 75 cm with or without a seating cushion.

DISCUSSION

The uniform throwing chair is intended to accommodate a broad range of athletes across all competitive levels of classification. The design allows accommodation for varying anthropometrics of the upper and lower extremities, and allows grab bar orientation for right and left handed athletes. Adjustments can be made without any specialized tools. Lengths, widths, and angles can be adjusted by one-handle pins which make the set-up easier and faster. In addition, the frame can be easily secured with the tie-down ring, because the part is unobstructed and radially-symmetric for multiple configurations.

Although, the design was developed to allow a broad range of throwing techniques, these features of the frame have not been assessed. The team has arranged to evaluate the performance of this design during routine field event competition by voluntary athletes outside of competition. The evaluations will take place at the Warrior Games of the US Paralympics from May 10-14, 2010 at the Olympic training center in Colorado Springs and the National Veteran's Wheelchair Games in July 4-9, 2010, in Denver, CO. Feedback from competitive athletes will inform future redesigns to enhance user satisfaction, ease of use and compatibility for varying throwing strategies.

FUTURE EFFORTS

Total cost of the prototype is estimated to be between 6,000 and 7,000 USD. However, this cost will change according to type of materials used. Currently, the prototype is made with steel but will later be redesigned for weight reduction and simplification of manufacturing steps. Additional iterations will improve generalizability and affordability for throwing event athletes to acquire a uniform throwing chair.

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ACKNOWLEDGMENTS

This material is the result of work supported with resources and the use of facilities at the Human Engineering Research Laboratories, VA Pittsburgh Healthcare System. Prototype development and design tools were sponsored by the WARE VA RR&D center grant (B6789C). Thanks are extended to Dr. Rory Cooper, Garrett Grindle, MS, and the Human Engineering Research Lab shop staff. The team also thanks the support of wheelchair athletes for contributions to the design requirements. This project was performed as part of the HRS 2709 course in the Department of Rehabilitation Science and Technology at the University of Pittsburgh.

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