Modular Walker Handles for a Motorized Posterior Walker

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Modular Walker Handles for a Motorized Posterior Walker

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Abstract

The Motion Analysis and Motor Performance Laboratory at the University of Virginia is conducting a clinical trial focused on developing a motorized posterior walker for children with Cerebral Palsy (CP). Phase two of the clinical trial involves testing two posterior walkers: a standard one and a motorized version. Data collection, including force analysis facilitated by force transducers attached to the walker handles, is a crucial step during these tests. However, due to cost constraints, only one pair of force transducers are available, necessitating their interchange between walkers, using an allen key. This error prone and time consuming process requires three people and five minutes to conduct. To address these challenges, a capstone project aims to redesign the locking mechanism, integrating the handle and transducer into a single unit to streamline the data collection process. Through iterative design and prototyping using computer-aided design and 3D printers, a button locking mechanism was developed, allowing for efficient attachment and detachment of the handle without any additional tools. The prototypes were printed in polylactic acid while the final design, being implemented for future clinical trials, will be machined out of metal. Finite Element Analysis ensured durability of up to 150 pounds of force for future iterations of the printed design. Additionally, efficacy testing confirmed improved efficiency, reducing attachment time to 30 seconds and requiring only one person for the procedure. The redesigned mechanism holds promise for enhancing data accuracy and reducing operational complexities in clinical trials involving mobility aids for children with CP.

Keywords: Motorized posterior walker, cerebral palsy, clinical trial, force transducers, modular design, efficiency, durability, finite element analysis, computer-aided design, 3-D printing

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Introduction

Project Background

Cerebral Palsy (CP) is a congenital disease that impacts the development of motor and balance skills, affecting one in 345 children in the United States[1]. The Motion Analysis and Motor Performance Laboratory at the University of Virginia is conducting a clinical trial to create a motorized posterior walker for children with CP to optimize energy consumption while walking[2]. This clinical trial is in phase two of testing two posterior walkers - one which is standard and one which is motorized, developed by Barron Associates. To measure effectiveness of the design of the walker, healthy children and those affected with CP are invited to the lab to participate in a clinical trial. Various instruments are placed on the patient during the clinical trial to measure energy consumption and gait cycle. These include electromyography (EMG) machines (measuring electrical response in response to nerve stimulation of the muscle in the leg), a VO_2 mask and monitor (measuring maximum oxygen consumption during the various walking trials to show aerobic endurance), and reflective markers (placed over various bones of the patient and can be transferred to the software used to be analyzed to track motion and deviation with respect from one another). The participant, ranging from age six to seventeen, is required to walk under three different circumstances during data collection: one without any external assistance, one using a standard posterior walker, and one using the motorized posterior walker. The mini45 model of ATI six axis force transducers are

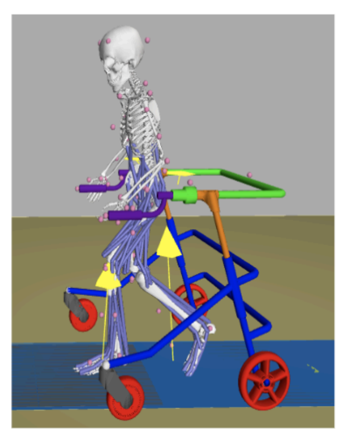

Fig. 1. Posterior walker in trial

attached on each handle to collect outputting forces and torques from all three cartesian coordinates (Figure 1). The information from this is used to inform the design for the start time and speed settings of the walker. These force transducers cost around $7000 each[3], thus only allowing the Gait Lab to have one pair of them. Due to the limited supply of them, the handles and force transducers are interchanged between the two walkers during data collection.

Existing Mechanism

The way the two pieces are interchanged is by using an allen key. First the handle is removed using the allen key, followed by the transducer. These pieces are then reattached to the remaining walker. Doing so takes around five minutes in total. Additionally, three support personnel are required: one to stabilize the walker, one to hold the handle, and one to unscrew the pieces. Figure 2 shows the allen key and old design of the handle locking mechanism.

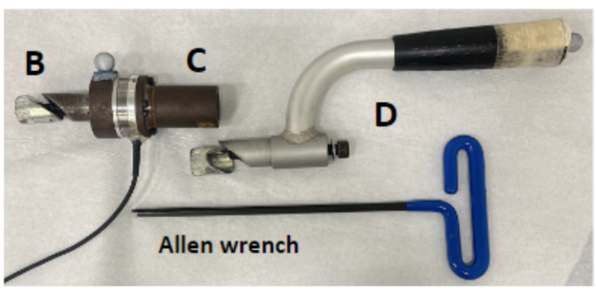

Fig. 2. Components of the original locking mechanism

This process is not ideal when working with children since it can often lead to a skewing of the data. The children have various markers, including electromyography, a VO_2 monitor, and reflective placement markers, on them which they may fidget with during extended periods of rest. To avoid potential errors in data collection, this capstone aims to redesign the locking mechanism to attach the transducer and handle, as one unit, into the walker.

Specific Aims

Three main objectives were developed to guide the project in designing an efficient handle system. The first aim was to design a modularized walker handle that fits both the walkers, self-propelled and motorized, used in clinical trials. The constructed walker handle had to securely mount to all walkers that the lab used. The handle was also designed to fit an ATI force transducer, while simultaneously not impairing the accuracy of force measurements. In addition, the design allowed the transducer to be easily removed to ensure efficient data collection. The second aim was to design a more efficient handle that could be mounted and calibrated by fewer people. As previously mentioned, the original design required three people, five minutes, and an allen wrench to loosen the handle and transfer between walkers. To increase efficiency, a novel locking mechanism will be utilized, that requires only one person to rapidly mount and dismount each handle. To determine the effectiveness of the design, comparisons were made between the original and updated designs' mounting speeds. The third aim was to create a cost effective, user-centric, ergonomic design for the handle. By utilizing rapid prototyping with polylactic acid (PLA) and finite element analysis (FEA), the team was able to keep the cost of development to a minimum, and the final proposed prototype utilizes a button-locking mechanism that is both more accessible and easier to use than the existing design.

Results

Design Considerations

To ensure that the mechanism does in fact increase efficiency, some general constraints were followed when creating the design, such as to avoid the usage of an external tool and to combine the transducer and handle into one unit. The original design requires the use of an allen wrench and multiple people to interchange each handle between walkers. However, an updated, modular design would eliminate the need for increased personnel and decrease the overall time required to complete the transfer process.

Iteration Development

Several prototypes of the locking mechanism were designed and then fabricated to determine effectiveness. There were two significant models that were developed with iterative adjustments made throughout the design process (Figure 3). The first design iteration consisted of a

Fig. 3. Iteration Timeline

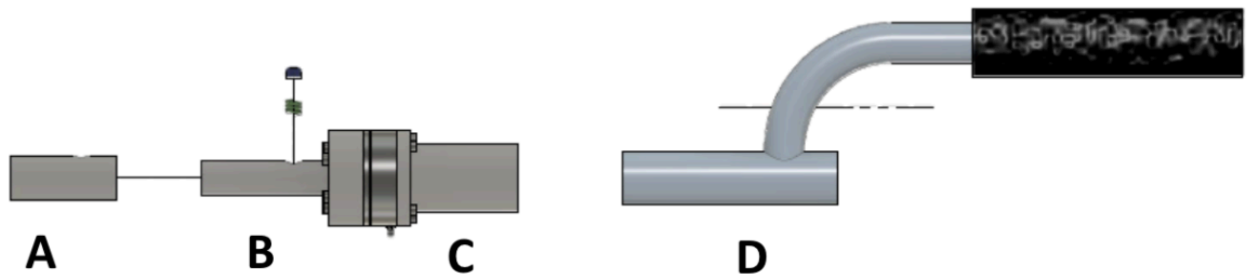

Fig. 4. Implemented Model

slide in groove mechanism, with protrusions on a cylinder (piece 1B) allowing it to slide into the channeled sleeve (piece 1A). However, when implementing this design, piece 1B slid out easily while in use. When working with children, they tend to fidget a lot, which in this case would result in the handle becoming detached from the walker. A potential solution would be to create a toothpick-like design to place into the groove and prevent movement. However, as previously mentioned, one of the two main design constraints was to avoid the use of additional tools, so a new iteration was developed. To ensure a more secure fit between the handle and the walker, a button locking mechanism was used, which is commonly found in orthopedic devices, such as crutches. This design consisted of two interlocking pieces, one containing the button mechanism (piece 2B) and the other containing a hole for the button to fit through (piece 2A). Due to its increased ease of use and secureness, this button locking mechanism was utilized in the final design.

Final Design

The implemented model consists of four main components (Figure 4). Piece A, as previously mentioned, contains a circular hole to guide the button as it is locked in place. This component fits directly into the walker frame to ensure a proper connection between the walker and handle system. Piece B contains the spring and button locking mechanism, and is attached to the casing around the transducer, which is shown in metallic material. Piece C fits securely around the handle (piece D), which were both unchanged from the original design. In addition, both piece B and piece C are bolted to the force transducer using M3 screws. This design increases efficiency by allowing the handle and transducer components to detach from the walker as one combined unit.

<u>Locking Mechanism</u>

The final design utilizes a button and spring locking mechanism (Figure 5). A spring is situated within a well on piece B, secured to the handle and to the bottom of the button. To operate the locking mechanism, piece B is inserted into the opening of piece A, which has been fitted into the walker. The spring-button assembly is compressed with a finger, allowing the end of piece B to fully slide into piece A until the button pops up through the circular hole in the side of piece A (Figure 6). Similarly to reverse the coupling of the parts, the button must be pressed down, allowing the handle to slide out of piece A and the walker.

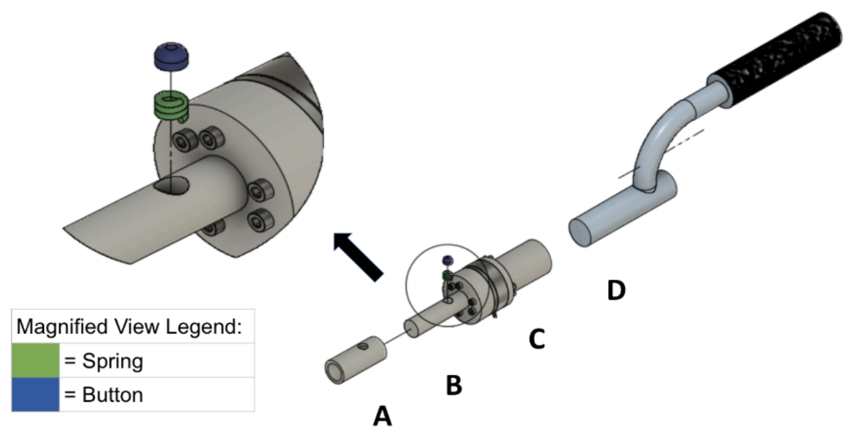

Fig. 5. Magnified View of Button and Spring Mechanism

Discussion

Efficiency

The handle and transducer stay attached as one unit using the locking mechanism from the original design. The new design no longer requires this piece to be detached, as the button attached on the transducer is separate from the handle piece. The new mounting procedure requires one person and a total of 30 seconds for the entire procedure (Figure 6). Since it is a simple one step procedure on each side, it also reduces the possibility of decalibrating the force transducers during transfer. However, some considerations need to be made for the future development of the design. When choosing a spring to use in the mechanism, the physical dimensions of the spring matter significantly more than the elasticity. During the iterative process, the team chose to use increasingly smaller springs as it became more apparent that an oversized or overly strong spring could hinder the locking mechanism rather than help. It would make pushing the button far enough down to achieve clearance and unlock the handle difficult. By using a smaller spring but making sure that it was securely attached to the button, the locking mechanism functioned properly as the button stayed in place, but was still easy and quick to press down. The team secured the metal spring used in prototyping to the PLA handle and button using adhesive, but in future iterations depending on the material the spring could be welded to the button and handle or secured with high strength adhesive.

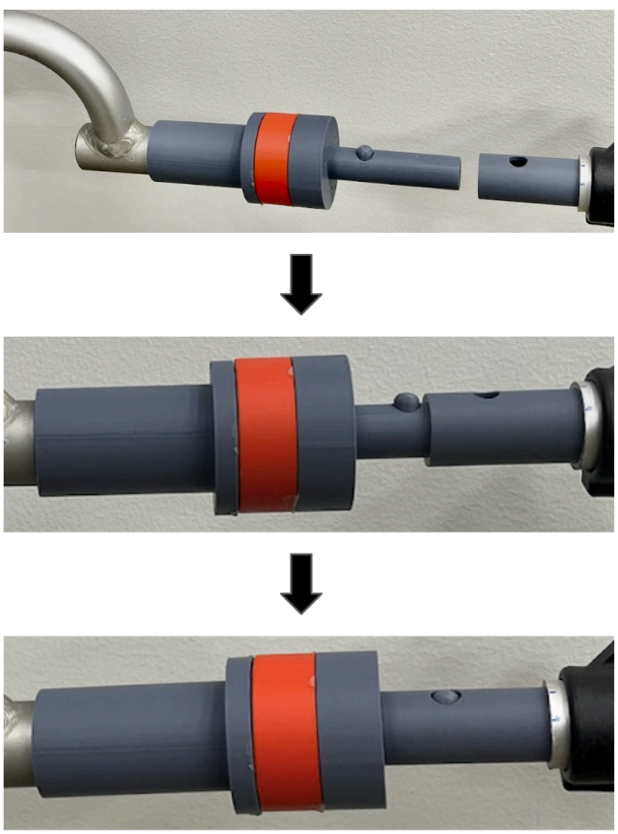

Fig. 6. Button Locking Mechanism. Process of mounting the handle prototype onto the walker

Durability

In order to determine the strength and durability of the design, finite element analysis (FEA) was used (Figure 7). In Solidworks an assembly was created, made up of the components of the prototype, the transducer, the handle, and M3 screws securing the transducer to the prototype. In anticipation of the future steps of this project, the material of the prototype was changed in Solidworks from PLA to 1060 aluminum alloy. This material was chosen due to its low mechanical strength and high workability in comparison to other metals and aluminum alloys[4], because the exact metal of choice for future manufacturing was undetermined. If the handle was able to withstand the simulated forces without deformation with 1060 aluminum, then it would be strong enough regardless of the final choice of metal. A force simulation was performed, pushing 150 lb of force onto the handle to quantify the magnitude of deformation and potential points of failure.

The button-locking mechanism was able to withstand this force without any deformation. The force simulation identified the weakest point of this design to be in component B, and this was validated during testing of the final prototype. During one test of the mechanism, the team was testing the efficacy of the PLA prototype and the locking mechanism part of component B broke off in the walker during the dismounting process, identifying a future need for reinforcement should the design be manufactured with weak material such as plastic.

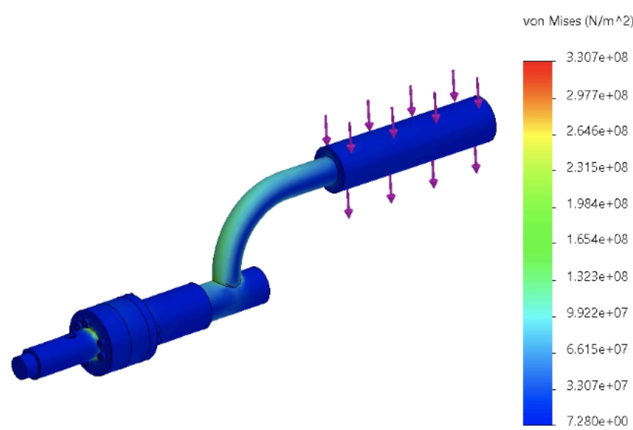

Fig. 7. FEA Simulation

Impact

With this final design, the motion lab and any other partners who utilize this handle will be able to more effectively collect force data in gait clinical trials. They will need less lab members dedicated to dismounting and remounting handles between walkers, the time required for this process will be significantly reduced, and as a result of this decreased waiting time, the patients participating in the trial won't need to stand idly for as long. This gives younger patients less time to fidget and accidentally decalibrate a measurement apparatus attached to them, such as physical markers or VO_2 monitors.

Future Work

The immediate next step for this project is to strengthen the weak point identified by FEA and prototype testing in the lab. This could be accomplished by addition of material to the edge through a tool on Fusion such as a fillet, smoothing and adding material to the weak corner. Once this area is addressed, the motion lab will be able to manufacture the design out of metal. This could be done by utilizing something like a 3xxx aluminum alloy, giving a moderate strength while retaining good workability, or it could be made with one of higher strength such as a 7xxx aluminum alloy[4]. However, the prototype is not limited to aluminum alloys and if increased strength of the handle is of larger concern than weight, a significantly higher strength metal such as steel could be used.

It should be noted that during the development of the designs, the team was operating under the assumption that there was an additional design constraint, which was that the design must be additive, not subtractive; we didn't want to make a locking mechanism that would require modifications to the walker frame itself. If this were not a limitation, component A of the implemented model (Figure 4) could be discarded. In its place the diameter of component B, containing the locking mechanism, could be increased to match the diameter of part A. Then, a hole could be drilled into the frame of the walker for the button to move through. Doing this would simplify the design, requiring less material to be machined, and shorten the total length of the handle. This is beneficial because according to the Law of the Lever[5], placing the applied force closer to the walker reduces the force experienced by the handle itself.

<u>Materials and Methods</u>

To redesign the handle effectively, the original design was studied in detail. There were two outlying issues causing the mechanism to be disruptive. One was the handle and force transducers being two separate units causing increased steps during transfer. The other was the use of an allen key, or an external tool in general. This required additional people to be present since one person was required to operate with the tool while the others controlled the walker.

Computer Aided Design of Model

The design process began using prior work which consisted of computer-aided design (CAD) models from the original handle and the walkers it would need to attach to, made with the software Autodesk Inventor. These models were imported into a similar software, Autodesk Fusion, which the team was more familiar doing CAD modeling with. Additionally, because Fusion has built-in cloud saving capabilities, every team member always had access to the most up-to-date iteration of the model. The first iteration of the locking mechanism was a direct modification to the original file, and each following iteration was a modification of the previous model until the final prototype was developed (Figure 4).

Creation of Physical Prototypes

For each significant iteration of the locking mechanism design, a rapid prototype was created by 3D printing in the UVA BME Fabrication Space at Stacey Hall. The filament used was polylactic acid (PLA) because it was readily available, low cost, and has a lower coefficient of thermal expansion than other common 3D printing filaments like Acrylonitrile Butadiene Styrene[6]. Minimizing thermal expansion meant that the prototype had less warping during the printing process, ensuring the dimensions and tolerances in the design were accurate. The printing was done on Bambu Lab X1 Carbon 3D printers, and a PLA model of the force transducer was created to allow for simulating the fitting of the locking mechanism, with the transducer and handle attached, to the walker.

Stress Testing

To test the strength of the locking mechanism designs, finite element analysis (FEA) was done (Figure 7), where the models underwent force simulations to identify potential deformation or points of failure if the handle were used by a person. The models were imported from Fusion into another CAD software called Solidworks, since the team already had experience doing force studies with it. To simulate the forces experienced by the handle during a potential clinical trial, the walker end of the sleeve component was treated as a fixed point while the part of the handle that would be gripped by a patient had a straight downwards force pushing directly onto it.

Efficacy Testing

To quantify the efficacy of the proposed locking mechanism designs, each iteration of the PLA prototype was tested on several metrics: The prototypes were first evaluated by how well the components fit the walker, transducer, and handle. They were then tested on how long it took to mount and dismount the handle, simulating the process of swapping the handles between walkers during trial. Finally, the designs were tested on how many people were required for the mounting and dismounting process, to ensure the walker stays stable and that no components are mishandled or dropped during the process.

End Matter

Author Contributions and Notes

Farrukh, S., Price, A., and Young, E. created CAD designs, 3D-printed and assembled prototypes, tested the efficacy of mechanisms, and wrote the final report. Russell, S. advised on device designs. The authors declare no conflict of interest.

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References

1. Centers for Disease Control and Prevention. (2023, February 23). *11 things to know about cerebral palsy*. Centers for Disease Control and Prevention. https://www.cdc.gov/ncbddd/cp/features/cerebral-palsy-11-things.html
2. Russell, S., Bennett, B., Sheth, P., & Abel, M. (2011). The gait of children with and without cerebral palsy: Work, energy, and angular momentum. *Journal of Applied Biomechanics*, *27*(2), 99–107. https://doi.org/10.1123/jab.27.2.99
3. *ATI: 6-axis force and Torque Sensor (Mini45 series) 9105-TW-mini45-R-5-IP65*. motionsupply.com. (n.d.). https://www.e-motionsupply.com/product_p/9105-tw-mini45-r-5-ip65.htm
4. Avallone, E. A., & Baumeister, T. (2006a). Aluminum and its alloys. In Marks' Standard Handbook for Mechanical Engineers: Standard handbook for mechanical engineers (10th ed., pp. 6–55). essay, McGraw-Hill.
5. On the equilibrium of planes, Book i. (2009). The Works of Archimedes, 189–202. https://doi.org/10.1017/cbo9780511695124.015
6. Rădulescu, B., Mihalache, A. M., Hrițuc, A., Rădulescu, M., Slătineanu, L., Munteanu, A., Dodun, O., & Nagîț, G. (2022). Thermal expansion of plastics used for 3D printing. Polymers, 14(15), 3061. https://doi.org/10.3390/polym14153061