Wheelchair Adaptive Devices for Quad Tennis

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Client: Daniel Dorszynski, Private Client **Advisor:** Dr. Ed Bersu

UW BME Design

Abstract

The client requires a suite of assistive devices for use in a quadriplegic tennis league as a result of his condition, Becker Muscular Dystrophy. The two main goals of this project are to design and fabricate a tennis ball launching system and an optimized tennis racket grip. Some important criteria for these designs are client safety, ease of use, and accuracy. After evaluating a range of brainstormed ideas with a design matrix, the team elected to move forward with a compressed air system to launch the tennis ball and a series of elastic bands around the racket handle for a supported grip. Testing of the racket grip proved successful for an initial prototype, but the tennis ball launcher failed to complete the task of launching the ball. Future work of the designs will focus on optimizing the tennis grip for comfort and developing a working model for the launching system.

Background

Becker Muscular Dystrophy

- Inherited muscular disorder[2]
- Genetic mutation that affects use of dystrophin[2]
- Progressively weakens muscles in upper and lower extremities[2]

Figure 1: Affected Muscles[1]

Quadriplegic Tennis

- Requires substantial loss of function in at least one of the upper extremities[4]
- Assistive devices must be ready at beginning of the match[4]
- Assistive devices may not alter physical characteristics of the racket[5]
- Current grip securing devices include athletic tape[6], velcro, and rubber bands
- Current serving method involves personal or assisted tossing of the ball

Figure 2: Athletic Tape Often Used to Secure Hand to Tennis Racket[3]

Motivation

- Client lacks ideal grip strength and consistency in his serve.
- Fourth and fifth digits become separated from grip when force is applied to racket.
- Commonly used athletic tape securing method greatly range of motion of wrist.
- Off court serving systems lack the consistency that the client needs during gameplay.
- Client's current serving method is both inconvenient and inconsistent.

Figure 3: Client's grip on tennis racket with applied force. Fourth and fifth digit become separated from grip.

Design Criteria

Tennis Ball Launcher

- Launch an ITF approved tennis ball 24-42 inches in the air for a serve
- Mount on the wheelchair
- Detachable from wheelchair when not in use
- Easy for client to activate/launch
- Does not interfere with play

Grip Support System

- Maintain a firm grip on the racket
- Allow full range of motion in the wrist
- Withstand a variety of environmental conditions
- Does not strain the wrist or affect circulation in the hand and wrist area

Figure 4: Client's wheelchairs for modifications

Tennis Ball Launcher Design Progress & Final Design

Figure 5: Launching system tank on back of wheelchair

Solenoid Valve Circuitry

Materials

- Switch
- 24V Source
- Solenoid Valve (Z=55Ω)
- 10k Resistor
- Field Effect Transistor

Fabrication and Testing

- Simplified the circuit by using FET Transistor
- Successfully built and tested circuit on a breadboard
- Soldering onto PCB presented difficulties in functionality
- Substituted simple mechanical switch/power source circuit

Launching System

Materials

- 2.5 L 200 PSI air tank
- Fill valve, 200 PSI relief valve, draincock valve, 300 PSI gauge
- Pressure Regulator
- 1/4" polyurethane hose
- 3" PVC tube and cap
- Line connectors & caps

Fabrication:

- Fitted valves to ports on air tank
- Air flow through solenoid valve, pressure regulator, and hose to launching tube
- PVC pipe and cap coupled to form launching tube, ½" hole drilled through cap to insert connector to air hose

Testing:

- Air flow diverts around the ball
- Outlet PSI = 0.4994(Tank PSI) + 10.94571, p < 2.2e-16, n = 46 shots

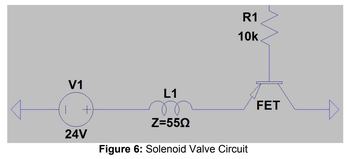

Figure 6: Solenoid Valve Circuit

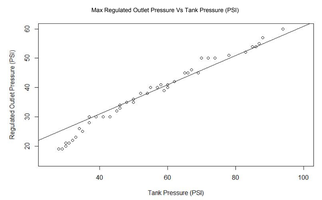

Figure 7: Linear regression model between tank pressure and max regulated outlet pressure

Figure 8: Launching tube attachment with tube

Storage Tank Attachment

Materials

- 9"X17"X0.25" Aluminum Plate
- 2 #385 x 5/16 in. x 2 in. x 3-3/4 in. zinc-plated u-bolts

Fabrication

- Sawed 2 1"X0.5" notches for wheelchair placement
- Drilled 4 5/16" holes for tank attachment, 4 ⅜" holes for U-bolt attachment to wheelchair

Testing

- Held 333.6 N (75 lbs) & 738.4 N (166 lbs)
- Deformation upon 925.2 N (208 lbs)

Launching Tube Attachment

Materials

- 6.5x2x0.55" & 7x2x0.75" steel c-channels
- 5" extension spring
- 4 hose clamps
- 6 washers
- 3 4-3/4 in. x 5/32 in. zinc-plated turnbuckles

Fabrication

- Dimensioned c-channels to fit wheelchair and launching tube
- 4 washers welded to wheelchair channel, 2 to launching tube channel
- Triangulation of turnbuckles for orientation, spring for support

Testing

- 44% chance making ball in tube (n = 25)
- p = 0.7878 for >50% chance making ball in tube

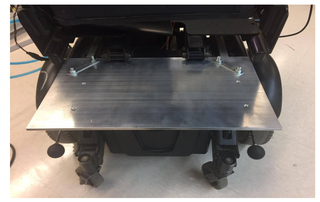

Figure 9: Tank attachment fixed to wheelchair bar

Racket Grip Design Progress & Final Design

Figure 10: Racket grip design in application

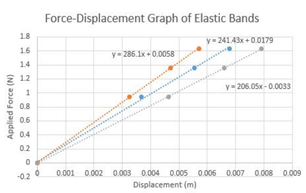

Figure 11: Force-Displacement graph which indicates the stiffness of a sample of the elastic bands

Materials

HDPE (High-density polyethylene)
Woven elastic

Fabrication

- Obtained 3x4x1'' HDPE (High-density polyethylene)
- Milled to the outer radius and inner dimensions
- Drilled holes for the screws
- Elastic knots are placed on the outside of the plastic laying flat against the racket handle

Testing

Properties of the materials:

- Elastic bands are held taut at stiffness of 244.52+/- 40.11 N/m, but can be adjusted for personal comfort
- Each half clamp weighs 33.7 +/- 1.2g for product mass of 147.08g (0.3lb)

We had 10 students try the racket in play and rate it in specific categories.

- Functionality: 5/5
- Comfort: 2.5/5*
- Aesthetics: 4/5
- Ease of Use: 4/5

*After the testing took place, the sharp corners were rounded

Figure 12: Close view of racket grip design in use

Figure 13: Testing of the racket grip in play

Future Work

Tennis Ball Launcher

- Implement a tank that can allow more serves per full tank of air
- Modify launching tube to better seal tennis ball for airflow
- Reconfigure the circuitry to release a consistent, preset amount of air
- Design covers/enclosure to protect air line and wires
- Obtain smaller turnbuckles so that the launch tube is not as close to the ground
- Determine possible design alternatives

Grip Support System

- Create notches for the elastic knots to prevent slipping
- Use less material to decrease mass
- Put screws on the long side of the racket to avoid interfering with the wrist motions

Acknowledgements/References

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