HUMAN PERFORMANCE-BASED PEDIATRIC WHEELCHAIR PRESCRIPTION

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INTRODUCTION

Mobility impaired children between the ages of 2 and 5 need appropriately designed and sized wheelchairs. Configuration guidelines exist for adults but little work has been done to establish appropriate guidelines for children (Brubaker, 1986). It was hypothesized that the propelling capabilities of pediatric wheelchair users could be predicted and improved using biomechanical analysis and testing.

Wheelchair wheels were tested to determine the forces required to initiate movement of a pediatric wheelchair. A static mathematical model and experimental testing techniques were utilized to identify the required joint torques in the initial pre-movement phase of the push. Seat configuration guidelines were developed based on results from these analyses and validated with human subjects. User friendly software was developed to assist therapists and wheelchair dealers prescribe age and strength appropriate wheel configurations that maximize the user's capabilities.

METHODS

A 3-phase design was implemented to develop pediatric wheelchair prescription guidelines. The forces required to initiate movement of a pediatric wheelchair were experimentally measured and validated in phase 1. Static coefficients of rolling friction were determined for three front wheels and three rear wheels on short carpet, wood, and a 0.95 cm high door threshold (Al-Eiwasi, 1999). Combinations of surface materials and wheels were tested on a fully assembled chair to insure that the coefficients were valid.

A static model of a pediatric wheelchair and child was developed and used in phase 2 for the purposes of determining a child's ability to self-propel and to determine an optimal wheelchair configuration. The model uses child-chair specific data (wheel type, ground material, age, weight, body segment lengths, and maximum voluntary contraction (MVC) joint torques) to examine the effect of variations in model parameters (normal force (F_n), hand position (θ_h), torso angle (θ_t), and distances to the hub (t_x,t_z)) on the minimum required joint torques (Figure 1).

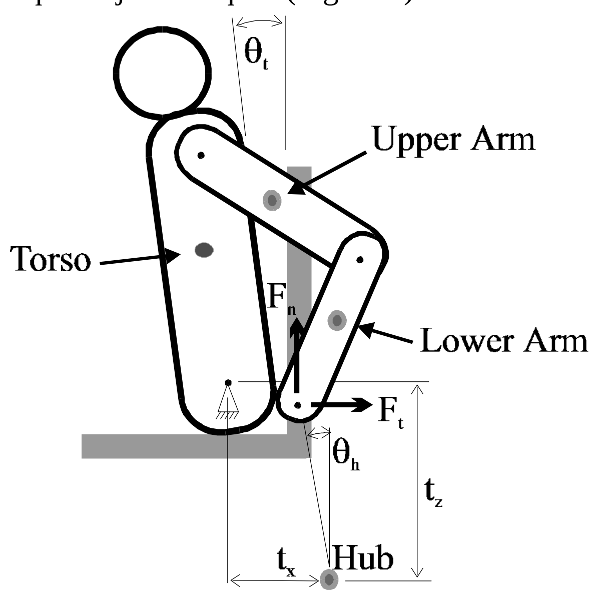

Figure 1. Model parameters.

Joint torques are calculated with static equations of equilibrium and normalized with respect to the subject's (MVC) torques. A cost function (the sum of the cubed normalized joint torques) is used to identify the model parameters that minimize the muscular effort required to initiate chair movement. The required torques of the optimal case are then specified and compared to the child's MVC torque data to determine if the child is strong enough to self propel.

The model is being validated by comparing data collected with a simulated wheelchair and pediatric wheelchair users, ages 4 and 5, with model predictions. The simulated pediatric wheelchair was designed to measure values corresponding to each model parameter in addition to the tangential forces (F_t) exerted on the handrim (Hughes 1992). Force and video data, recorded for each static, simulated wheelchair push, are used to obtain actual parameters for comparison with those predicted by the model.

Phase 3 of the project involves the development of software to assist in pediatric wheelchair prescription. Software incorporates the model of pediatric wheelchair and child to determine if the child can successfully self-propel and if so prescribe an appropriate configuration.

RESULTS AND DISCUSSION

Coefficient of static rolling friction (μ_{sr}) data depended on wheel type, diameter and ground material (Table 1). For a given wheel type, resistance was less as wheel diameter increased. Larger diameter, pneumatic wheels had greater resistance to movement than small rubber or polyurethane wheels. Lowered air pressure in pneumatic wheels decreased the resistance to traversing a threshold.

Table 1. Coefficients of Static Rolling Friction (μ_{sr}). Note: Italics indicate an exponential best-fit equation.

Wheel Diameter And Type	Wood	Carpet	0.476 cm Threshold
7.9 cm Polyurethane	0.015	0.126	0.375
12.4 cm Rubber	0.015	0.108	0.384
15.2 cm Pneumatic	0.019	0.096	$0.569F_n^{0.904}$
32.9 cm Pneumatic	0.023	0.049	$0.573F_n^{0.823}$
39.4 cm Pneumatic	0.023	0.045	$0.512F_n^{0.830}$
52.4 cm Pneumatic	0.015	0.037	$0.397F_n^{0.873}$

Additionally, for the pneumatic-threshold case, resistance was non-linearly dependent on normal force. The μ_{sr} data allowed accurate prediction of the static friction associated with initiating chair movement.

Preliminary results from testing one child in two horizontal positions (wheel ±15.24 cm relative to the hip) indicated that MVC torque measurements at the shoulder and elbow were, on average, 18% (S.D. 12) greater than predicted values. Torque at either the elbow or shoulder was the limiting factor in all trials. The subject's actual measured forces and model-predicted forces both exceeded that required for self-propelling on wood, carpet, and an access ramp. The forces required to self-propel over a threshold were very similar to the child's MVC capabilities. Actual values indicated that the subject could self-propel in both configurations tested. The model predicted the child could not self-propel in the forward wheel configuration.

SUMMARY

A new approach is being developed to facilitate pediatric wheelchair prescription. This approach determines if a child can self-propel and if so prescribes the optimal seating configuration.

REFERENCES

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