Development of an Engineering Protocol for Achieving the Optimum Configuration of Manual Wheelchairs for Better Energy Efficiency for Frail or Elderly Carers Pushing the Wheelchair, Taking into Account Static Stability

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Introduction

The primary aim of this research is to determine if it is feasible to identify the main adjustments that could be made to a manual wheelchair in order to affect a carer's energy expenditure and to quantify the impact of those adjustments thus enabling the development of a tool to aid assessors to produce the best configuration for that carer.

This issue has arisen as an increasing number of carers are approaching posture and mobility services commenting on how difficult some manual wheelchairs are to move. Due to the home environment, transport reasons or the carer's abilities, add on power packs or electric wheelchairs may not be suitable solutions.

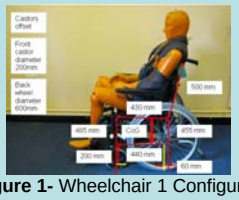

Figure 1- Wheelchair 1 Configuration

Method

10 staff volunteers were sourced from the Artificial Limb and Appliance Service (ALAS). Seven Invacare Action 2 NG wheelchairs[1] were configured differently and an anthropometric dummy weighing 77kg was used.

Each volunteer completed a fitness questionnaire[2] and was connected to a three lead ECG and oxygen saturation finger probe (Philips IntelliVue MP2 monitor)[3]. Each volunteer pushed a configuration around a 150m course then sat for a minimum of 5 minutes before repeating. This pattern was repeated three times for each configuration.

Results

Wheelchair configurations: Table 1 shows the adjustments made while Figure 1 shows the measurements obtained. Wheelchairs 1,2, 4, 5 and 6 had small modifications made that allowed the wheel to be moved forwards. Tilt table tests were also conducted for comparison with theoretical calculations (the Centre of Gravity (CoG) position was assumed to be fixed as seen in Figure 2).

Fitness questionnaire: The volunteers could be put into one of three fitness categories from the results of the questionnaire. From there they were further subdivided according to gender and age banding.

Vital signs data: Figure 3 shows a volunteer taking part in the research while Table 2 shows the varied results of the effort required by a particular volunteer. This ranking could then be compared to other volunteers' ranking profiles.

Statistical analysis: The statistical analysis of the vital signs data showed that there were no statistically significant results (see Discussion).

Development of an engineering protocol: A volunteer's height and weight data were plotted and this information could identify a volunteer that is most similar to a real carer. This configuration could then be applied to the client's wheelchair. Had the results been statistically significant then it would have demonstrated that it is feasible to match the characteristics of a specific carer to the optimum wheelchair configuration for energy efficiency and stability.

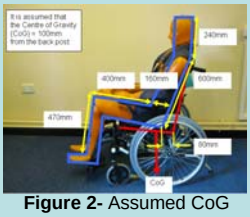

Figure 2- Assumed CoG

Figure 3- A volunteer pushing Wheelchair 1

Table 1- Wheelchair Configurations

Wheelchair	Title	Specification	
Wheelchair 1	Perceived most efficient	1. Wheel forwards	4. Correct handle height
		2. Large castors	5. Self propel wheel
		3. Pneumatic wheel	
Wheelchair 2 (inline castors)	Change wheel diameter	1. Wheel forwards	4. Correct handle height
		2. Large castors	5. Transit wheel
		3. Solid wheel	
Wheelchair 3	Change wheel position	1. Wheel back	4. Correct handle height
		2. Large castors	5. Self propel wheel
		3. Solid wheel	
Wheelchair 4	Change type of wheel	1. Wheel forwards	4. Correct handle height
		2. Large castors	5. Self propel wheel
		3. Solid wheel	
Wheelchair 5	Change front wheel	1. Wheel forwards	4. Correct handle height
		2. Small castors	5. Self propel wheel
		3. Solid wheel	
Wheelchair 6	Change handle height	1. Wheel forwards	4. High handle height
		2. Large castors	
		3. Solid wheel	5. Self propel wheel
Wheelchair 7 (inline castors)	Perceived least efficient	1. Wheel back	4. High handle height
		2. Small castors	5. Transit wheel
		3. Solid wheel	

Table 2- Ranking of Effort for Each Wheelchair Configuration

	Heart Rate	Respiration Rate	Overall Performance
Highest Effort	WC 1	WC 2	WC 1 WC 2
	WC 3 WC 5	WC 6	WC 5
	WC 2	WC 1	WC 3 WC 6
	WC 7	WC 5	WC 4 WC 7
	WC 4 WC 6	WC 3	
		WC 4	
Lowest Effort		WC 7	

Discussion and Conclusions

Though no statistically significant results were obtained that is not to say that the data was not meaningful. Wheelchair 1 was the theoretically most energy efficient while Wheelchair 7 the opposite, however Table 2 shows that Wheelchair 1 required the most energy to push while Wheelchair 7 required the least. This contradiction could be for several reasons; weight differences, the pneumatic wheels not being correctly inflated, and/ or most likely, the difference between offset and inline castors (due to sourcing problems that prevented consistency; Table 1 shows wheelchairs with offset castors unless stated otherwise).

Future work would need to address several issues; the pushing order, rest duration, breaks where the volunteer was moving, wheelchair weights, the volunteer's exposure to wheelchairs, how useful is SPO2, and the sourcing of similar wheelchair components. Much greater numbers of volunteers would be required to get more accurate results and would determine whether the data would be statistically significant or not. Furthermore more volunteer information would be required such as body mass index, and muscle and fat percentages.

While posture and mobility services are primarily concerned with the needs of the client, the needs of the carer must also be considered without compromising the client and further work in this area would be highly beneficial to all concerned.

References

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