# Clinical Assessment of Pushrim Activated Power Assisted Wheelchairs Towards Establishing a Criteria for Provision

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**Objective**: To assess Pushrim Activated Power Assisted Wheelchairs (PAPAWs) in a clinical setting in terms of energy consumption and user satisfaction.

**Design**: A single blinded controlled study

**Setting**: NHS Rehabilitation Centre

**Subjects**: Thirty three consenting randomly selected adult self-propelling wheelchair users.

**Interventions**: Four trials for each participant (subject's own manual wheelchair, PAPAW-On and Off modes and dummy PAPAW wheels).

**Main Measures**: Energy consumption and time taken to complete each trial. A questionnaire scoring on a Likert scale between 1 to 5 to assess the user's perspectives on five aspects of the wheelchairs. A record of a brief verbal interview was also completed.

**Results**: Significant benefits were found for energy consumption ($P$<0.001). PAPAW-Off consumed significant more energy than the client's Own ($F_{1,9}$ = 17.73, $P$=0.002). Significant differences were found for time ($P$=0.002), less time was required to complete the course in their own chair compared to the other wheel types. Scores for the wheel types showed that the PAPAW-On mode scored higher ($P$<0) than the other types. Users' comments described particular benefits and problems encountered with the PAPAWs-on mode.

**Conclusions**: The energy savings with PAPAWs is minimal under these test conditions. The study identified:

1. Requirement of good upper limb control and cognition to control PAPAWs properly
2. Need for possible training prior to provision.
3. Heavy weight of PAPAW wheels being a difficulty for a majority of participants.

Further studies are required to assess the advantages of PAPAWs in day to day community living through longitudinal trials.

# Introduction

Wheelchairs offer the only effective mode of independent mobility for disabled individuals who lose their ability to walk. Improved independent mobility enhances social and vocational integration, which is a primary aim of rehabilitation. Davies et al (2003) showed that the quality of life (QoL) of community dwelling disabled people improved with the provision of electric powered wheelchairs. Similarly manual wheelchairs (MWC) were found to improve the QoL of people with differing disabilities such as spinal cord injuries (Chaves et al, 2004), multiple sclerosis (Devitt et al, 2003) and elderly disabled people (Trefler et al, 2004). At one end of the spectrum of disability, there are severely physically impaired people who do not have the ability to use MWCs. For them, electric powered wheelchairs (EPW) offer the only suitable avenue for independent mobility. At the other end are the young and otherwise healthy persons who have good upper body strength and good cognitive abilities. They are able to use MWCs to achieve high levels of mobility. In between these two, is a wide spectrum of abilities, which require a range of other options to promote independent mobility.

Encouraging people to use MWCs may improve their general physical fitness and reduce the risk of undesirable weight gain. However, excessive use of MWCs may also lead to premature wear and tear in the upper limbs, particularly in the shoulders. There is plenty of evidence (Ballingerer et al, 2000; Dalyan et al, 1999; Curtis et al, 1999) to show that in spinal cord injured (SCI) people, there is a 30% – 64% prevalence of shoulder pain. Subarro et al (1995) surveyed 800 people with SCI and found a higher (72.7%) prevalence among 451 of their respondents. They found that in these people, wheelchair propulsion and transfers caused most shoulder pain. Lal (1998) also found a positive correlation between wheelchair use and shoulder pain among SCI people. Although shoulder pain in other MWC users has not been studied in such detail, there is general consensus that prolonged wheelchair propulsion leads to premature osteoarthritis in shoulders. Therefore, it is sensible to look at reducing upper limb joint strain with a view to delaying the development of premature osteoarthritis among frequent MWC users.

Pushrim Activated Power Assisted Wheelchairs (PAPAWs) have been designed to enable users to maintain the ability to self-propel whilst propulsion is assisted by motorised wheels. By applying force on the pushrims, the user can activate motors that provide an additional force. On face value, these wheelchairs may offer a suitable alternative to MWCs for people at the upper end of the ability spectrum by allowing them to use their manual propulsion ability to keep themselves fit, at the same time giving them a power option to improve their range and speed at an energy cost less than in a standard MWC. In addition, PAPAWs are lighter in weight than EPWs and the wheels can be detached easily, making them easier to dismantle and transport than EPWs. Encouragingly, Cooper et al (2002) have found that the torque that needs to be applied to PAPAWs compared with standard MWCs to do the same quantum of work was reduced by 50%. They concluded that PAPAWs were capable of significantly reducing the strain on the upper extremities during propulsion.

Very few studies have been conducted to assess the efficiency of PAPAWs for patients in actual clinical practice. Most of them have come from one group of researchers. Corfman et al (2003) compared the range of motion of upper limb joints and stroke frequency when using MWCs and PAPAWs for the same task in 10 volunteers. They found a significant reduction in range of movement of all joints for a given range of speed and resistance combinations. Algood et al (2005) did a detailed comparison of metabolic demands, a range of movements of upper limb joints and stroke frequency for MWCs and PAPAWs in a laboratory setting and in activities of daily living course using a group of 15 tetraplegic volunteers. In both these settings, there was a significant improvement in all measured parameters for PAPAWs compared to MWCs. Lightall-Haubert et al (2009) also completed a comparison study of shoulder electromyographic activity during standard manual wheelchair and push-rim activated power assisted wheelchair propulsion in 14 male participants with complete tetraplegia, they found a significant decrease in push phase muscle activity in PAPAWs compared to standard pushrim WC. They have recommended measuring these parameters in a community/home environment. Another study by Fitzgerald et al (2003) found that in a small group of people, there was no significant difference in community usage between PAPAWs and MWCs. These authors suggest that their results may be due to the small number of participants in their sample or sample selection. Nevertheless, other recorded benefits are significantly more important even if the usage does not increase with PAPAWs.

With the improvements in long term management of SCIs, more people with high spinal cord injuries survive and go on to enjoy a good quality of life (Hemmel, 2004). If managed properly, their life expectancy should not be any different to their able bodied counterparts. Progress in the management of several other neurological and musculo-skeletal conditions such as muscular dystrophies and rheumatoid arthritis has enabled more and more people to be independent and socially integrated. Maintaining their mobility is an important consideration and health care professionals have to consider the implications of long term manual wheelchair propulsion in their rehabilitation programmes as suggested by Scherer (1996). In addition, in the NHS, where patient choice is given very high priority, more and more people demand wheelchairs which enable them to maintain an active lifestyle and get back to work. For these reasons, provision of PAPAWs can be considered an important future development when planning rehabilitation programmes.

Apart from the evidence presented in this literature review, there are no publications in peer review journals about the benefits of PAPAWs over manual wheelchairs to patients in clinical settings. Therefore, this research project has been designed to assess the energy cost benefits of using PAPAWs for a wide range of clinical conditions in more normal usage and to assess user satisfaction with this type of wheelchair. It is extremely difficult, if not impossible, to design a double blind randomised crossover trial with this type of research. Therefore, the study has been designed in a single blind, controlled manner to minimise bias that may arise from any of the users' preconceived notions about PAPAWs.

*This project was funded by **The Posture & Mobility Group** and the **West Midlands Wheelchair Service Managers Group**, The PAPAWs used in this study were the Alber E-Motion M12$^{c}$ wheels kindly loaned by **Gerald Simonds Healthcare Ltd**. No conflicting interests were raised.*

# Method

### *Measurement Devices / Data Collection*

The following measuring devices were used to assess various parameters of wheelchair users:

1. The Cosmed $K4b^2$ cardio pulmonary diagnostic equipment was used to measure energy consumption and time. It is a lightweight telemetric system that calculates energy expenditure from $CO_2$ production and $O_2$ consumption using Weirs equation (Littlewood et al, 2002). The device consists of a main unit and battery, facemask and turbines. The system was calibrated at the start of the day as per manufacturer's instructions and the masks were sterilised after use with each participant. The main unit and battery was attached to the wheelchair and the data was stored on the unit's memory and uploaded to a computer at the conclusion of all four trials.

2. Qualitative data was obtained following each trial using a purpose designed satisfaction questionnaire. The questions were scored on a Likert scale between 1 to 5, using the participants' manual chairs as reference. The questions were based on:
    a. ease of propelling
    b. feeling of safety in the chair
    c. weight of the PAPAWs
    d. how well it meets overall needs
    e. PAPAWs Vs Other chairs

3. Participants' additional verbal comments about the above five aspects were also recorded

### *Sample Selection*

The study population was drawn from wheelchair users of the Birmingham Wheelchair Services (BWS). Using the BWS database, all self propelling wheelchair users over 18 years of age were identified. An invitation to participate in the study was sent to them together with a patient information sheet. A questionnaire enquiring about the type of wheelchair in use, ability to propel 50 metres outdoors independently and other concurrent illnesses was also included in this pack.

A second letter was sent to all respondents who fulfilled the selection criteria, giving them details of the procedure involved and possible dates for participating in the trials. The GPs of these participants were also informed by post and invited to provide any further information which may be relevant. The medical records of the participants were scrutinised to check their health and cognitive ability. None of the respondents needed to be excluded on these criteria.

### *Data Collection and Experimental Protocol*

The study commenced following a review and approval of the study design by the South Birmingham Research Ethics Committee. The participants attended the West Midlands Rehabilitation Centre (WMRC) for the trials. An explanation of the procedure was given verbally and informed consent was obtained. Each participant then had a medical examination during which their diagnoses, duration of their condition, ability to propel, transfer, upper limb strength and cognitive ability were recorded.

Following this, the participants completed the trials using the four different wheel configurations. For each trial, energy consumption and the time to complete the course were recorded.

Trials took place on a predetermined 60m track outside the WMRC, which included a level section and an incline (approximately 1 in 12).

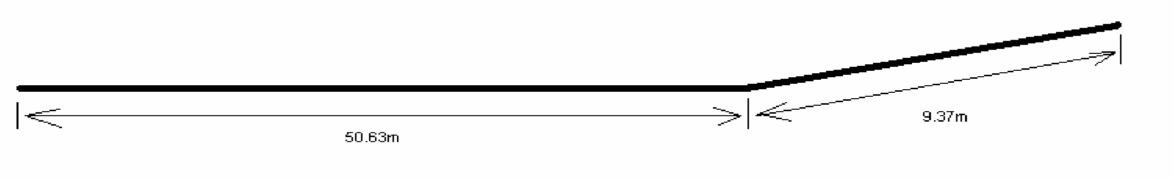


**Figure 1: Figure of Path at WMRC**

The trials were carried out in a random order, in their own wheelchairs, with the dummy PAPAW, with PAPAW - off and PAPAW -on. At the end of each trial the participants were asked to complete a questionnaire on the five aspects of the four configurations, scoring from 1-5 where, 1 = much Worse, 3 = same as their own, 5 = much better than their own chairs. It was explained to the participants that their own chair should be used as the control for comparison (score = 3, their own chair will score 24/40).

The participants were blinded to the type of configuration that they were using. Information regarding the type of configuration used for each trial was recorded in code by the researchers. The Participants were closely monitored during the trials and if there was any indication of distress, the reason for this was recorded and the trial discontinued. Participants were free to withdraw at anytime if they wished to do so.

It was considered desirable to use the participants own wheelchair frame with the standard wheels exchanged for PAPAWs – On and Off modes and dummy wheels so that the only variable was the PAPAWs. However, some of the participants had chairs that could not be adapted, at this instance, to receive PAPAWs, for example fixed axle active user chairs. In these situations the user was given a standard light weight Action 3 MWC to use for all four trials after a short period of acclimatisation. If a participant was unable to negotiate the incline, they were aided in the ascent; this was recorded where appropriate

### *Data Analysis*

Each participant in their own chair was used as the control. The dummy wheels were used to blind the participants to which chair they were using.

Data was analysed using SPSS for Windows. Frequency distribution and descriptive statistics were carried out on all variables, and histograms were produced. The Shapiro-Wilk statistic determined that population energy consumption and score of each type of wheel were normally distributed.

The energy cost and time data, where participants were aided up the slope were removed from the statistical analysis. A listwise repeated-measures model analysis of variance was used to examine the main effects for diagnosis with energy consumption and time between each wheel type and between the client's Own and PAPAW-On. Post Hoc tests and contrasts (each wheel type compared to the client's Own) were carried out to further analyse the significant interaction effects.

A non-parametric Friedman statistical test was carried out on the questionnaire scores for each wheel type. A post-hoc pair-wise application of the Wilcoxon test.

## Results

The initial database trawl provided 320 manual wheelchair users. Thirty three (9%) replied agreeing to take part in the project and were able to propel the required 50m. This consisted of 17 male, 16 female, Mean 47±14.7 (age ± SD), range 20-77.  The study sample consisted of 11 spinal cord injuries, 7 amputees, 5 with cerebral palsy, 3 with multiple sclerosis and 7 others (such as Post polio, Arthritis).

Four (1 CP, 1 SCI, 1 Amputee, 1 Other) participants could not complete the course using any of the wheel configurations so were excluded from the quantitative analysis. Eighteen participants (8 SCI, 4 Amputee, 2 CP, 4 Others) completed all four trials unaided. However, due to technical reasons 5 participants' quantitative data had been lost. Three participants (SCI, MS, Other) could only complete the trials unaided in their Own wheelchair and in the PAPAW-On. Four participants (CP, MS, Amputee, Others) could only complete the trials unaided with the PAPAW-On. Two (SCI, MS) completed all trials unaided except for with the PAPAW-Off. One (Amputee) completed all the trials unaided except for with the Dummy PAPAW. Figure 2 shows a breakdown of the number of participants that completed each of the different trials. Table 1 shows the mean test results for the questionnaire scores, energy consumption and the time for each of the wheels broken down by diagnosis.

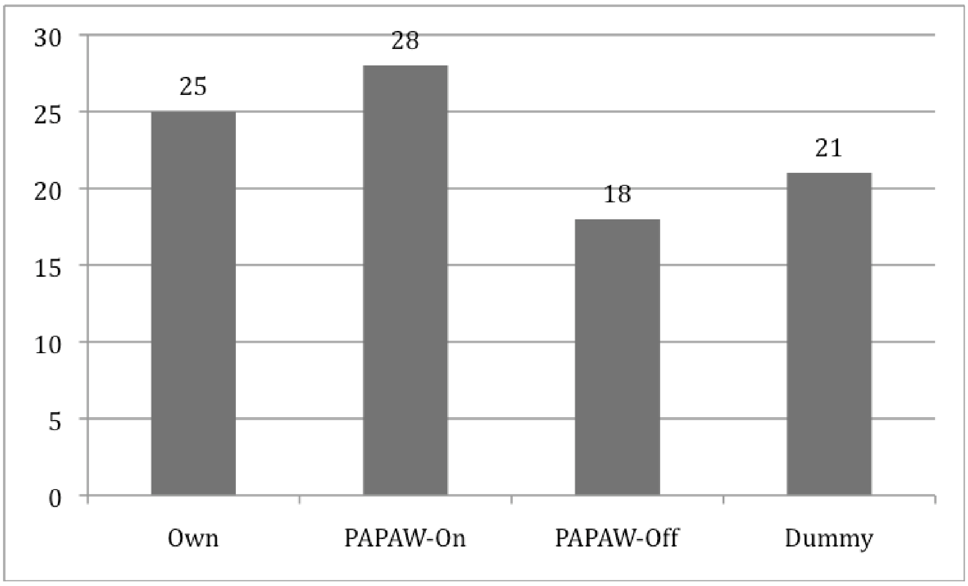


**Figure 2: Trials Completed Unaided**

**Table 1: Test results based on different user Diagnosis**

| Diagnosis | Wheel | Questionnaire Score | Energy Cost (KCal) | Time (Sec) |
|---|---|---|---|---|
| **Amputee** | Own | 24.0 ± 00.00 | 2.26 ± 0.78 | 90.67 ± 0.58 |
| | On | 31.14 ± 05.96 | 3.49 ± 1.32 | 116.75 ± 22.14 |
| | Off | 22.67 ± 03.32 | 2.73 ± 1.34 | 106.67 ± 39.50 |
| | Dummy | 23.80 ± 05.51 | 2.26 ± 1.90 | 113.50 ± 34.64 |
| **CP** | Own | 24.0 ± 00.00 | 4.52 ± 2.64 | 115.67 ± 56.15 |
| | On | 18.80 ± 08.44 | 3.58 ± 1.81 | 135.33 ± 64.13 |
| | Off | 19.20 ± 10.49 | 5.84 ± 1.39 | 140.67 ± 47.01 |
| | Dummy | 22.75 ± 09.14 | 3.88 ± 1.82 | 119.67 ± 42.36 |
| **SCI** | Own | 24.0 ± 00.00 | 2.66 ± 1.03 | 75.87 ± 14.79 |
| | On | 29.41 ± 9.08 | 2.11 ± 0.96 | 82.62 ± 13.21 |
| | Off | 12.90 ± 04.86 | 2.57 ± 1.36 | 82.83 ± 13.01 |
| | Dummy | 18.33 ± 04.36 | 2.90 ± 0.94 | 84.00 ± 14.05 |
| **MS** | Own | 24.0 ± 00.00 | 3.17 ± 1.28 | 121.25 ± 6.72 |
| | On | 36.83 ± 01.61 | 2.12 ± 1.24 | 117.00 ± 55.76 |
| | Off | 16.50 ± 14.39 | | |
| | Dummy | 23.67 ± 02.52 | | |
| **Other** | Own | 24.0 ± 00.00 | 2.01 ± 0.89 | 73.25 ± 7.80 |
| | On | 30.86 ± 06.92 | 1.44 ± 0.91 | 69.00 ± 21.83 |
| | Off | 20.00 ± 03.32 | 1.91 ± 0.78 | 92.00 ± 3.61 |
| | Dummy | 23.10 ± 05.79 | 1.84 ± 1.07 | 75.00 ± 11.78 |

Note: Values are Mean ± Standard Deviation

### ***Energy Consumption***

Estimated marginal means showed an energy cost savings for the PAPAWs On compared to Own for all diagnosis except for Amputees. Significant benefits were found for energy consumption ($F_{3,27}$ = 6.941, $P$<0.001). Contrasts revealed that the PAPAW-Off consumed a significant amount more energy than the client's Own ($F_{1,9}$ = 17.73, $P$=0.002). Figure 3 shows the mean results for each of the wheel types.

A Significant effect was found between the interaction of energy consumption of each of the wheel types and the diagnosis ($F_{9,27}$ = 3.112, $P$=0.011), thus showing that the energy consumption of the different wheel types varied between each diagnosis. To breakdown this interaction, contrasts were performed. Significant effects were found for PAPAW-Off ($F_{1,9}$ = 4.127, $P$=0.043). Figure 4 shows the mean energy consumption for each wheel type broken down by diagnosis, from this it can be seen that participants with CP used a significantly more amount of energy with the PAPAW-On compared to their Own chair.

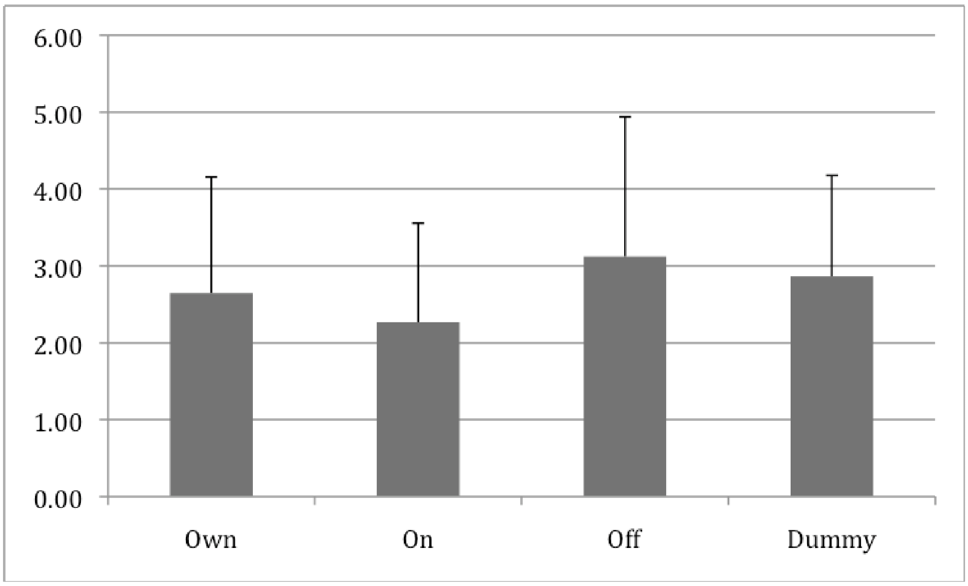


**Figure 3: Mean Energy Cost (KCal) For Each Wheel type**

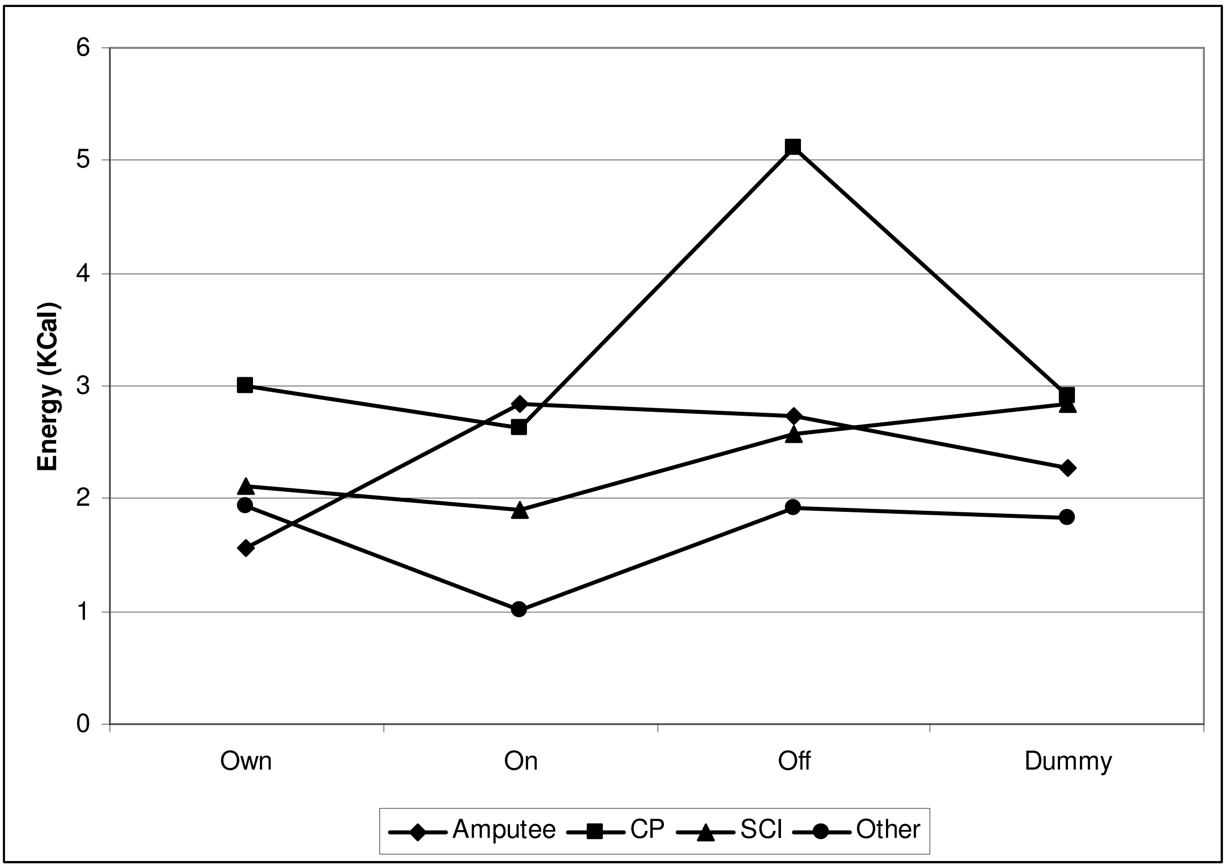


**Figure 4: Estimated Marginal Means for Energy**

### *Time*

Significant differences were found for time ($F_{3,27} = 6.586$, $P=0.002$). Analysis of contrasts demonstrated significant increases in time for PAPAW-On ($F_{1,9} = 5.643$, $P<0.042$), PAPAW-Off ($F_{1,9} = 39.424$, $P<0.001$), and Dummy ($F_{1,9} = 8.987$, $P<0.015$) compared to the participant's Own wheelchair. Figure 5 shows the mean time taken for each wheel type.

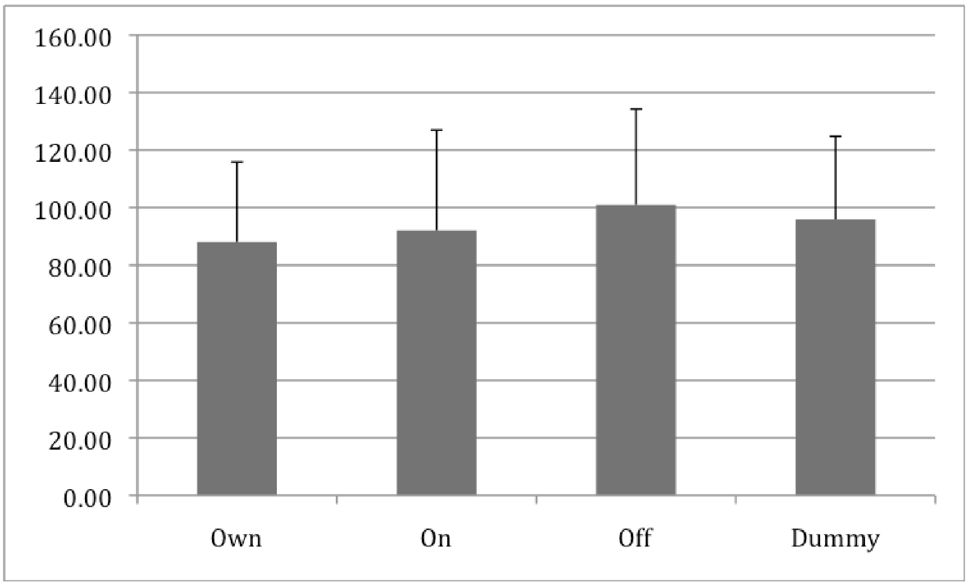


**Figure 5: Mean Time for Each Wheel Type**

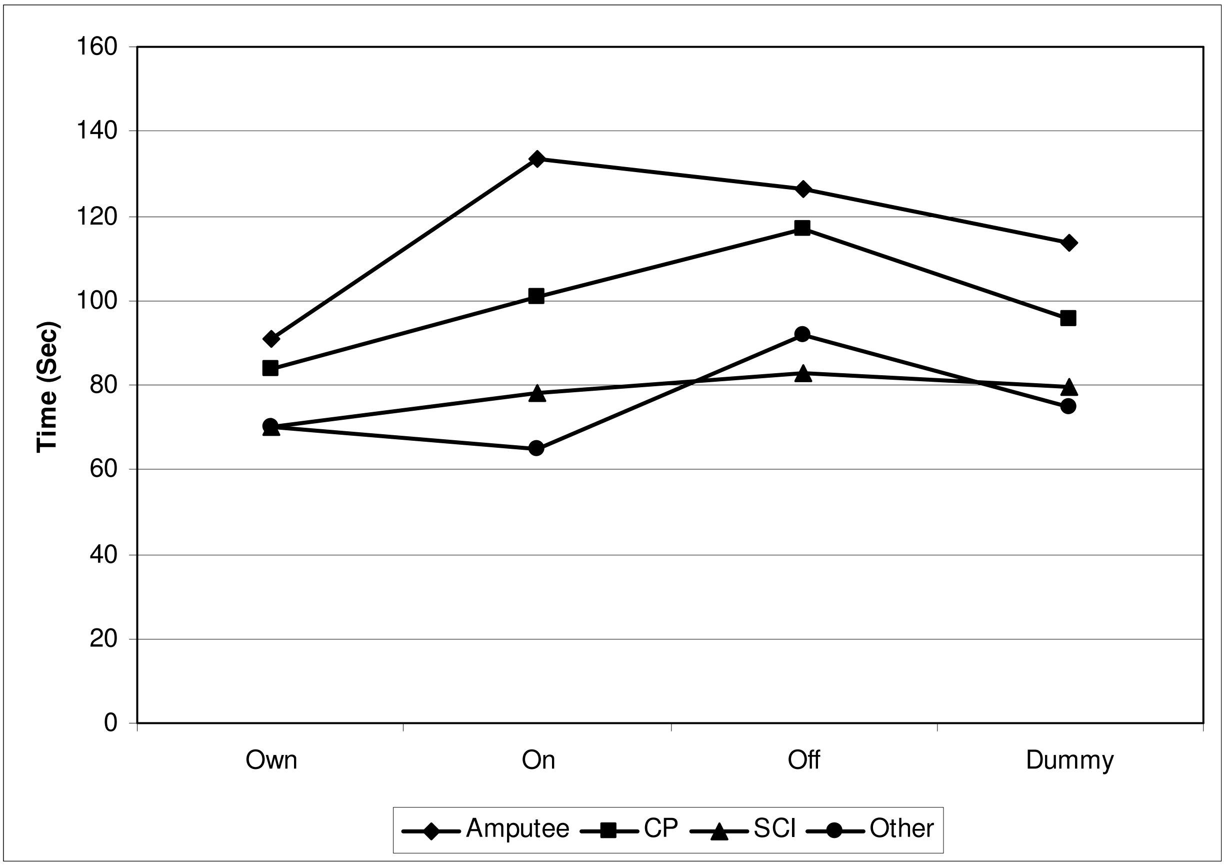


**Figure 6: Estimated Marginal Means for Time**

### ***Questionnaire Score***

Application of Friedman's test showed that the distribution of the scores for the four different wheelchair types was statistically highly significant ($X^2 = 41.28$, df = 3, $P<0.01$)

A pair-wise application of the Wilcoxon test showed that the scores of the PAPAWs – on mode were significantly higher than that of the participant's own chair (Z=2.172, n=33, $P=0.03$); higher than PAPAWs off (Z=4.543, n=33, $P<0.01$); and higher than the dummy chair (Z = 4.01, n= 33, $P<0.01$).

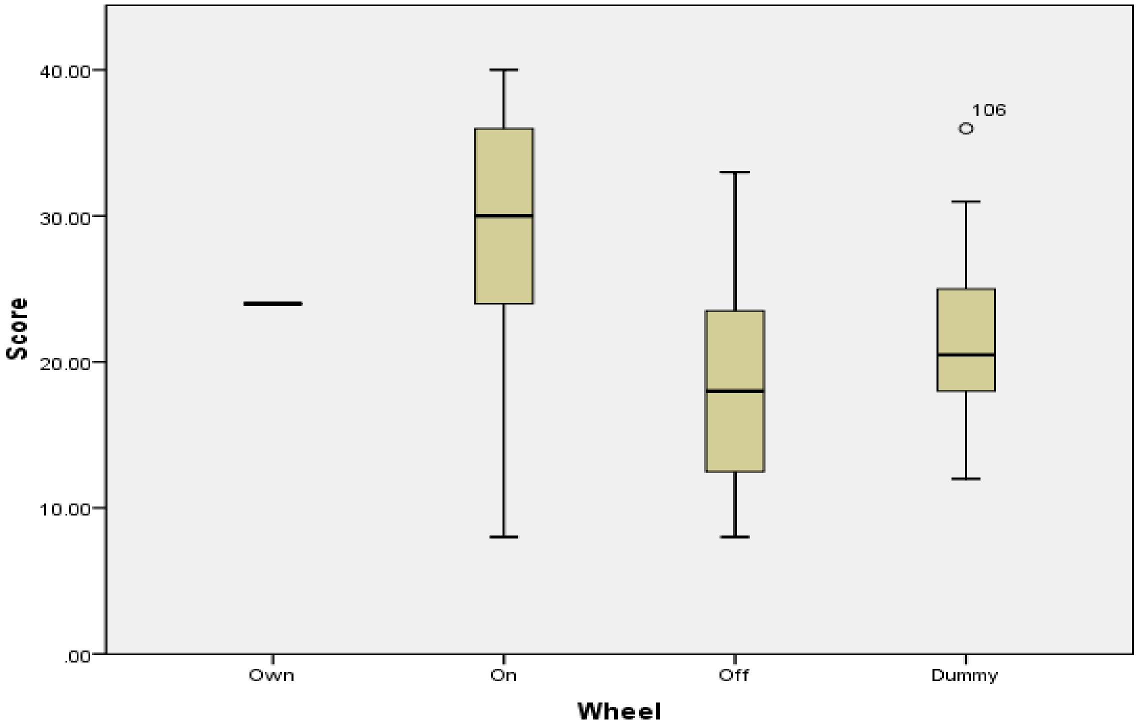


**Figure 7: Box Plot for Questionnaire Score for Each Wheel.**

### *User Comments*

The comments were split up into to common themes that appeared regarding.
Below are summaries of themes along with some comments from the users found within the questionnaires:

**Ease of propelling**

"*Big difference going up incline*" – Other (Amputee); "*I found it unnerving going up the slope and was concerned the chair would tip-over*" – CP; "*100% better on inclines and more secure going down a slope; it doesn't run away with you*" – SCI.

Out of all the comments this is the area where most participants found the greatest benefit. (7/9 users who could not propel up the slope in their own chair where able to with the PAPAWs)

The benefit was not only because of the saving in energy but participants felt it would allow them to go wherever they wanted rather than having to plan their route.

**Feeling of safety in the chair**

"*Difficult to control*" – CP; "*I didn't feel like I had any control*" – CP, "*It has a mind of its own*" – amputee; "*It's a bit difficult to control at first but fine when I got used to it*" – SCI; "*Control of the chair would be problem initially*" – SCI; "*Control will improve over time*" – MS;.

It was clear from both the comments and observations the participants initially found the PAPAWs difficult to control. In most cases participants said they would be happy to practice. However participants with CP found lack of control very disconcerting and in some cases would not go along the track in a straight line.

"*Needs a slower speed*" – Amputee; "*Nippy*" – Other (ME); "Tippy" – CP; "Tippy but anti-tippers are substantial" - SCI
The same comments came up several times and maybe useful information to feed back to the manufacturer; More settings rather than in / outdoor

**Weight of the PAPAWs**

"*Heavy for lifting into a car*" – SCI; "*Wheels are too heavy for transportation*" – MS; "*The weight of the wheels will also prevent me from lifting the chair in/out of the car*" – SCI; "*Even though the* *chair will be of benefit in the long run, it would be too much trouble loading it into/out of the car due to the weight"* – CP;

Weight was identified as being an issue by those participants who currently independently transfer themselves in / out of the car and would not be willing to lose this independence.

It was also noted that this extra weight would cause problems if the battery was to run out when the user was propelling the chair as most of the participants did not feel they could propel the chair in this state.

**How well it meets overall needs**

"*Hurt my shoulders more to push*" – CP; "*Not so painful on my shoulders and hands*" – SCI; "*I don't feel so out of breath*" – SCI; "*Would be of benefit health wise*" - Other (Arthritis)

Participants who came on the trial who normally experienced pain and breathing problems when propelling felt that the PAPAWs reduced both of these problems.

"*I feel using the wheels will give me greater independence*" – SCI; "*I would go out more" – SCI* "I *can see how the chair would be useful and of benefit to people, though due to my problems (the difference in arm strength) it wouldn't really be of much use to me*" – SCI; "*The weight of the wheels would put me off having them*" – Amputee.

Many of the participants liked the PAPAWs because it gave them the freedom to go where they want rather than having to plan routes, allowing them to gain back some of the independence they felt they had lost.

**Other type of Wheelchairs Vs PAPAWs**

"*Would choose the Venus over the emotion wheels because it is easier to control / move in a straight line*" – SCI; "*Ideal mix between manual and powered*" – MS; "*Would prefer to use power assist wheels over a powered chair- has the advantages of a powered chair but with more independence*" – Other; "*In comparison with my powered chair the emotion wheels would help retain my muscle mass but require more effort to manoeuvre / propel due to lack of strength in my arms.*" – MS;

The comments from those who came into the trial who used both a powered and manual chair commented that the PAPAWs would be far better then having 2 different chairs. It was also commented that the PAPAWs would be seen less like the ‘end of the road’ than a powered chair and possibly more portable.

Those participants who normally used active user chairs such as the Venus and RKG (titanium) chairs tended to prefer their own lightweight chairs as they were relativity easy to propel and allowed them to transfer into the car. Although they could see the long term health benefits of using the PAPAWs they would not be willing to use them.

## Discussions

The incline portion of the course proved to be the area where the majority of assistance was required. However a larger proportion of the participants managed to negotiate the incline in the PAPAW-On compared to any of the other wheelchair types. From the results obtained, overall it can be seen that the PAPAW turned On provided an energy saving compared to the other configurations of the wheels, however this is not significant. The experimental design and the limited work done could have attributed towards the results. It maybe, that users who choose to use PAPAWs, will benefit more in daily use; the reduction in energy cost and the ease of climbing inclinations would increase independence, allowing them to access a wider community while reducing the prevalence of fatigue. The use of PAPAWs instead, of powered wheelchairs, would also allow for some cardiovascular activity thus promoting a healthier lifestyle while reducing the chance of premature wear and tear of the upper limbs as often seen in standard wheelchairs. However further clinical studies would be required to confirm these as long-term benefits.

The increased time required to complete the course raises issues around the study design. Participants possibly required longer periods of orientation towards the PAPAW-On to allow them to control the chairs effectively. This could also raise questions about providing appropriate wheelchair skills training specifically towards use of PAPAWs.

Participants with lower limb amputations seemed to be the only participant group not to have an energy cost benefit from utilising the PAPAW-On. These participants went on to comment on how “tippy” the chair was, particular at the beginning of a propulsion cycle. This reduced stability probably accounted for this increased energy cost. Therefore it is likely that this type of wheelchair is not suitable for amputees unless adaptations have been completed.

The questionnaire scores also provided an important insight into users views, with PAPAW-On obtaining the highest scoring. All Participants who used the PAPAWs, successfully gave positive comments about its usefulness. Users who negotiated the slope with the PAPAW commented on its ease, and gave them an increased independence. Control was a major issue raised about the chair, many found it hard to keep the chair in a straight line, and felt the chair tip back regularly. However with time and some practice this was less noticeable. This would, again, suggest that some training would be beneficial to potential users.

Both participants and carers raised concerns about the weight of the wheels. The results of the trials showed a very small number of participants being able to complete the course with the PAPAW-Off. If a participant was to be independently utilising the wheels, he/she would find it difficult to dismantle the chair and would find it difficult to propel if the batteries died or a malfunction occurred.

When comparing the PAPAWs with other types of wheelchairs, the majority preferred the PAPAW over an EPW. Two participants were already utilising lightweight active user wheelchairs, they did not show a saving in energy cost when using the PAPAWs, however they did recognise the benefits of utilising one. Possible further investigations into the comparison of active user wheelchairs and PAPAWs (fitted to standard wheelchairs) could give an indication of where PAPAWs lie within the mobility sector.

### ***Study Limitations***

Even though important information was obtained from the study, some limitations can be highlighted. The limited amount of work done within these trials could have attributed to the marginal energy savings. The wheels also required a period of orientation due to the abnormal control. Possible long-term trails could provide better results.

### ***Further Research***

Possible future work utilising an updated set of wheels which has been released by the manufacturer, could provide better results. Comparison of PAPAWs with other MWC assist devices and light weight active user chairs could prove to be a beneficial study. The study design could also involve a longer track so that more significant quantitative data can be obtained.

Giesbrecht et al (2009) completed a community-based study to compare PAPAWs and powered wheelchairs. Utilising outcome measures of number of hours reported utilising each wheelchair, Quebec User Evaluation of Satisfaction with assistive Technology (Quest), Functioning Everyday with a Wheelchair (FEW), Psychosocial Impact of Assistive Devices Scale (PIADS) and Canadian Occupational Performance Measure (COPM). They found no significance in the hours of participation in the self-identified activities, and a significance of self-esteem of the PIADS. They concluded that PAPAWs allowed and enabled participants to continue to function in activities similar to those in their powered wheelchairs. Similar studies of long term (weeks/Months) trials can be completed to gain a more realistic opinion from the user of the PAPAWs compared to MWC. This could be done by short term issue of the wheels to volunteers, and can be assessed by structured interviews before and after the trial period, and maybe incorporate the WUSPI and the above outcome measures.

A study could also be conducted to compare the benefits of the PAPAWs and active user wheelchairs, so it can be seen where PAPAWs lie in the mobility sector.

## Conclusion

This study does not confirm previous laboratory data regarding energy savings with PAPAWs but there is a minimal energy saving in these test conditions. There appears to be a group of high end users who would derive maximum benefit from PAPAWs. For others, weight appears to be an issue which needs to be addressed. Some training maybe required for the marginal users.

In the course of the study, the manufacturer has released an updated version of the wheels; this addresses some of the above issues, such as incorporating a hill stop feature which could further aid users in negotiating slopes.

From this study it can be recommended that a practical training and tests are completed to assess a potential user’s ability to use PAPAWs. Bi-manual dexterity and cognitive ability appear to be important factors for effective propulsion.

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