| Author Year<br>Country<br>Research Design<br>Score<br>Total Sample Size | Methods | Outcome |
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| Kloosterman et al. 2013<br>Netherlands<br>Systematic Review of published studies between 1980-2012<br>N=15 | **Method:** Studies were included if they investigated the effect of power-assisted wheel-chair propulsion on human functioning compared to hand-rim or powered wheelchair propulsion; was a clinical trial or (randomized) controlled trial; was published as a full-length paper in a peer-reviewed journal in the English language.<br>**Databases:** The Cochrane Library, REHABDATA, CIRRIE and CINAHL.<br>**Level of evidence:**<br>15 crossover trials were assessed for their methodological quality using the 'Checklist for Measuring Quality' of Downs and Black Maximum attainable score=32<br>**Questions/measures/hypothesis:**<br>1. To examine the current knowledge about transition from a hand-rim or powered wheelchair to a power-assisted wheelchair. | 1. The Downs and Black score assigned to all studies ranged between 9-15 points out of the maximum score of 32. All compared power-assisted to hand-rim or powered wheelchair use.<br>Results from quantitative analysis:<br>2. Movement analysis of the arm during power-assisted propulsion compared to hand-rim propulsion was found to be significantly associated with a decrease in wrist ulnar-radial deviation and flexion-extension and decreased, flexion-extension and internal-external rotation in the shoulder. There was no significant association between either type of propulsion and shoulder abduction.<br>3. Healthy populations found the hand-rim wheelchair more effective for tasks requiring greater control, whereas power-assisted wheelchair was preferred for easier tasks.<br>4. Power-assisted wheelchairs were more preferred for activities within a confined space (or indoors) whereas powered wheelchairs were preferable for outdoor activities.<br>5. There were no significant differences found for the association between wheelchair type (power-assisted, hand-rim or powered) and activity social participation, and psychological outcomes, within a home environment.<br>Results from the qualitative analysis:<br>6. Most participants experienced increase ease of propulsion with a power-assisted wheelchair;<br>7. Most rated power-assisted prolusion on level and inclines and carpet as (very) easy compared to hand-rim wheelchair propulsion.<br>8. Some limitations were that power-assisted wheelchair in confined spaces were difficult to manoeuvre, car transfer from power-assisted WC wheels can be difficult. |

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| | | 9. Other positive experiences were accessibility to new and different activities, and more independence. |
| Giesbrecht et al. 2009<br>Canada<br>RCT<br>PEDro=6<br>N=8 | **Population:** Age Range: 33-63 yr; Gender: males=6, females=2.<br>**Intervention:** Participants were randomly assigned use of a pushrim-activated power-assisted wheelchairs (PAPAW) or their own power wheelchair (PWC) for 3 wk and then crossed over to the alternative for 3 wk.<br>**Outcome Measures:** Activity Level: Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST, Functioning Every day with a Wheelchair (FEW), Psychosocial Impact of Assistive Devices Scale (PIADS); Participation Level: Canadian Occupational Performance Measure (COPM). | 1. Temporal Outcomes:<br>• Mean hr per day spent in PAPAW (5.5 hr, SD=3.63) and PWC (6.1 hr, SD=5.36) and not significantly different (t(7)=-0.33, p=0.75);<br>• Mean time spent per day in any wheelchair (manual and power wheelchair) was 8.83 hr (SD=5.34) and 9.17hr (SD=5.83) for the PAPAW and PWC blocks; not significantly different (t(7)=-0.54, p=0.60);<br>• Total number of hr per week participating in identified occupations (56.1, SD=52.0; 62.8, SD=42.6) and not significantly different between PAPAW and PWC blocks (t(7)=-0.33, p=0.75);<br>2. Outcome Measures at Activity Level (Quest, FEW, PIADS):<br>• No identified difference identified between PAPAW and PWC on Quest Device subscale median (range) PAPAW score 3.8 (3.0-4.5) versus3.8 (1.9-5.0); p=0.945;<br>• PIADS Self-Esteem subscale demonstrated a statistically significant difference with PWC rated higher median (range) PAPAW score 1.5 (-4-7) versus median (range) PWC score 7.5 (-2-18); p=0.016.<br>3. Outcome Measure at Participation Level (COPM): Performance Component: no statistically significant difference found median PAPAW score 6.5 (4.0-9.0) versus median PWC score 8.2 (4.3-10.0); p=0.195<br>4. Satisfaction Component: no statistically significant difference found median PAPAW score 7.2 (2.7-8.4) versus median PWC score 8.2 (2.3 -10.0); p=0.469. |
| | **Effect Sizes:** Forest plot of standardized mean differences (SMD ± 95%C.I.) as calculated from pre- and post-intervention data. | |

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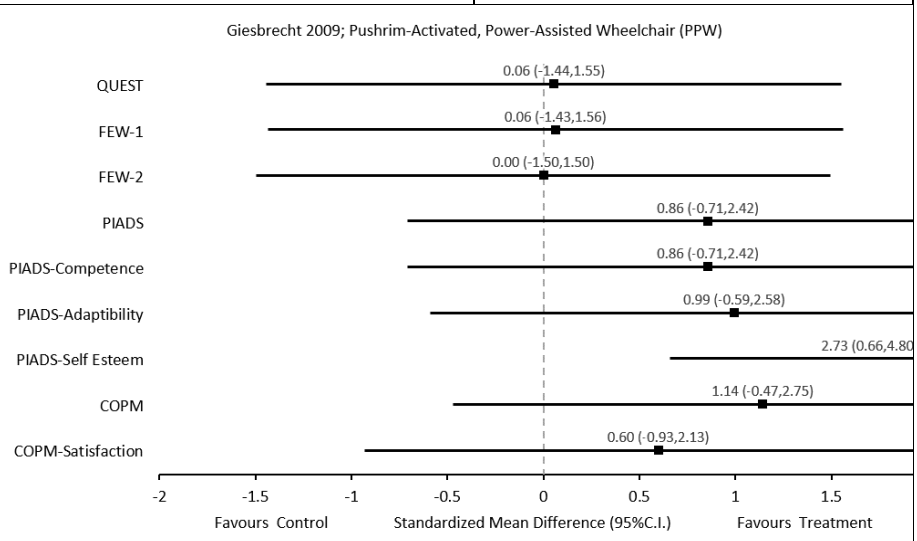
| |  | |
| Nash et al. 2008<br>USA<br>RCT<br>PEDro=5<br>N=18 | **Population:** Mean age: 39.1 yr; Gender: males=18, females=0; Level of injury: paraplegia=12, tetraplegia=6; Severity of injury: complete=18.<br>**Intervention:** Study participants were asked to complete five testing sessions during which they were asked to propel their chairs randomly on either their own wheels or the pushrim-activated power-assisted wheelchairs (PAPAW) wheels. Subjects performed each test twice.<br>**Outcome Measures:** Oxygen consumption, Distance, Energy cost, Ratings of perceived exertion (RPE). | 1. 6 min steady state test sessions; Oxygen Uptake; $VO_2$ significant effects found for group ($F_{1.32}=17.2$, $p<0.001$), time $F_{3.96}=37.6$, $p<0.001$) and group x time interaction ($F_{3.96}=11.2$, $p<0.001$); significant increases at each time point between 0 and 6 for paraplegia, not for tetraplegia.<br>2. Distance propelled: significant effect for group ($F_{1.32}=50.3$, $p<0.001$), type of wheel ($F_{1.32}=27.3$, $p<0.001$), time ($F_{3.96}=247.5$, $p<0.001$) and group interaction effect ($F_{3.96}=14.7$, $p<0.001$) with individuals with paraplegia traveling farther than tetraplegia and PAPAW traveling farther than traditional push wheels.<br>3. Energy Costs: significant effort for wheel was found for energy cost ($F_{1.32}=9.7$, $p<0.01$) with the traditional wheels requiring greater energy costs than PAPAW.<br>4. Perceived Exertion: time was the only significant effect observed ($F_{3.96}=52.3$, $p<0.001$) with score getting significantly higher at each stage for all subjects.<br>5. Twelve Minute Test Sessions: Oxygen Uptake: Vo2 significant effects were found for group ($F_{1.32}=14.8$, $p=0.001$), time |

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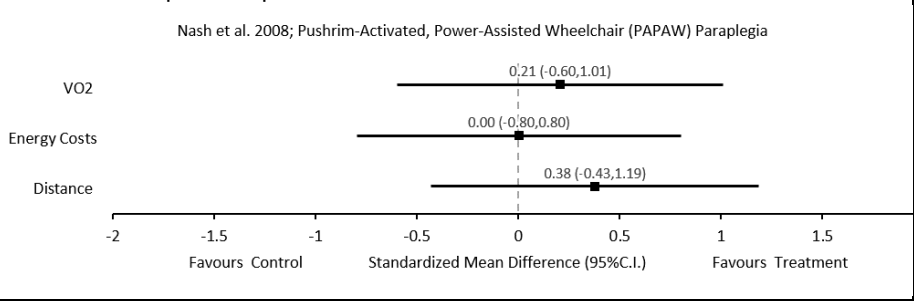
| | | (F6.192=18.0,p<0.001) and the group x time interaction (F6.192=7.5, p<0.001), significant increases at each time point between 0 and 12 for paraplegia, not tetraplegia.<br>6. Distance Propelled: significant effects found for group (F1.32=59.6,p<0.001), type of wheel (F1.32=66.9, p<0.001), time (F6.192=216.5, p<0.001) the group x time interaction (F6.192=22.3, p<0.001) and wheel x time interaction (F6.192=25.8, p<0.001) with persons with paraplegia travelling farther than tetraplegia and PAPAW travelling farther than regular wheels, magnitude of change greater in persons with paraplegia and when using PAPAW.<br>7. Energy Costs: significant effect for type of wheel (f1.32=20.4, p<0.001) with traditional wheels requiring higher energy cost than PAPAW.<br>8. Perceived Exertion: RPE, time (F6.192=89.6; p<0.001) and wheel x time interaction (F6.192=2.2; p<0.05) were different with scores rated significantly higher at each stage across all subjects and in overall score for PAPAW being lower than traditional wheels; significant increase in RPE between time 0 and 12 for both wheels and PAPAWs with change greater in customary wheels at time 2, 4, and 12. |
| | **Effect Sizes:** Forest plot of standardized mean differences (SMD ± 95%C.I.) as calculated from pre- and post-intervention data.<br>  | |

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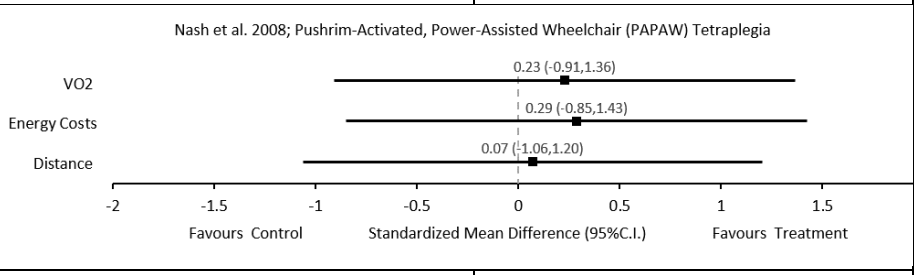
| |  | |
| Guillon et al. 2015<br>France<br>RCT<br>PEDro=5<br>N=52 | **Population:** Mean age: 38.8 yr; Gender: males =31, females=21.<br>**Intervention:** Individuals were evaluated on the use of manual wheelchairs and three pushrim-activated power-assisted wheelchairs (PAPAW): Servomatic A, Servomatic B and E-motion. The study was conducted in three phases: phase 1 consisted of participants propelling all the wheelchairs on a dynamometer (n=10), phase 2 consisted of using wheelchairs on indoor and outdoor courses (n=46), while phase 3 evaluated participants' ability to transfer themselves and their wheelchairs into and out of cars (n=10). Participants used all wheelchairs for each phase, the order of wheelchair use was randomized for each participant.<br>**Outcome Measures:** Oxygen consumption per unit time ($VO_2$), Heart rate, Completion time, Handrim push frequency, Patient satisfaction. | 1. All PAPAW showed a significantly greater decrease in oxygen consumption and heart rate during phase 1 compared to manual wheelchairs ($p<0.005$). There were however no significant differences between the three PAPAW groups.<br>2. During the outdoor tests, a MANOVA revealed statistically significant effects of wheelchair type ($p<0.0001$), lesion level ($p<0.0001$), and interaction between wheelchair type and lesion level ($p<0.0004$) on several dependent variables (completion time, handrim push frequency, maximal heart rate and patient satisfaction).<br>3. For the indoor tests, a MANOVA revealed statistically significant effects of wheelchair type ($p<0.0001$) on completion time, handrim push frequency and patient satisfaction.<br>4. More participants required help for transfers with PAPAW compared to manual wheelchairs ($p=0.04$). |
| Ding et al. 2008<br>USA<br>Pre-Post<br>N=15 | **Population:** Mean age: 38.3 yr. Gender: NR; Level of severity: tetraplegia=15; Mean time since injury: 15.8 yr.<br>**Intervention:** Individuals used their own personal wheelchairs for 2wk and then pushrim-activated power-assisted wheelchairs (PAPAW) for 2wk. Mobility levels with both wheelchairs were recorded by a datalogger.<br>**Outcome Measures:** (Primary): Daily distance traveled, Average speed, Accumulated driving (movement) time, Number of starts/stops, Maximum period of continuous movement, Maximum distance of continuous movement. (Secondary variables): Percentage of time between | 1. No significant differences were found for the distance traveled with both wheelchairs ($p=0.009$).<br>2. There was a statistically significant difference found between PAPAW and personal manual wheelchairs for the speed traveled (PAPAW: average speed=0.74±0.31 m/s; Personal: average speed=0.60±0.23 m/s, $p=0.03$).<br>3. Participants traveled similar distances in the PAPAW trial and the own chair trial ($p=0.16$).<br>4. Results of secondary mobility variables were the following: Number of starts/stops (per 1000 m): [PAPAW: 65.4±25.7 m; Personal wheelchair: 78.3±21.8 |

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| | 0.5m/s, Percentage of time between 0.5m/s and 1.0m/s, Percentage of time over 1.0m/s, Psychosocial Impact of Assistive Devices Scale (PIADS). | m; Own Chair Trial (2 wk) Personal wheelchair: 75.2±22.7 m]. Maximum period of continuous movement (min): [PAPAW: 3.0±2.4 min; Personal Wheelchair: 2.1±2.7 min; Own Chair Trial (2wk) Personal Wheelchair: 3.3±4.6 min], Maximum distance of continuous movement (m): [PAPAW: 229.2±289.4 m; 135.4±248.7 m; Own Chair Trial (2wk) Personal Wheelchair: 229.8±409.3 m).<br>5. Self-perceived PIADS assessment revealed no significant differences for ratings of adaptability, competency, and self-esteem between the PAPAW and the traditional manual wheelchair (p=0.18, p=0.07 and p=0.09, respectively). |
| Finley et al. 2007<br>USA<br>Pre-Post<br>N=17 | **Population:** Mean age: 46 yr; Gender: males=9, females=8; Injury etiology: SCI=11, spina bifida=1, polio=1, stroke=1, ataxia=1, spinal stenosis=1, rheumatoid arthritis=1.<br>**Intervention:** Individuals used a manual 2-speed geared wheelchair wheel over five months (MAGICWheels intervention).<br>**Outcome Measures:** The Wheelchair Users Shoulder Pain Index (WUSPI); Wheelchair Users Functional Assessment (WUFA); Timed hill climb test with rating of perceived exertion (RPE). | 1. There was a statistically significant reduction in WUSPI (shoulder pain score) with the MAGICWheels intervention at wk 2 (p=0.0444); these results remained statistically significantly different from baseline until wk 16 (p=0.015), however not at wk 20 (p=0.062).<br>2. Post-hoc correlation analysis revealed no significant relationship between duration of wheelchair use and pain reduction for any wks of the MAGICWheels intervention (p>0.05).<br>3. After the 5-mo period, there was no significant difference in WUFA scores (p>0.05). |
| Haubert et al. 2005<br>USA<br>Pre-Post<br>N=5 | **Population:** Mean age: 48 yr; Gender: males=5, females=0; Injury etiology: tetraplegia=4, paraplegia=1; Mean time since injury: NR.<br>**Intervention:** To compare the propulsion characteristics between a standard manual WC and each of three pushrim-activated power-assisted wheelchairs (PAPAW): iGLIDE Xtender with a 1.5X power-assist; an e-motion with settings adjusted to mid-sensitivity; and maximum power-assist.<br>**Outcome Measures:** Energy Expenditure (average heart rate and $O_2$ consumption); Average velocity (m/min±1SD); Average cadence (cycles/min±SD). | 1. Compared to standard WC propulsion, during iGLIDE propulsion, velocity increased for two subjects due to increased cycle length and cadence (mean increases: 15% and 28%), respectively. Average velocity decreased in the iGLIDE for three subjects as a result of decreased cadence and cycle length (mean decreases=19%, 46%, 33%, respectively).<br>2. Compared to standard WC propulsion, during Xtender propulsion, velocity increased for 3/5 participants by 20%, 16% and 40%. Velocity increased from |

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| | | increased cadence for one subject by12% and decreased by 7% for another subject, from decreased cadence.<br>3. Compared to standard WC propulsion, during propulsion, velocity increased by 22% from increased cycle length and cadence for one subject. For another, it slightly increased by 3% from increased cycle length; and further decreased for three subjects by 5%, 7% (from decreased cadence) and 5% (from reduced cycle length), respectively.<br>4. Compared to standard WC propulsion, three subjects were found to have a decreased average $O_2$ heart rate and consumption<br>5. An increase in $O_2$ consumption during PAPAW propulsion was observed during iGLIDE propulsion by 5% for one subject; another subject by 18% for Xtender; and by 25% for propulsion.<br>6. On average, the $O_2$ consumption cost decreased for all subjects during Xtender and propulsion in each PAPAW.<br>7. On average, there was an increase in $O_2$ cost for two subjects with respect to propulsion of iGLIDE, and similar $O_2$ costs as standard WC for another. |
| Algood et al. 2004<br>USA<br>Pre-Post<br>N=15 | **Population:** Age range: 27-52 yr; Gender: males=12, females=3; Weight range: 45-116 kg; Height range: 152-193 cm; Level of injury: tetraplegia=15; Chronicity: chronic.<br>**Intervention:** Propulsion of personal wheelchair and pushrim-activated power-assisted wheelchairs (PAPAW) in dynamometer at 0.9 m/s for 3 min/trial, with three difference resistances (10 W, 12 W, 14 W).<br>**Outcome Measures**: Mean steady state oxygen consumption, Ventilation, Heart rate, Mean stroke frequency, Maximum upper extremity range of motion (ROM). | 1. Subjects had a significant reduction in ventilation and oxygen consumption in all PAPAW trials compared to manual wheelchair trials ($p<0.05$).<br>2. When using the PAPAW, heart rate only decreased in the 14 W condition ($p<0.001$) and stroke frequency only decreased in the 10W and 12W conditions ($p=0.001$).<br>3. When using the PAPAW, horizontal flexion/extension, shoulder flexion/extension, internal/external rotation and wrist ulnar and radial deviation ROMs were all significantly decreased in all weight resistance conditions ($p<0.05$). |

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| | | 4. Forearm supination/pronation ROM was significantly decreased in the 12 W and 14 W trials ($p<0.01$) when using the PAPAW. Elbow and wrist extension/flexion ROM were also significantly reduced in the 14 W trials ($p<0.05$). |
| Fitzgerald et al. 2003<br>USA<br>Pre-Post<br>N=7 | **Population:** Mean age: 42.1 yr; Gender: males=5, females=2; Level of injury: paraplegia=7; Time since injury range: 5-22 yr; Chronicity=chronic.<br><br>**Intervention:** Manual wheelchair and pushrim-activated power-assisted wheelchairs (PAPAW) wheelchair.<br>**Outcome Measures:** Distance traveled and velocity-Data logger; Qualitative information-Visual Analog Scale. | 1. No significant differences were found between the subject's personal wheelchair and the PAPAW for distance or velocity; however, some trends were noted.<br>2. Subjects would use the PAPAW more often upon leaving their homes. Subjects seemed to like the PAPAW's ease of use (85%), quick travel abilities in short or longer distances (29%) and the ability to climb hills easier (43%). They also rated the PAPAW as comfortable and easier to propel.<br>3. More activities were accomplished in a day when using the PAPAW, as the subjects felt it was faster than their power wheelchair and it supplied relief when tired.<br>4. With the PAPAW, subjects did not like battery location, height and weight of chair, lack of control over power levels and transportability. |
| Corfman et al. 2003<br>USA<br>Pre-Post<br>N=18 | **Population:** Mean age: 34.5 yr; Gender: males=6, females=4; Level of injury: paraplegia=18; Chronicity=chronic.<br>**Intervention:** Propulsion of a Quickie 2 manual wheelchair configured as a pushrim-activated power-assisted wheelchairs (PAPAW) and personal wheelchair on a dynamometer at 2 speeds and 3 resistance levels for 3 min per trial (minimal-0.9 m/s and 10 W; 1.8 m/s and 25 W; slight-0.9 m/s and 12 W; 1.8 m/s and 25 W; moderate-0.9 m/s and 14 W).<br>**Outcome Measures:** Stroke pattern, Stroke frequency, Range of motion (ROM)-shoulder flexion/extension, abduction/adduction, internal/external rotation, horizontal flexion/extension-elbow flexion/extension, supination/pronation, ulnar/radial deviation. | 1. No stroke pattern difference was found between the two wheelchairs.<br>2. Stroke frequency was different when comparing the two wheelchairs; however, this difference was dependent on speed (0.9 m/s or 1.8 m/s).<br>3. During both of the slight trials and 0.9m/s moderate trial, shoulder flexion/extension ROM was decreased ($p<0.05$). During the 0.9m/s slight trial and 1.8 m/s normal trial, elbow and wrist flexion/extension ROM was decreased ($p<0.05$). Also, the wrist ulnar/radial deviation ROM was decreased during the 0.9m/s slight and moderate trials ($p<0.05$). |

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| | | 4. With the exception of shoulder internal/external rotation, the PAPAW was accountable for reducing ROM values for all dependent variables. |
| Cooper et al. 2001<br>USA<br>Pre-Post<br>N=10 | **Population**: *Phase 2:* Mean age: 35 yr; Gender: males=6, females=4; Level of injury: paraplegia=9, MS=1; Mean time since injury: 13 yr. *Phase 3*: Mean age: 45.2 yr; Gender: males=6, females=4; Level of injury: paraplegia=9, multiple sclerosis=1.<br>**Intervention:** *Phase 2*-Propulsion of personal chair and pushrim-activated power-assisted wheelchairs (PAPAW) on dynamometer. *Phase 3*-Propulsion of personal chair and PAPAW through standardized activities of daily living obstacle course three times.<br>**Outcome Measures:** Phase 2-Oxygen consumption, Ventilation, Heart rate. Phase 3-Performance on course; Completion time, Self ratings of comfort and ergonomics, Stroke frequency, Heart rate. | **Phase 2:**<br>1. Subjects using the PAPAW had lower oxygen consumption (VO2 mL/min, and VO2 mL/kg x min, $p<0.001$) and heart rate ($p<0.05$ in two conditions) when compared to their manual wheelchair use.<br>2. Oxygen consumption and heart rate, but not ventilation, were significantly different when comparing chairs and speed ($p<0.001$).<br>**Phase 3:**<br>3. The PAPAW had a higher ergonomic evaluation than the manual wheelchair ($p<0.01$).<br>4. Subjects had faster completion times of the Activities of Daily Living (ADL) course ($p=0.01$) and had less difficulty over the large speed bump between trial 1 and 3 ($p=0.02$), when using the PAPAW as compared to the manual wheelchair.<br>5. The PAPAW had lower ratings on car transfer tasks of taking wheels off ($p=0.004$) and putting wheels back on ($p=0.001$). |
| Algood et al. 2005<br>USA<br>Post-Test<br>N=15 | **Population:** Age range: 20-53 yr; Gender: males=11, females=4; Weight range: 45-114 kg; Height range: 152-193 cm; Level of injury: tetraplegia=15; Time since injury range: 0.8-30.0 yr; Chronicity: sub-acute-chronic.<br><br>**Intervention:** An obstacle course containing activities of daily life. Subjects used both their personal wheelchair and a pushrim-activated power-assisted wheelchairs (PAPAW) three times each.<br>**Outcome Measures:** Heart rate, Completion time, Visual analog scale (VAS), Amount of assistance required. | 1. It was significantly easier for subjects to complete the obstacle course with the PAPAW, as compared to their own wheelchair ($p<0.001$). This was most apparent with the carpet, dimple strips, ramp incline and up curb cut obstacles ($p<0.001$).<br>2. Completion time of the course, response to ergonomic questions and amount of assistance needed did not differ between wheelchairs.<br>3. Mean heart rate was significantly lower in all three PAPAW trials when compared to the three personal wheelchair trials ($p=0.015$, $p=0.001$, $p=0.003$). |