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RESEARCH PAPER

Comparison of activities of daily living in two different one arm drive wheelchairs: a controlled trial

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Abstract

Aims. This pilot study measured activities of daily living (ADLs) in users propelling both a standard dual handrim Action 3 wheelchair and a standard Action 3 wheelchair with a Neater Uni-Wheelchair (NUW) kit attachment. The kit consists of a steerable front castor and a single pushrim propelling both rear wheels via a differential.

Hypothesis. There would be a difference in the efficiency of ADL skill performance, speed and heart rate.

Methods. Twenty non-disabled participants simulating hemiplegia were used in a cross over, repeated measures trial. Assessment of Motor and Process Skills (AMPS) of users undertaking making a bed and laying a table 'Swedish style', tasks, were measured. Heart rate at rest and post-task and time taken to complete each task were recorded.

Results. Heart rate when laying the table was lower in the NUW ($p < 0.005$) and task completion time was quicker ($p < 0.0001$). There was no difference in motor and process ability skills.

Conclusion. ADL tasks in the NUW were completed more efficiently with no loss in quality of motor and process skills performance. This suggests that the NUW is a viable alternative to current one arm drive provision.

Keywords: *Activities of daily living, ergonomic efficiency*

Introduction

The standard self-propelled wheelchair is an inefficient means of transport for hemiplegic users [1]. Mandy et al. [2,3] in their review of the literature have identified that wheelchair provision for this group is limited, unsuitable and inefficient to use. Inappropriate provision of a manual wheelchair for hemiplegic users can result in loss of self-esteem, depression, diminished quality of life and social isolation [4,5]. Individuals may also experience adverse consequences to their physical functioning, safety, quality of life, vocational and economic standing [6]. In the current climate of medical economics, clinicians are challenged to provide quality and cost-effective care, including the prescription of appropriate equipment [6]. Further, self-propulsion in a wheelchair can be used as a method of improving and maintaining physical strength in a functional and real-life way [7]. Limitation of physical activity as a result of motor impairment may result in subsequent physical de-conditioning, disability and a heightened risk of cardiovascular disease [8]. This may therefore, indicate that the prescription of an appropriate self-propelled wheelchair, be more beneficial for the individual than that of a powered wheelchair. Moreover, issues of battery life and source, storage difficulties, weight of the wheelchair, initial cost and maintenance costs are all factors that need to be considered prior to the purchase of a powered wheelchair. However, for users who have particularly weak upper limbs, and limited stamina, powered wheelchairs are invaluable.

Mandy et al. [2,3] have developed the Neater Uni-Wheelchair (NUW) 1 kit which has been designed to meet the needs of hemiplegic users (Figure 1). It has been scientifically demonstrated to be ergonomically more efficient, easier to manoeuvre and preferred by

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hemiplegic users when compared to a dual handrim wheelchair. Dual handrim wheelchair users propel themselves straightforward by spanning both rims, to turn, the outer rim controls the contralateral wheel and the inner rim controls the ipsilateral wheel.

Their clinical studies ($n = 13$), involving manoeuvring both a dual handrim wheelchair and the NUW around an indoor circuit which included obstacles, slalom and different surfaces, indicate that oxygen consumption (O_2 mls/min) and exhaled carbon dioxide (CO_2 mls/min) were significantly lower in the NUW ($p < 0.004$ and $p < 0.04$, respectively) [2,3]. All comfort ratings were significantly greater in the NUW compared to a dual handrim equivalent ($p < 0.01$). The dual handrim wheelchair has both handrims for propulsion on one rear wheel. The inner rim propels the left rear wheel and the outer rim propels the right rear wheel. Propulsion in a straight line requires both rims to be propelled together and requires significant effort and a big hand span. Separate propulsion of the rims results in a snaking motion of the wheelchair.

The kit involves an attachment of a gear differential built into one rear drive wheel which enables a single pushrim to drive both rear wheels equally resulting in the wheelchair moving in a straight line with steering that can be employed as required. The novel steering mechanism enables the user to steer with the footplate which is connected to a front castor (Figure 2).

Steering is intuitive: rotating the foot to the right turns the wheelchair to the right; rotate the foot to the left and chair turns left. Small rotational movements of the footplate result in large movements of the front castor in a ratio of 2.5:1 which enables the wheelchair to make extremely tight turns. For example, one rear wheel can be completely stationary with the whole wheelchair turning around it. The differential fitted to the rear wheel shares the torque equally between each wheel regardless of the direction of steering. The telescopic axle can still be removed easily in order that the wheelchair can be collapsed for storage. These devices comprise the 'NUW kit' and are fitted to the wheelchair on the users' functional side and are operated independently by the individual wheelchair user. There is no handrim on the non-functional side (Figure 3). The NUW has been Medicines and Healthcare Regulatory Agency (MHRA) tested and approved.

While their studies were encouraging, they were undertaken in a laboratory environment and not in a home situation where space can be limited. If the wheelchair is to promote independence and well-being by enabling users to more easily participate in meaningful activities, then it should be assessed against these criteria. The research question was: Does the use of the NUW affect the performance quality of Activities of Daily Living?

The aim of this study was to assess motor and process skills in non-disabled users undertaking two different activities of daily living (ADLs). The assessment of motor and process skills (AMPS) is a validated standardised assessment tool for specifically measuring quality of performance in ADLs [9]. A second aim was to measure efficiency of the

Figure 2. The steering mechanism.

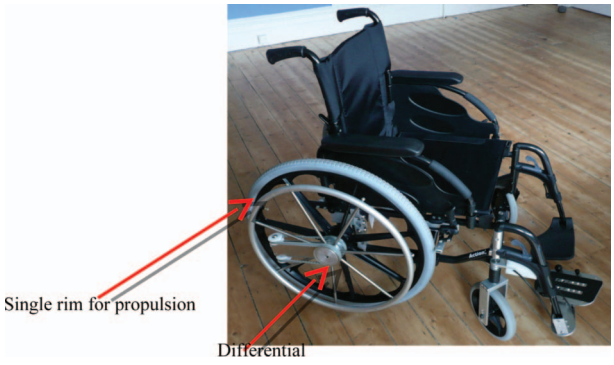

Figure 1. The NUW kit attached to an Action 3 wheelchair.

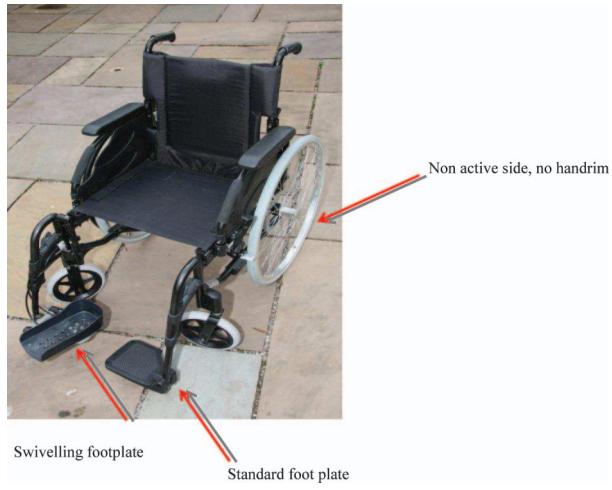

Figure 3. The non-active side of the wheelchair.

activities in relation to time and changes in heart rate. Users were measured in both a standard dual handrim Action 3 wheelchair and one to which the steering kit has been applied called the NUW.

Methods

Ethical Approval was gained from the University of Brighton, School of Health Professionals, School Research Ethics and Governance Panel.

Study design

This was a controlled same subject study that compared motor and process skills of a group of users in a standard dual handrim Action 3 wheelchair to the same skills performed in the NUW when performing two different ADLs.

Participants

A power analysis, using an alpha value of 0.05 to detect 25% difference in motor skills indicated that a sample size of 18 would be sufficient at a power of 0.9.

Randomisation of the wheelchairs

The order in which the participants used the wheelchairs was determined by the use of random numbers.

Recruitment and screening

Able-bodied participants were used for this study. Hemiplegia was simulated by their non-dominant arm strapped to their chest to prevent any accidental use during the testing. Simulated hemiplegia is a valid technique when examining wheelchair performance [10,11].

Twenty able-bodied participants were recruited using posters from the University of Brighton, Faculty of Health and Social Sciences.

The inclusion criteria were aged between 18 and 65 years, weight to be between 59 and 90kg and height between 163 and 185 cm in order that they would fit in the wheelchairs.

The exclusion criteria were currently, or previously, a wheelchair user or unilateral weakness.

All participants were given an information sheet detailing the study, and informed written consent was taken.

Assessment materials

The AMPS [9] is a standardised assessment measuring the quality of performance in ADLs which gives rise to logit scores. The AMPS considers functional behaviour (occupational performance) as a complex set of interactions between the person and his or her environment. AMPS was developed on the premise that accurate determination of a person's ability to perform daily life tasks is most directly assessed through the assessment of his or her skills (practised abilities) observed in the context of his or her dynamic interaction with the environment during a performance of specified tasks [12]. AMPS raters have to undergo a rigorous training and validation procedure before being qualified to rate performance [9].

The person's performance on 16 motor and 20 process skills items is rated on a scaled of 1–4 using the criteria detailed in Table II. The many-faceted Rasch model was used in the development of the AMPS, as Rasch analysis generates true interval measures from the ordinal scores [13].

There is no time limit for the completion of the tasks or instruction concerning the speed of completion of the tasks. The participant is required to indicate when they consider the task has been completed.

The AMPS skill items and tasks have been developed through a series of pilot studies that included the development of a table of specifications, content validation of the skill items and tasks by panels of experts and examination of the reliability and validity of the AMPS motor and process skills scales [9]. It has been extensively tested for reliability and validity [9] on people with hemiplegia [14] and in wheelchair users [15].

Environment

Training and familiarisation. All participants were able to familiarise themselves with forward and reverse manoeuvring of both wheelchairs until they felt competent to undertake the trial.

Measurement of the motor and process skills occurred in the Activities of Daily Living Suite at the University of Brighton, which simulates a home environment. Two activities of similar complexity to sufficiently challenge the motor and process skills of the participants were chosen from those detailed in the AMPS manual [9]; laying a table Swedish style and making a bed. Laying a table Swedish style involves setting four place settings at the table along with butter and bread.

Figures 4 and 5 show the layout of the kitchen and bedroom where the activities were undertaken.

Procedure

A heart rate monitor was fitted to the participant and the resting heart rate was noted and their non-dominant arm was strapped to simulate limited usage as for a person with hemiplegia. Laying the table involved the use of plates, cutlery, butter knife, glasses, bread, bread baskets, butter/margarine and serviettes. Items were stored in cupboards and the fridge in the kitchen area.

Each task was video-recorded and stored for scoring at a later date by an independent trained and calibrated AMPS rater. Heart rate was recorded after completion of each task. Length of time taken to complete each task was also recorded. Each participant completed both tasks in both wheelchairs. After each task, each user had a 10 min period of rest to enable the heart rate to return to resting state, prior to the process being repeated in the alternative wheelchair. Heart rate was re-measured after a minimum of 10 min rest.

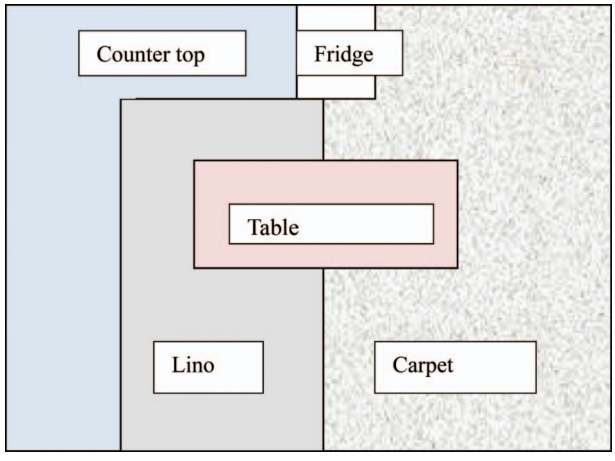

Figure 4. To show the kitchen layout.

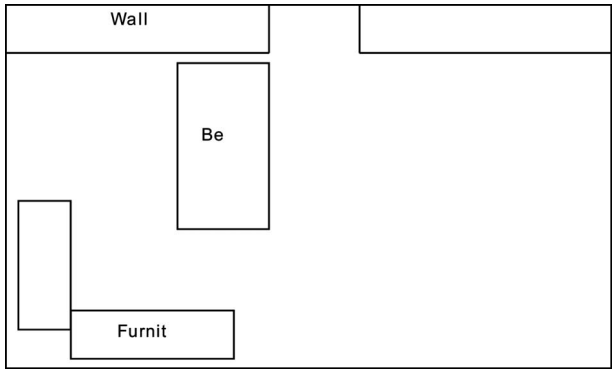

Figure 5. To show the bedroom layout.

Scoring for the AMPS

Overall measures of participants' motor and process skills, expressed in logits, were calculated from the ratings of performance. The motor and process skills were classified for each activity and presented in Table I.

Statistical analysis

Heart rate and length of time taken to complete each task were tested for normal distribution using a Kolomorgov-Smirnov test. The data were found to have a normal distribution. A paired *t*-test was used to compare differences in scores. The alpha level was Bonferroni-adjusted to $0.05/6 = 0.008$. This is to protect against α-level inflation due to undertaking multiple tests of significance.

The motor and process skills logit scores were described as indicated in the scoring manual.

Results

All participants were right handed and met the inclusion criteria for using the wheelchair. In all, 19 females and 1 male with simulated left side weakness participated. The mean age of the participants was 29.3 years, SD 6.5 years, range 22–46 years.

Motor and process skills using AMPS

Descriptive statistics for the motor skills and process skills logit scores for the AMPS are presented in Table I.

Table I. Motor and process skills mean logit scores.

	Motor skills		Process skills	
	Dual handrim wheelchair	NUW	Dual handrim wheelchair	NUW
Mean	1.10	1.15	0.91	0.96
SD	0.16	0.23	0.26	0.37

Table II. Mean heart rate scores per activity.

	Swedish table-laying activity		Bed-making activity	
	Dual handrim wheelchair	NUW	Dual handrim wheelchair	NUW
Mean	90.55	86.34*	95.1	93.7
SD	10.83	10.36	9.5	11.45

*A significant result that the heart rate for the NUW is statistically lower than in the table laying activity than in the dual handrim wheelchair.

There was no significant difference in the motor skills scores ($t = 1.20$; $p = 0.242$) and process skills scores ($t = 0.62$; $p = 0.54$) between the two wheelchairs.

Heart rate

Heart rate was significantly lower after laying the table in the NUW than in the dual handrim ($t = 2.82$, df = 19, $p < 0.01$). There was no significant difference in heart rate in the bed-making activity ($t = 0.783$, df = 19, $p = 0.44$) (Table II).

Time taken

The time taken by each participant to complete the tasks was significantly faster in the NUW. Laying the table: ($\overline{X} = 2.63$, SD = 1.48; $t = 7.94$, df = 19, $p < 0.0001$) and making the bed ($\overline{X} = 2.733$, SD = 1.49; $t = 8.17$, df = 19, $p < 0.0001$) (Table III).

Discussion

This pilot study measured efficiency of ADLs in users propelling both a standard dual handrim Action 3 wheelchair and in a novel self-propelled wheelchair called the NUW. Efficiency, in terms of quality ADL performance was measured using AMPS and it was also measured through speed of undertaking the activities and changes in heart rate.

The mean AMPS scores for the motor and process skills were not statistically significant in participants using the NUW. However, the time taken to complete the tasks was significantly quicker in the NUW and heart rate was also lower with no reduction in quality of motor or process skills performance. The heart rate and time taken results suggest that participants in the NUW undertook the activities more quickly and in the table laying the participants were more ergonomically efficient. While there was a statistical difference in heart rate, it should be acknowledged that clinically this may not be significant. There was no difference in heart rate in the bed-making activity. The table-laying activity required the participant to make multiple trips to the cupboard and fridge to locate all the items needed to lay the table. This in turn resulted in considerable amount of energy expenditure in multiple small trips and manoeuvring the wheelchair in confined spaces. Moreover, making the bed only involved straightening the sheet and duvet. This was not a particularly demanding activity and therefore it not surprising that heart rate was not significantly altered.

Table III. Time taken to complete tasks.

	Swedish table-laying activity		Bed-making activity	
	Dual handrim wheelchair	NUW	Dual handrim wheelchair	NUW
Mean (min)	5.79	3.16	5.29	2.55
SD	1.75	1.38	2.03	1.3

Considering these results collectively, the findings suggest that participants were able to perform the activities in the NUW at a faster rate with no loss in quality of motor and process skills performance and with a lower heart rate in one task.

The use of heart rate monitoring to assess energy expenditure has been used extensively in healthy individuals and those with pathology, although its limitations are acknowledged [16,17]. Moreover, it is a normally used in activities where a steady state has been achieved for more than 3 min. In this study, the mean time taken to undertake the activities was in excess of 3 min for three of the four activities, however, it is questionable whether a steady state was achieved in all of them. Acknowledging this limitation, the results would endorse the earlier work of Mandy et al. [2,3] that the NUW was more efficient than the dual handrim equivalent.

The overall findings, however, do have a number of implications. First, they endorse earlier work by Mandy et al. [2,3] and provide further evidence that the NUW reduces the cardio-vascular demand experienced by users. However, unlike the previous studies, this research demonstrates the phenomena in a more real-life context. Metabolic costs and mechanical work are related to device efficiency; therefore, the reduced metabolic cost is likely to relate to less stress on the upper extremities. This is an important factor, considering wheelchairs are known to be an inefficient means of mobility [11]. Less energy expenditure and increased speed in completing everyday activities may mean the user will be able to complete more activities during the day as fatigue levels will not be so high. This may in turn impact on quality of life, psychosocial functioning and engagement in meaningful occupations [18,19].

The concept of choice in assistive technology has become increasingly important in recent years [20]. Choice has been identified as a key contributing factor in client's use or non-use of assistive technology such as wheelchairs [21–23]. Eggers et al. [6] created a conceptual model of wheelchair service delivery that promotes client-centred decision making, matching the device to the person and their environment. Providing a client with greater choice may improve clinical cost-effectiveness by avoiding

non-use of equipment. The NUW creates more choice in a currently limited market, providing clinicians with another effective solution to wheelchair prescription. Unlike other studies into novel hemiplegic wheelchairs [24,25], this study has considered the use of the wheelchair in a simulated home environment. Eggers et al. [6] also suggest that the environment is a key factor in their model of wheelchair service delivery. The device needs to fit to the environment in which it is to be used, or else it is worthless. This is not an easy fit due to the plethora of environmental barriers and lack of accessibility for wheelchair users. The benefits of the NUW include its small turning circle, its ease of manoeuvrability and increased efficiency, thereby allowing users to access confined spaces and providing a better quality of performance of ADLs.

While the positive outcomes of this study have been considered, it is important to acknowledge the limitations of this study which include the age and gender distribution of the subjects. It is also important to recognise that the participants did not have any impairment arising from co-morbidities or perceptual problems that are more commonly associated with stroke and hemiplegia. A further limitation could also be that the participants were only asked to complete two tasks and thus a small subset of all the tasks that might be used by a hemiplegic person. However, the AMPS breaks down the tasks into motor and process skills which were assessed and are essential to nearly all ADLs. This is the theoretical [9] and empirical basis [15] on which the AMPS claims to be able to produce valid scores of motor and process skills performance. A further limitation was also that the participants were only given a limited period of time in which to learn how to propel the wheelchairs, although all reported that they were competent to proceed with the study and that further time was not required. However, aside from these limitations there is still sufficient evidence presented to support a full evaluation of performance of ADL's in people with hemiplegia. The dual handrim wheelchair, to which the NUW was compared, is not the most commonly prescribed one arm drive wheelchair because of the difficulties in propelling using two handrims. However, it is still available and prescribed by wheelchair services even though it is an inefficient mode of propulsion [26].

Anecdotally it is also known that users, who are prescribed one arm drive wheelchairs, may resort to using a standard wheelchair using their able arm and leg (the hemiplegic pattern). There is some international work which has explored this hemiplegic pattern compared to propulsion using a two handed patterns of propulsion [27]. While this punting style is not endorsed by clinical rehabilitation teams in the UK, it would be useful to explore this method of propulsion as it is commonly adopted by hemiplegic users. Therefore, a useful addition to the literature would be a comparison of the NUW in tasks and ADL to that of a standard wheelchair which is manoeuvred using the hemiplegic pattern.

Note

1. The research was undertaken as a DoH funded collaboration between Neater Solutions and the University of Brighton. There is no financial, commercial or conflict of interest between any of the parties. There is no financial relationship between any of the authors and Neater Solutions.

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