Introduction:

Manual wheelchair propulsion is known to be an inefficient means of ambulation which has been associated with high a prevalence of upper limb injuries [1,2]. Such injuries are thought to occur from a combination of repetitive movements, heavy loads on the extremitie 0 0 Tm /2Mds on the

(Insert Fig 1 and 2). The body of work to date suggest that the NUW is ergonomically more efficient to drive and preferred by users in both a laboratory setting [9,10] and in a simulated activities of daily living setting [12]. A further study evaluated users experiences of using the NUW in their own homes [11] from which four key themes of increased user independence and freedom, ease of use and maneuverability, usefulness and increase in activity were reported [11]. These studies suggested that NUW could meet the unmet needs of the hemiplegic user group and provide them with additional choice in their wheelchair provitl anterior deltoid and pectoralis major for the push phase and posterior deltoid for the recovery phase) were the same as for level propulsion (Chow et al., 2009). The goal of this investigation was to quantify changes in the activity of muscles surrounding the shoulder in three different one arm drive wheelchairs. The research hypothesis was: There will be differences in EMG activity around the shoulder when propelling different one arm drive wheelchairs.

Methods:

Ethical Approval was sought and obtained from the University of Brighton Research Ethics committee for the study.

Subjects were recruited from the University of Brighton Campus using posters. The inclusion criteria were: willingness to participate, no cardiac or respiratory disorder, no functional impairment, right hand dominant and to be within the height and weight restrictions of 163-185 cm high and 54-90 kg weight. Exclusion criteria: inability to learn how to propel safely. Participants were provided with an information sheet prior to be recruited into the study to enable them to make an informed decision concerning their involvement. All subjects who wished to participate completed a health declaration sheet and informedQ q 0.24 0.2rm drihi5 (BT 50 00 Tm B()0.2 (e)1) 0.2 (t) 0.2 ( )] TJ ET Q q 0.2o(..2 50 00 f

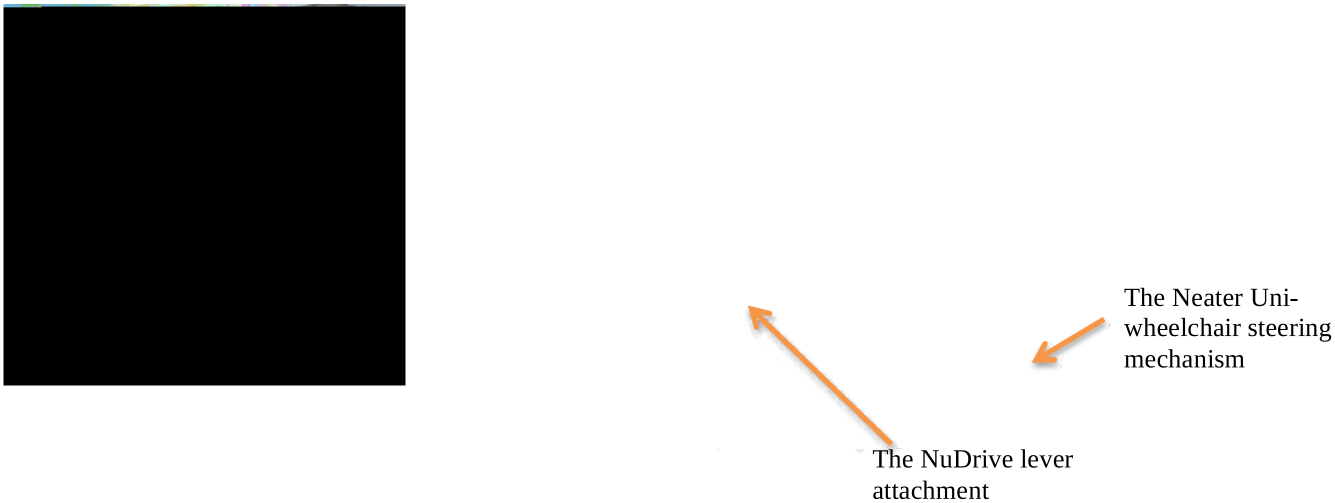
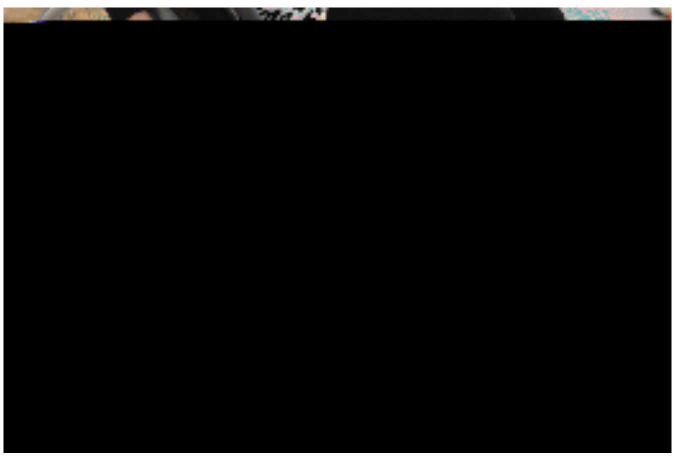


Figure 3: The Standard Action3 wheelchair with Neater Uni-wheelchair steering.



EMG Measurement System

EMG activity in biceps, triceps, pectoralis major, anterior and posterior deltoid and infraspinatus muscles was collected using the Biometrics DLK 900 system with version 7.5 software. The data was sampled at 1000Hz. The skin under the electrodes was cleaned using alcohol wipes prior to attachment of the electrodes using double sided tape. The EMG electrodes were positioned according to Seniam guidelines. The reference electrode was positioned over the left wrist.

The Theatir

The study was conducted at an indoor circuit at the University of Brighton (Fig 4). All participants were given familiarisation training in the use of all the wheelchairs until they

Procedure

Demographic data including age, and gender were recorded for all subjects. The users had the electrodes positioned over each of the six muscles on the right shoulder and arm prior, to commencement of the trial. Subjects were randomly allocated the wheelchairs using random numbers.

The participants were asked to drive the wheelchair round the course (Fig 4) at their own speed. Data was captured continuously throughout each circuit. Time taken to complete

The data were statistically investigated to explore the differences in muscle activity around the shoulder in the different wheelchairs.

In all cases analyses were also performed to show differences during the different activities.

The data was found not be normally distributed.

Total voltage generated within the muscles was measured and compared during each activity. A Friedman's test (K-related-samples test) and additional post-hoc analysis with Wilcoxon signed-rank test was performed to compare total voltage generated during each key section of the circuit in each of the different wheelchairs.

Results

Gender distribution: 10 women and 7 men.

Table 1: To Show Demographic variables of the Participants

Male	Mean	SD	Female	Mean	SD
Age (yrs)	25.86	11.05	Age (yrs)	30.3	11.34
Height (cm)	183	9.70	Height(cm)	166.9	6.54
Weight(kg)	77.29	19.03	Weight(kg)	62.1	7.43

Table 2: To show differences in muscle activity during the different activities

Activity	**Biceps**	**Triceps**	**Ant Deltoid**	

Biceps Muscle

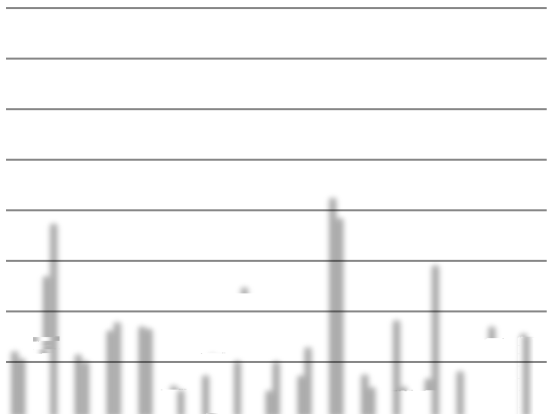
Measurement in Straight running

There was no significant difference in the total activity generated during straight running

There was a significant difference in the activity generated in biceps when driven around corners between the three different wheelchairs (Freidmans $X^2 = 17.28$, n=17, df=2, p< 0.001).

Post-hoc analysis with Wilcoxon signed-rank tests, conducted with a Bonferroni correction, indicated that the activity generated in the NuDrive wheelchair was significantly greater than the activity generated in the Action3 with steering (Z= -3.258, n=17, df=2, p<0.001). The least activity was generated in the Neater Uni-

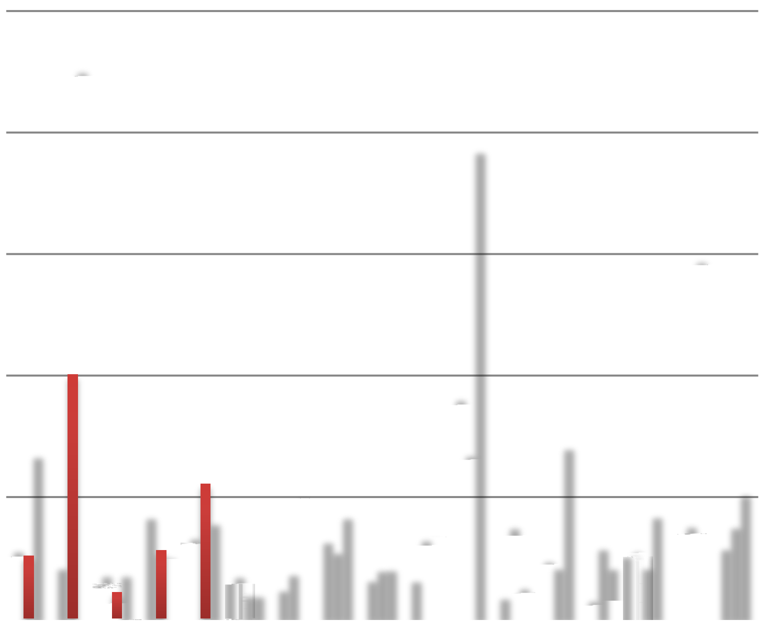
There was no significant difference between the wheelchairs across mats (Friedmans X^2 = 0.209, n=17, df=2, p0.90) or during slalom corner driving (Friedmans X^2 = 2.41, n=17, df=2, p0.2).



Measurement around corners and slalom driving:

There was a significant difference in activity generated around corners and slalom between the three different wheelchairs (Friedmans $X^2 = 8.149$, n=17, df=2, p=0.017). Post-hoc analysis with Wilcoxon signed-rank tests, conducted with a Bonferroni correction, indicated there was significantly less activity generated whilst propelling the Neater compared to the NuDrive (Z=-2.896, p=0.004). The Action3 with steering also produced significantly less activity than the NuDrive (Z=-2.059, p=0.035).

Graph 5: To Show Pectoralis Major activity during slalom



The following muscles did not show any significant differences between chairs in each activity.

Anterior Deltoid Muscle

Measurement in Straight running:

There was no significant difference in muscle activity between the wheelchairs (Friedmans X^2=81.7, n=17, df=2, p=0.42).

Measurement Over Mats:

There was no significant difference in muscle activity between the wheelchairs (Friedmans X^2=1.16, n=17, df=2, p=0.55).

Measurement around Corners and Slalom driving:

There was no significant difference in muscle activity between the wheelchairs (Friedmans X^2=5.04, n=17, df=2, p=0.08).

Posterior Deltoid Muscle

Measurement in Straight running:

There was no significant difference in muscle activity between the wheelchairs (Friedmans X^2=0.627, n=17, df=2, p=0.73).

Measurement Over Mats:

There was no significant difference in muscle activity between the wheelchairs (Friedmans X^2=3.85, n=17, df=2, p=0.14).

Measurement around Corners and Slalom driving:

There was no significant difference in muscle activity between the wheelchairs (Friedmans X^2=1.46, n=17, df=2, p=0.48).

Infraspinatus

Measurement in Straight running:

There was no significant difference in muscle activity between the wheelchairs (Friedmans X^2=1.88, n=17, df=2, p=0.39).

Measurement over Mats:

There was no significant difference in muscle activity between the wheelchairs (Friedmans X^2=2.71, n=17, df=2, p=0.25).

Measurement around Corners and Slalom driving:

There was no significant difference in muscle activity between the wheelchairs (Friedmans X^2=3.07, n=17, df=2, p=0.21).

Discussion

The aim of this study was to measure and compare the activity of six muscles involved in wheelchair propulsion in a sample of non-disabled wheelchair participants using right sided one armed propulsion mechanisms. The objective of the study was to identify which one armed wheelchair generated the least amount of activity when maneuvering in a controlled environment and around obstacles.

The results suggest that the NuDrive required the greatest amount of activity in biceps, and pectoralis major muscles in propelling over mats and around corners. The Neater Uni-wheelchair however, involved the least activity of these muscles in propulsion during these same key activities. Triceps activity was significantly greater in the Action 3 wheelchair with steering in straight running when compared to the other two wheelchairs.

Biceps is not normally considered to be a muscle used in the propulsion of wheelchairs since the action of propulsion involves extension of the elbow. The traces produced by both biceps and triceps would concur with this and indicated that biceps was active in the return of the arm following the propulsive stroke. Similarly triceps was activated during the propulsive phase.

The results for biceps may be explained through the differences in the mechanism of propulsion for the different wheelchair. The wheelchairs us (i) 0.2hac et al., 2010; Rodgers et al., 2003; Sabick et al., 2004) and suggests that wheelchair users likely select arm configurations that allow the shoulder flexors to function as the primary actuators during the push phase.

The involvement of triceps in straight running is not surprising because the long head is known to contribute to propulsive power (Rankin 2011). During resisted propulsion this may be explained through the greater activity of pectoralis major acting as the primary muscle of propulsion. It was evident during the trial that all participants found the mats and slalom parts of the course more challenging and appeared to change their position in the chair to enable them to cope with the increased resistance. This may have led to a change in movements of the upper limb for propulsion which in turn may have changed the primary muscle for propulsion from triceps to pectoralis major. Kinematic studies would confirm this suggestion.

The Action3 wheelchair produced higher forces than the Neater Uni-wheelchair over mats or during slalom driving but less than the NuDrive. This is not surprising because the The Action3 was only fitted with the foot steering mechanism and did not have the differential attached to the rear wheel. The differential 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 differential ensures that the load on the

Further work is indicated to explore propulsive effort at the shoulder in these wheelchairs in relation to forces generated at the hand/handrim interface. These findings will contribute to our understanding of over use injury in propelling one arm drive wheelchairs.

Implications for Rehabilitation:

*To review the clinical reasoning in prescribing lever drive wheelchairs.

*To improve clinicians understanding of forces incurred in wheelchair propulsion

*To illuminate clinicians understanding of the causation of

5. Hellström K, Lindmark B, Wahlberg B, Fugl-Meyer AR. Self-efficacy in relation to impairments and activities of daily living disability in elderly patients with stroke: a prospective investigation. J Rehabil Med 2003;35:202–207.

6. Fullerton H.D, Borckardt J.J, Alfano A.P. Shoulder pain: a comparison of wheelchair athletes and non-athletic wheelchair users. Med and Sci in Sports and

12. Bashton D, Mandy A**,** Haines D, Cameron J. Measurement of Activities of Daily Living (ADLs) in the Neater Uni-Wheelchair. A Controlled Trial". Disab and Rehab Assist Technol. 2012;7(1):75-81

13. Mandy A, Redhead L, McCudden C, Michaelis J (2013) A comparison of vertical reaction forces during propulsion of three different one-arm drive wheelchairs by hemiplegic users. Disab and Rehab Assist Technol. 2013; Early Online: 1–6 Informa UK Ltd. DOI: 10.3109/17483107.2013.782575

14. Goldberg E.J , Kautz S.A , Richard R. Neptune R.R 2008 Can treadmill walking be used to assess propulsion generation? J Biomech 41(8): 1805–1808.

15. Crowe, A., P. Schiereck, R. Boer and W, Keessen, 1993. Characterization of gait of young adult females by means of body center of mass oscillation derived from ground reaction forces. Gait and Posture 1, 61-68.

16. Gagnon D, Nadeau S, Noreau L, Dehail P, Gravel D. Quantification of reaction forces during sitting pivot transfers per-formed by individuals with spinal cord injury. J Rehabil Med. 2008;40(6):468–76.

17. Tekscan Inc [internet]. South Boston, MA:-[cited 2013 Nov 1st]; available from: www.**tekscan**.com

18. Härkönen R., Piirtomaa M., Alaranta H., Grip strength and hand position of the dynamometer in 204 Finnish adults. , 1993, 18(1), 129–132

19. Mathiowetz V., Kashman N., Volland G., Weber K., Dowe M., Rogers S., Grip and pinch strength: normative data for adults. , 1985, 66(2), 69–74.

Rankin J.W, Richter W. M, Neptune R.R (201