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Measures of energy expenditure and comfort in an ESP wheelchair: a

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sample of 10 subjects using a similar same subject repeated measures design.

Study design

This was a controlled same subject study that compared wheelchair skills performance of a group of hemiplegic participants in a standard dual handrim Sunrise Breezy wheelchair to the skills performed in the modiPed Sunrise Breezy wheelchair.

Randomisation of the wheelchairs

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

Recruitment and screening

The inclusion criteria were: willingness to participate, competence to give informed consent, hemiplegia due to stroke, hemiplegic-propulsion pattern (1 arm and 1 leg on the same side) wheelchair user, tolerance of the Cosmed mask, controlled hypertension.

Exclusion criteria included unstable medical condition (e.g., angina, uncontrolled hypertension, seizures), mask phobia and height and weight restriction of 163–185 cm and 54–90 kg in order that they could fit into the wheelchairs.

The participants were pushed around the driving course by the principle investigator initially to familiarise themselves with it. A heart rate monitor was attached to the subjects' chest. The Cosmed analyser was attached using a face mask to the subject and a baseline measure of oxygen consumption, carbon dioxide expulsion and heart rate taken once all the parameters had stabilised.

Subjects were randomly allocated either the ESP wheelchair or the standard dual handrim Sunrise Breezy with using random numbers. The total length of the driving course was 150 m. Participants were initially asked to drive across the gymnasium floor for 30 m and complete a 90° left turn and continue for 10 m. A further 45° left hand turn took the user onto carpet. The carpet was 30 m long and included a slalom of four closely placed bollard markers which required tight 108° right and left hand turns. At the end of the carpet, the user completed a 90° right hand turn back onto the gym floor for 10 m. A further drive 90° right hand turn took the user to 6 m of sponge matting. At the end of the matting was a further 90° right hand turn back onto the gymnasium floor for 10 m. A final 90° right hand turn and 10 m of driving took the user back to the start/finish line (Figure 2).

Prior to commencing the course a steady baseline heart rate and oxygen consumption levels were achieved. The participants were asked to drive the wheelchair round the course at their own speed. At completion of the course, participants were asked to complete a ride comfort questionnaire and also a handrim comfort questionnaire. The course was repeated once per wheelchair with a 30 min gap, or however much time was necessary, between testing to restore the heart rate to its resting state. Once this had occurred they were asked to repeat the

same course and complete the same hand and ride comfort questionnaires using the different wheelchair.

Statistical analysis

Oxygen consumption, carbon dioxide levels and heart rate were tested for normal distribution using the Kolmogorov-Smirnov test. The data was found not to be normally distributed. A Wilcoxon signed-rank test was used to compare the data for differences. Time taken to complete the course was

There was no difference in mean heart rate (beats/min) between the two wheelchairs. (Wilcoxon test: $Z = 1.64$, $p = 0.1$).

The oxygen consumption for the ESP (O_2 /ml/min/kg) was significantly lower than the standard dual handrim Sunrise Breezy wheelchair (Wilcoxon test: $Z = 2.8$, $p = 0.004$).

The carbon dioxide levels (CO_2 /ml/min/kg) were significantly higher in the standard dual handrim Sunrise Breezy wheelchair (Wilcoxon test: $Z = 1.1$, $p = 0.00$).

Conclusion

The results from the pilot study of hemiplegic users suggest that the ESP is a viable kit that has the potential to be a useful attachment to the standard dual handrim Sunrise Breezy wheelchair. The results suggest that the kits make propulsion of the wheelchair easier, and more comfortable to drive. The kits also potentially afford individuals with a CVA, who use a wheelchair, a satisfactory alternative to current wheelchair provision. The engineering of the prototype was robust and resulted in adequate wheelchair performance under trial conditions. There is a clear justification for the ESP Wheelchair to be tested in users' homes.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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