Effect of seat height on manual wheelchair foot propulsion while wheeling forward on a smooth level surface: a repeated-measures crossover study

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ABSTRACT

Purpose: To test the hypotheses that, during manual-wheelchair foot propulsion forward on smooth level surfaces, lowering the seat height increases speed, push frequency and push effectiveness, and decreases perceived difficulty.
Methods: In a repeated-measures crossover study, 50 able-bodied participants used one foot to propel a manual wheelchair 10 m on a smooth level surface at 5 seat heights, in random order, ranging from 5.08 cm below to about 5.08 cm above lower-leg length ("neutral"). We recorded Wheelchair Skills Test (WST) capacity scores and used the Wheelchair Propulsion Test (WPT) to calculate speed (m/s), push frequency (cycles/s) and push effectiveness (m/cycle). We also recorded the participants' perceived difficulty (0-4) and video-recorded each trial.
Results: WST capacity scores were reduced at the higher seat heights. Using repeated-measures models (adjusted for age and sex), there were negative relationships between seat height and speed ($p < 0.0001$) and push effectiveness ($p < 0.0001$). Lowering the seat height by 5.08 cm from "neutral" corresponded to improvements in speed of 0.20 m/s and in push effectiveness of 0.20 m/cycle. The trend for push frequency was also significant ($p = 0.003$) but the effect size was smaller. Perceived difficulty increased with seat height ($p < 0.001$). The video-recordings provided qualitative kinematic data regarding the seated "gait cycles".
Conclusions: During manual-wheelchair foot propulsion forward on smooth level surfaces, lowering the seat height increases speed and push effectiveness, and decreases perceived difficulty.

INTRODUCTION

For people who use wheelchairs for mobility, seat height can affect the biomechanics of two-hand propulsion (e.g. by people with paraplegia), a subject that has been extensively studied.[1-8] Manual wheelchairs can also be self-propelled with one or both feet. For instance, many people with hemiplegia propel themselves using their sound-side arms and legs ("hemiplegic-pattern propulsion") [9-11] and many frail elderly people or those with central-cord syndrome propel their wheelchairs with both feet.[12]

There has been research done on some aspects of foot propulsion, including foot-ground contact and kinetic analysis.[10, 11, 13-17] People using foot propulsion are often prescribed wheelchairs with a reduced seat height to ensure adequate foot contact with the ground.[18] If the seat is not lowered, the wheelchair user needs to shift his/her buttocks forward on the seat to reach the ground;[18] this alters sitting posture and can contribute to pressure injuries.

Unfortunately, however, there is limited published research data [19,20] that can be used to guide the optimization of seat height for wheelchair users who use foot propulsion. Murata et al. [19] used a motion-capture system to study 7 able-bodied participants using two-leg propulsion with seat heights ranging from 6.0 cm above to 6.0 cm below lower-leg length. They found a significant increase in speed as the seat height was lowered but no significant effect on push frequency (cadence). Wong et al. [20] reported on 10 wheelchair users who used hemiplegic propulsion in regular and lowered seat-height conditions while negotiating an obstacle course. When using the lowered seat height, their participants were faster, more accurate and more comfortable. Unfortunately, this study was only published in abstract form and details are not available. Given the limited number of research studies on seat height and foot propulsion, and the limited sample sizes in these studies, we perceived the need for a study to corroborate and extend the findings of these two earlier studies.

The primary objectives of this study were to test the hypotheses that, during manual-wheelchair foot propulsion forward on smooth level surfaces, lowering the seat height increases speed, push frequency and push effectiveness, and decreases perceived difficulty. Our secondary objective was to quantify the extent of these effects.

METHODS

In a repeated-measures crossover study, 50 able-bodied participants used one foot to propel a manual wheelchair 10 m on a smooth level surface at 5 seat heights, in random order, ranging from 5.08 cm below to about 5.08 cm above lower-leg length ("neutral"). We recorded Wheelchair Skills Test (WST) capacity scores and used the Wheelchair Propulsion Test (WPT) to calculate speed (m/s), push frequency (cycles/s) and push effectiveness (m/cycle). We also recorded the participants' perceived difficulty (0-4) and video-recorded each trial.

RESULTS

WST capacity scores were reduced at the higher seat heights. Using repeated-measures models (adjusted for age and sex), there were negative relationships between seat height and speed ($p < 0.0001$) and push effectiveness ($p < 0.0001$). Lowering the seat height by 5.08 cm from "neutral" corresponded to improvements in speed of 0.20 m/s and in push effectiveness of 0.20 m/cycle. The trend for push frequency was also significant ($p = 0.003$) but the effect size was smaller. Perceived difficulty increased with seat height ($p < 0.001$). The video-recordings provided qualitative kinematic data regarding the seated "gait cycles".

CONCLUSIONS

During manual-wheelchair foot propulsion forward on smooth level surfaces, lowering the seat height increases speed and push effectiveness, and decreases perceived difficulty.

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