ISB2011 Brussels

SHOULDER LOAD IN HANDBIKE AND HANDRIM WHEELCHAIR PROPULSION

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SUMMARY

Hand rim wheelchair propulsion is a risk factor for upper extremity pain among wheelchair dependent persons. The handbike is considered to be a good alternative to hand rim wheelchair propulsion outdoors since it is physiologically more efficient and less straining. But so far, nothing is known about the load of handcycling and its possible benefit in preventing overuse injuries. The objective of this study was to determine the glenohumeral contact force and the relative muscle forces of handcycling and to compare them to wheelchair propulsion under similar conditions. Eight male subjects with a spinal cord injury underwent handbike and wheelchair tests at 25, 35, 45 and 55W. The glenohumeral contact forces and relative muscle forces were calculated with a musculoskeletal model. The results showed that mean and peak glenohumeral contact forces of handcycling are lower than during hand rim wheelchair propulsion at the same power output. For most of the shoulder muscles also mean and peak relative muscle forces were lower during handcycling. This suggests that handcycling might be a good alternative to wheelchair propulsion in order to prevent shoulder complaints.

INTRODUCTION

There is a high prevalence of upper-extremity complaints within the wheelchair user population, related to overuse due to wheelchair propulsion and ADL [1]. However, an active lifestyle is important to prevent long term health problems. Since hand rim wheelchair propulsion (WC) has been proven to be physiologically inefficient and straining [2], alternative propulsion mechanisms have been developed, such as the handbike (HB), which has been shown to be physically more efficient and less straining [3]. However, the mechanical load of handcycling is expected to be lower due to the larger active muscle mass which is used almost over the complete cycle during hand-cycling. The mechanical load on the shoulder can be expressed as the force of the shoulder muscles and as the glenohumeral contact force. The purpose of this study was to determine the mean and peak relative muscle forces and glenohumeral contact forces of handbike propulsion at different power output levels in comparison to the load of wheelchair propulsion under similar conditions. It is hypothesized that handcycling is mechanically less straining than hand rim wheelchair propulsion.

METHODS

Eight male subjects with chronic paraplegia and experience in WC and HB propulsion participated in this study after having given written informed consent. Subjects' characteristics (mean ± SD): age 38 ± 7 years, height 1.80 ± 0.07 m and body mass 77 ± 9 kg. Lesion level ranged between Th2 and L4. Subjects were asked to propel the WC at 1.1m/s and the HB at 1.7m/s on a level treadmill at different power output levels (3.5 min each). Power output was 25, 35, 45 and 55W respectively, regulated by a pulley system. Kinetic and kinematic data were measured during the last 30 seconds of each exercise bout. Propulsion forces were obtained by a SmartWheel (Three Rivers, USA) and an attach-unit handbike with an instrumented handle bar with a 6 DOF force transducer (AMTI, USA). Kinematics were recorded with 6 infra-red-cameras (Oqus, Sweden). Five unique clusters of reflective markers (4 markers each) were attached to the subject's hand, forearm, upper arm, acromion and thorax. These clusters were related to the anatomical landmarks and the local coordinate systems [4].

The Delft Shoulder and Elbow model (DSEM) was used to calculate the shoulder load [5]. Input data to the model were the 3D forces, moments and kinematics of five regular consecutive propulsion cycles for each condition (HB: 5 revolutions, WC: 5 push and recovery phases). The load was expressed as the relative muscle forces of the most active shoulder muscles, as well as the glenohumeral contact force (GH force), which is the sum of the external forces and the muscle forces around the glenohumeral joint. Muscle forces were calculated on the basis of a minimum stress cost function and the maximum muscle forces were based on a force of 100N/cm2 of the physiologic cross-sectional area and obtained from Veeger et al. [6].

A linear mixed model was used to analyze the influence of the propulsion device on the GH force and relative muscle forces. The fixed effect factors were device (handbike, wheelchair). To account for the variances in the achieved power outputs at the exercise levels, measured power output was included as a covariate (random effect). Level of significance was $p < 0.05$.

RESULTS AND DISCUSSION

The mean and peak GH forces over the whole propulsion cycle were lower for handcycling compared to wheelchair propulsion over all exercise levels (Figure 1).

The mean values might have been lower due to the difference in the external applied force, which was lower during handcycling because of the gearing system and the higher velocity. Further, an additional force might be generated during wheelchair propulsion by the shoulder muscles for stabilization of the shoulder joint during the coupling and uncoupling of the hands to the rim.

The peak GH forces for WC propulsion found in this study are similar to results from previous studies. Veeger et al. [2] reported peak GH forces of 1100 N for WC propulsion at 20W at 0.83 m/s. Peak GH forces for HB propulsion are found to be much lower. This might be due to a more continuous force application during HB propulsion. In WC propulsion, GH force is high during the push phase, which was 56% of the propulsion cycle, whereas in the recovery phase GH force is rather low. In HB propulsion the GH force is distributed more evenly since it is a circular movement where propulsion force can be applied during the whole cycle by pushing and pulling.

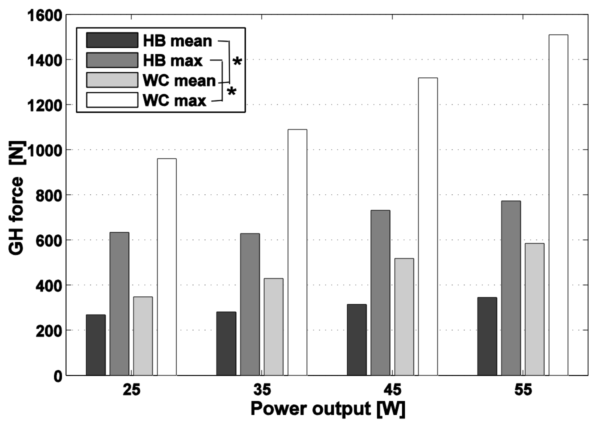

Figure 1: Mean and peak glenohumeral contact forces of wheelchair and handbike propulsion at different power output levels (N=8). *Significant difference between wheelchair and handbike at all levels, $p < 0.05$.

The mean and peak relative muscle forces were, for most of the muscles, higher during wheelchair propulsion compared to handcycling (Figure 2).

During WC propulsion, the peak values of the rotator cuff muscles, which are particularly prone to overuse in the population with a spinal cord injury [7], are more than twice as high as during handcycling. This indicates that handcycling could be beneficial in order to lower the overuse injuries to the rotator cuff.

Except for the m. deltoideus, m. triceps and m. teres major, all shoulder muscles had higher mean relative muscle forces. This again might result from the higher external force, which was exerted during wheelchair propulsion, as well as from the additional stabilization force during coupling and uncoupling of the hands to the rim. Further, some of the muscles are active during the recovery phase for swinging the arms back and this additional force does not contribute to propulsion. This could further explain why the relative muscle forces are lower during handcycling where there is no such idle period.

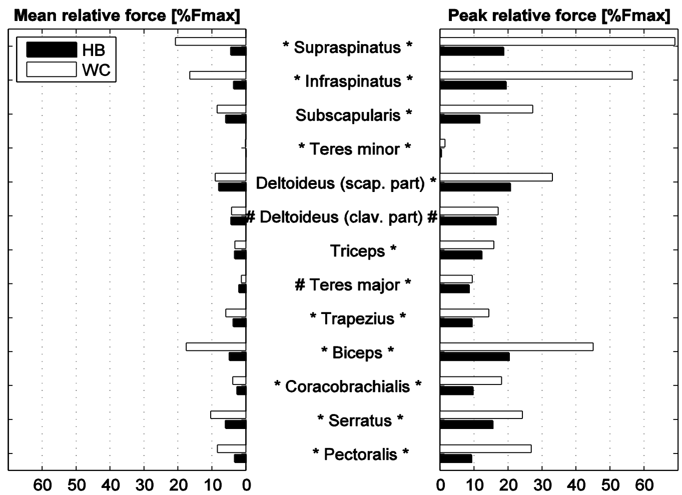

Figure 2: Mean and peak relative muscles forces at a power output of 55W (N=8). Significant difference between wheelchair and handbike over all levels ($p < 0.05$): *handbike < wheelchair #handbike > wheelchair.

CONCLUSIONS

These results showed that the handbike is not only more efficient, as shown in previous studies, but also mechanically less straining. Since GH force and relative muscle forces are considered to be good predictors of shoulder load, these results indicate that handbiking is a good alternative to wheelchair propulsion in order to prevent shoulder complaints. The handbike should therefore be used more frequently for covering longer distances.

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