SEGMENTAL CONTRIBUTIONS DURING QUADRIPLEGIC WHEELCHAIR PROPULSION IN A 1500-M EVENT

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An emerging body of literature is developing on performance related aspects of athletes who are quadriplegic as a result of a spinal cord injury. Individuals with quadriplegic involvement are those who have some degree of paralysis in all four limbs, and whose injury occurred in the area of the cervical vertebra. The amount of remaining innervation varies as is reflected in the anatomical classification system used by the National Wheelchair Athletic Association.

Athletes who are quadriplegic are classified as Class IA, IB, and IC. Class IA athletes have involvement of both hands, weakness of triceps, and severe weakness of the trunk and lower extremities which interferes significantly with trunk balance and the ability to walk. The injury has occurred around C5. Class IB athletes have sustained an injury around C6 or C7, have less involvement of the upper extremities than Class IA athletes, have normal or good triceps and a generalized weakness of the trunk and lower extremities. Class IC athletes have been injured around C7 or C8, have involvement of the upper extremities, have normal or good triceps, normal or good finger flexion and extension, but lack intrinsic hand function, and have generalized weakness of the trunk and lower extremities (Sherrill, 1986).

Reported studies on athletes with quadriplegic involvement in the areas of physiology, stroke technique, and analysis of performance times confirm that several parameters for quadriplegics differ from those reported for paraplegics. Differences have been reported between paraplegics and quadriplegics in the areas of cardiovascular and cardiorespiratory efficiency, muscular strength and endurance, anaerobic power, and training responses (Wells & Hooker, 1990). Longer stroke time, similar ratio of propulsion/recovery as a percentage of total stroke, lower stroke frequency, lower velocity per cycle, and less handrim contact range of motion were observed for quadriplegic subjects compared to athletes with paraplegic involvement propelling a racing chair on a roller system (Gehlsen, Davis, & Bahamonde. 1990). Many of these findings were similar to those reported by Ridgeway, Wilkerson, and Pope (1989) in a field based study on propulsion patterns in a 100-m sprint during competition, indicating that the velocities of quadriplegics were lower than paraplegics over all distances, and that Class IA athletes differed from Class IB and IC athletes (Coutts & Schutz, 1988; Higgs, Babstock, Buck, Parsons. & Brewer, 1990).

Two strokes are typically used by athletes with quadriplegia and are described by Adams and McCubbin (1991). The traditional stroke uses palm pressure to apply force to the rim of the wheel using shoulder depression. For this technique to be effective, strong wrist flexors are needed to bring the hands in toward the wheel. The second stroke that is used by many athletes with quadriplegia is the backhand technique, which does not require strong wrist flexors or gripping ability. Typically in this stroke, the athlete will wear a glove which is covered with a thick rubber pad on the back. It is the back of the hand that is actually in contact with the rim of the wheel, usually from just behind the top of the wheel and down the front of the wheel to near the bottom of the rim. Alexander first described the technique and muscle involvement in the literature in 1985 and 1987. Theuerkauf (1987) described the backhand technique from a coaching perspective and emphasized the gains in speed that have been possible as a result of athletes learning and perfecting its use.

From the information described in reviewing the existing literature, it can be seen that there are a number of differences in wheelchair performance characteristics of athletes with quadriplegic involvement, including physiological responses, performance times, and stroke characteristics. In order to further understand the unique aspects of quadriplegic stroke propulsion, it was the intent of the study to investigate the contributions of the upper extremity segments in relationship to overall stroke performance during a competitive situation. No literature has been found investigating the sequence of velocity patterns used by athletes with quadriplegia. Therefore, the purpose of the study was to examine the segmental velocity patterns of propulsion used by experienced wheelchair athletes with quadriplegic involvement. Research questions included: (a) did an identifiable pattern of increasing velocity exist in the upper extremities in wheelchair propulsion, (b) was there a pattern identified with faster wheelchair velocity, or did athletes with better performance times display patterns different from those with slower times, and (c) if patterns existed, how were they similar or different from reported patterns for paraplegic athletes?

METHODOLOGY

Data were collected during competition at a regional track and field meet. The four subjects included 2 males (IB, IC) and 2 females (IA, IB) who had spinal cord injuries resulting in quadriplegic involvement. Data were collected using a Panasonic high speed shuttered video camera with 1/1000 shutter factor operating at 30 fps. The camera was on a tripod in a position to obtain the left sagittal view of the racers during each lap of the race.

Variables included wheelchair velocity, absolute segmental velocities of the upper body (upper arm, forearm, and trunk) during propulsion and recovery, and the path of the hand during the stroke cycle, including position of when the hand went on and off the rim. For discussion purposes, the propulsion cycle was considered to be when the hand was in contact with the push rim, and the recovery cycle was when the hand was off the push rim.

Video recordings as subjects moved right to left were viewed using a Panasonic video camera recorder interfaced to an 80286 computer. A Freeze Frame card was used as the video frame grabber. The Kansas State University Film Analysis System (Noble, Zollman, & Yu, 1988) was used for data reduction and analysis. Data were smoothed using a second order recursive Butterworth digital filter set proportionally to sampling rate.

RESULTS AND DISCUSSION

Selected graphs of the upper arm and forearm segmental angular velocities and corresponding graphs of the resulting wheelchair velocities are presented in Figures 1-4. In examining the graphs, specific points of interest include:

1. When did peak forearm velocity occur in relation to peak upper am velocity. and also in relation to peak wheelchair velocity?
2. How did the magnitude of the slope of the line away from the zero baseline compare during flexion and extension movements?
3. How similar were the graphs from one lap to the next?

For the first lap of Subject 1 (see Figure 1), who was a Class IC male athlete who used the traditional propulsion style, peak forearm velocity occurred immediately after hand off at the beginning of the recovery phase. Peak upper arm velocity occurred during the middle of the propulsive phase. Wheelchair velocity continually increased through hand contact and peaked at hand off. A very similar pattern was seen during the third lap. Peak forearm velocity occurred just right after hand contact, and again, peak upper arm velocity occurred during the middle of the propulsive phase. Wheelchair velocity followed the same pattern, continually increasing, and peaking at hand off. The magnitude of the curves, however, was not as large as in the first lap, nor was the velocity of the wheelchair as high. During the last lap of the race, a somewhat similar pattern was seen, but with some differences in the magnitude of the slopes of the curves. Forearm velocity was somewhat higher in this lap toward the end of the propulsive phase, rather than in the beginning, and the magnitude of the slope more closely resembled that of the first lap.

Subject 2 (see Figure 2) was an international Class IB female competitor who used the backhand technique. Peak forearm velocity occurred just prior to hand contact, while peak upper arm velocity occurred during the propulsive phase. Wheelchair velocity gradually increased and then leveled off during the propulsive phase, and then slightly increased and peaked during the recovery phase. During her fourth lap, peak forearm velocity was achieved just prior to and at hand contact, and a similar magnitude was also seen at hand off. Peak upper am velocity occurred again during the middle to last half of the propulsive period. In both laps, the magnitude of the forearm velocity curves was similar in both directions, while that of the upper arm curve was slightly higher during

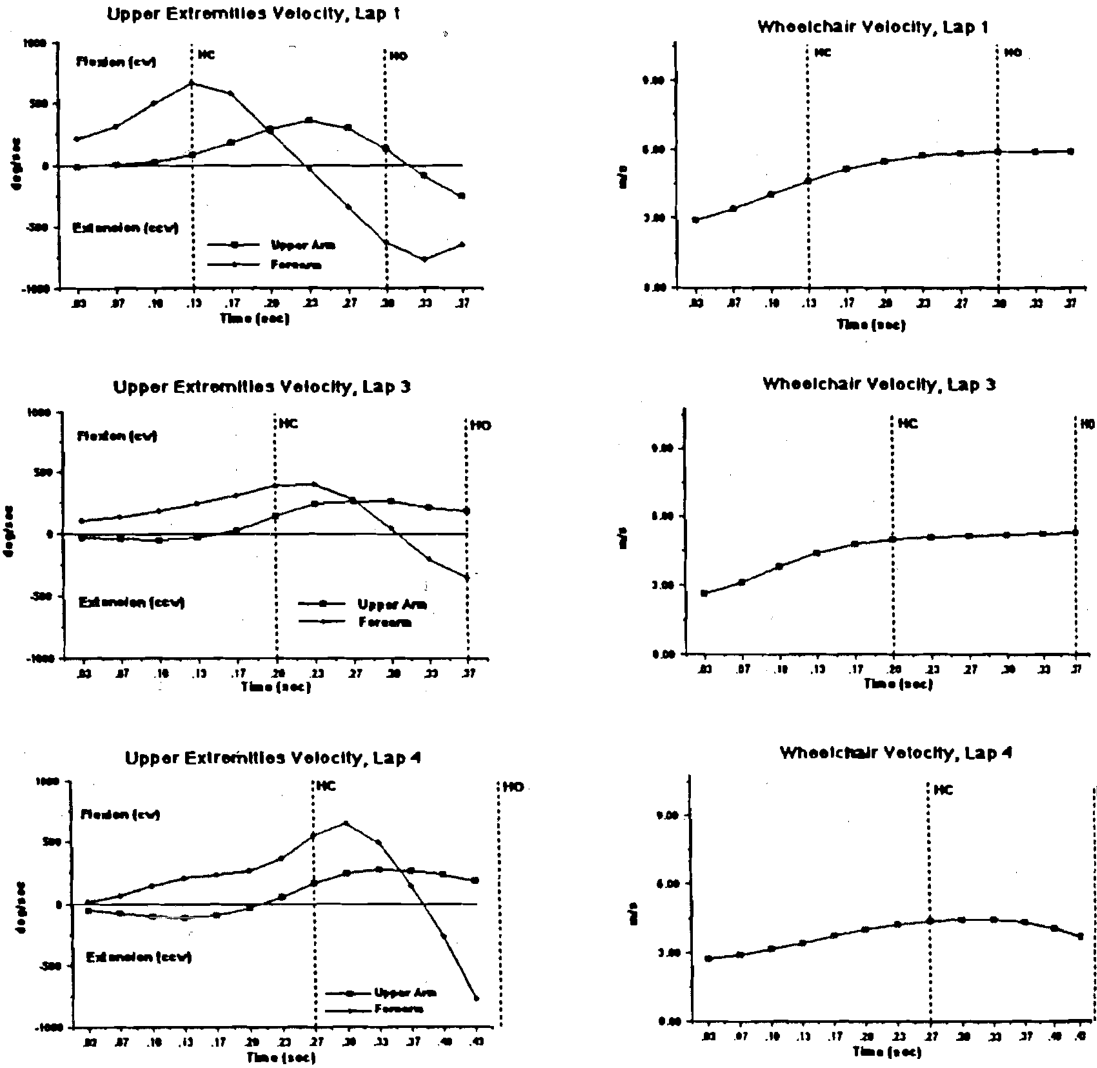

Figure 1. Subject 1: Patterns of upper arm, forearm, and wheelchair velocities during a 1500-M race. Note: HC= Hand contact and beginning of the propulsive phase; HO = Hand off and beginning of recovery phase.

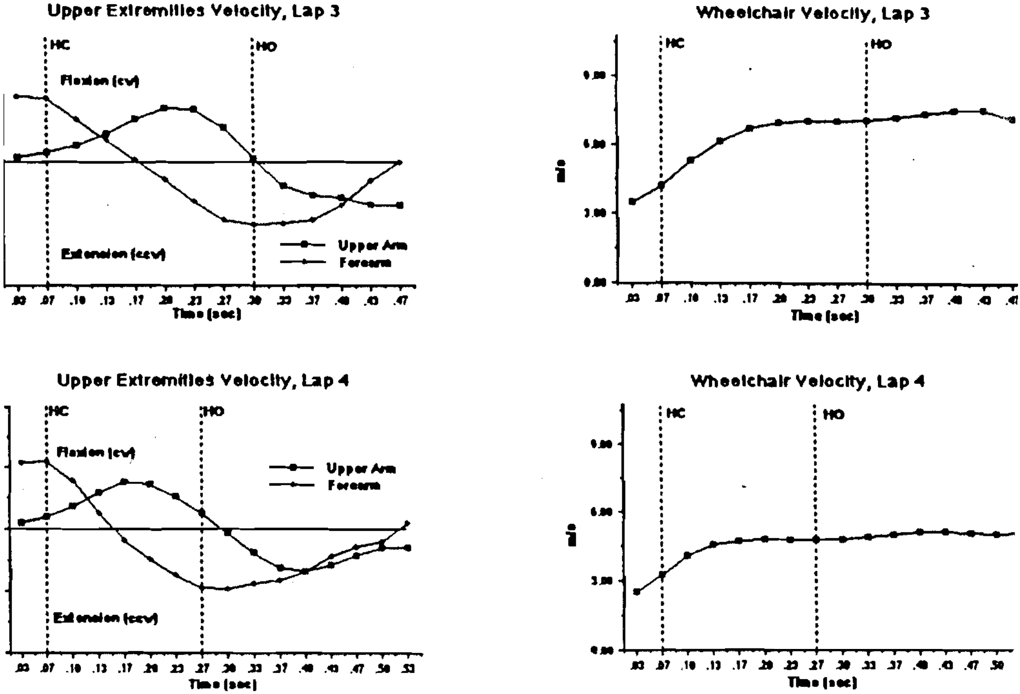

Figure 2. Subject 2: Patterns of upper arm, forearm, and wheelchair velocities during a 1500-M race.

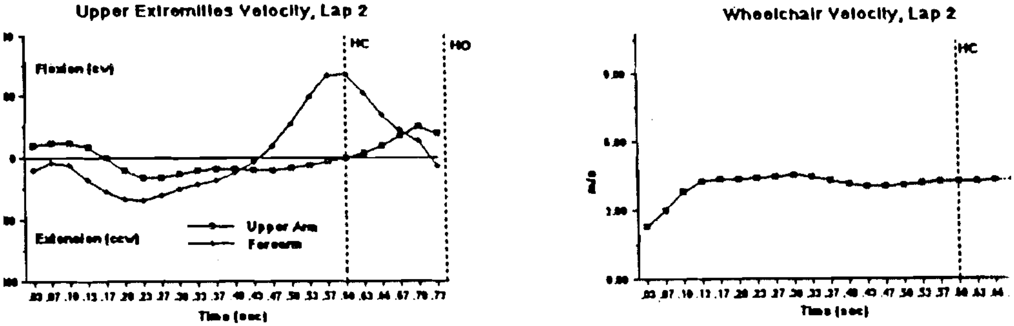

Figure 3. Subject 3: Patterns of upper arm, forearm, and wheelchair velocities during a 1500-M race.

the flexion segment. Again, wheelchair velocity followed a similar pattern as in the third lap, but was not as high.

Subject 3 (see Figure 3) was a Class IA female who is a regional competitor using the backhand technique. Unfortunately, typical of field research, e v e n t s o c c d where only her second lap was usable from the film. She had a much longer stroke cycle than subjects 1 or 2 with a long recovery period and very short propulsive period. She was considerably more limited in her shoulder movements than were the other athletes studied, so her time on the rim was shorter, from about a 12:30 position to a 9:30 position. The path of her hand over the rim was more of a shuttle pattern cutting across a diagonal diameter of the rim of the wheelchair. The IB and IC athletes circled the rim from about a 12:00 to 7:00 position, and then used elbow extension followed by shoulder extension and elbow flexion during the recovery period. Subject 3's peak forearm velocity occurred just prior to and at hand contact, and her peak upper arm velocity was during the last segment of the propulsive phase. Wheelchair velocity was fairly consistent across the stroke, dropping off slightly toward the end of the propulsive period.

Subject 4 (see Figure 4) was a Class IB male national level competitor. During his third lap, peak forearm velocity o c c d at hand off, while peak upper arm velocity occurred during the middle of the propulsive period. Wheelchair velocity continued to increase, peaking and leveling off during the propulsive period, decreasing slightly at hand off. In the fourth lap, the forearm segment was moving considerably faster than it was during the third lap, although the upper arm was moving at about the same rate. Peak forearm velocity was achieved just prior to hand contact, while upper arm velocity was achieved during the middle of the propulsive period. Peak wheelchair velocity was achieved during the end of the propulsive period, and then began to decrease.

Findings indicated that identifiable velocity patterns did exist In every instance. peak forearm velocity preceded peak upper arm velocity by approximately two to four frames. Also, the velocity of the forearm was consistently higher than that of the upper arm. Both of these findings would be expected since the forearm is the distal end of the segment. Secondly, the contribution of the forearm appeared to be more influential than the upper arm in overall stroke efficiency with the quadriplegic athletes. The magnitude of the forearm velocity curves was similar in both directions of flexion and extension, indicating that the forearm is constantly generating momentum during both propulsion and recovery. The magnitude of the upper arm curve was higher during the flexion segment, indicating that its greatest contribution is in the driving or propulsive phase of the stroke. This was different than what was observed in an earlier study with paraplegic athletes, where upper arm and forearm velocities appear to be more similar in magnitude in the graphs of an international paraplegic competitor in a similar event (Pope. & Wilkerson, 1991). Additionally, changes were observed in these patterns during different stages of the race. The magnitudes of the upper arm and forearm velocity curves were similar during the first and last lap for both subjects 1 and 2 (or in the case of subject 4 the magnitude was greater during the last lap), but the resulting wheelchair

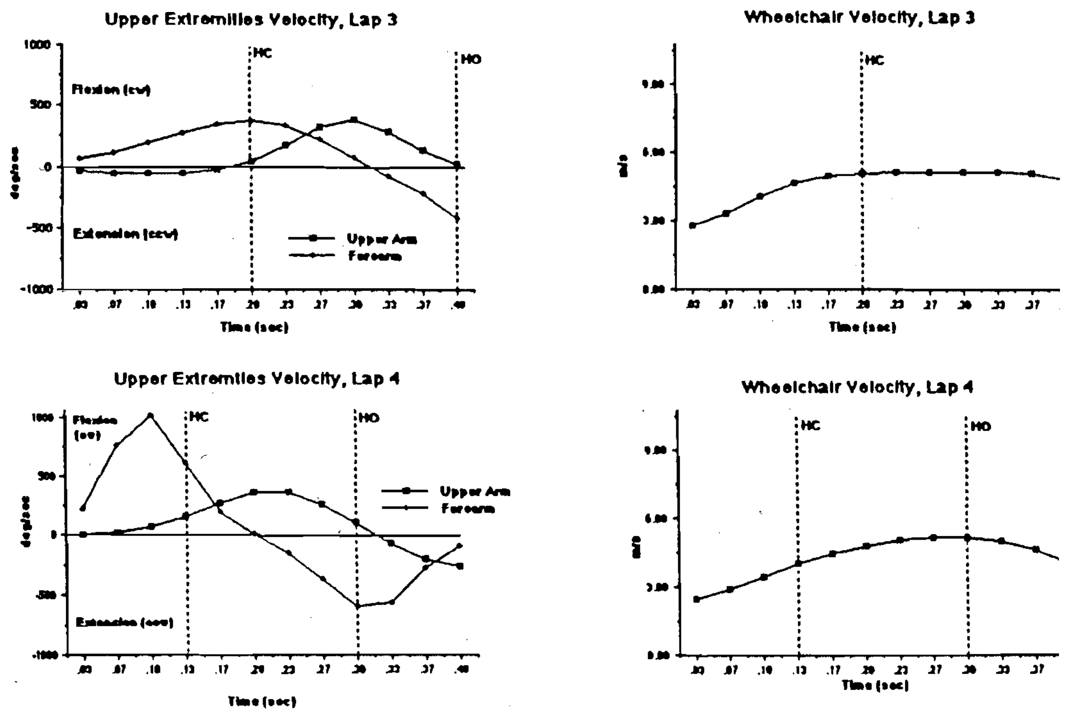

Figure 4. Subject 4: Patterns of upper arm, forearm, and wheelchair velocities during a 1500-M race.

velocity was not as high during the last lap. In other words, the segments are moving as fast, but may not be generating as much force when the hand is on the rim which would indicate that fatigue could be a factor.

CONCLUSION

In closure, identifiable velocity patterns did exist; the contribution of the forearm appeared to be more influential than the upper arm in overall stroke efficiency; and changes were observed in these patterns during different stages of the race. Further studies will be conducted using a larger subject pool in an experimental setting with high speed film where the athlete will propel the wheelchair on a set of rollers. These initial field-based findings will then be compared to the lab-based findings. It is hoped that by identifying and describing the segmental contributions of the upper extremities, coaches and athletes will be able to use this information as another tool in training and improving the performance of athletes with quadriplegic involvement.

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