ANALYSIS OF FACTORS INFLUENCING THE START PUSH IN WHEELCHAIR RACING

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The purpose of this study was (1) to identify muscle strength potentials of wheelchair racing athletes of different performance levels and (2) to identify factors which determine the successful initial push during start. Kinematic and force data were sampled for analysis. Initial acceleration was found to be dependent on the length of the propulsion path as well as on the position of the hands on the hand rim. Favourable handrim positions could be identified for the start. Hand positions preferred by the athletes produced comparable force values but highest power output compared to alternative positions given through the protocoll. The stiffness of the wrist joint prior to release contributed considerably to the acceleration of the wheelchair-athlete system.

KEY WORDS: wheelchair racing, start, wheelchair propulsion, push phase, hand position

INTRODUCTION: With only few exeptions scientific considerations of wheelchair racing have been made under physiological perspectives alone (Van der Woude, et al., 1998; Dallmeijer et al., 1998). Neuromuscular and biomechanical aspects have neither been dealt with nor have they been dealt with in realistic setups (Chow, et al., 2001). No investigations have been found that deal with the start in wheelchair racing. The purpose of the recent study was:

a.) to identify muscle strength potentials of wheelchair racing athletes of different performance levels.

b.) to identify factors which determine the successful initial push during start.

The start in wheelchair racing has the aim to accelerate the wheelchair-athlete system as strong as possible to achieve an advantage over the rest of the competitors early in the race. An optimal start performance will yield a tactically favourable position within the field of drivers and thus a good control over the race.

The mechanical demands of a successful start are:

- to overcome the moment of inertia of the wheelchair-athlete system as fast as possible
- to maintain optimum friction between the hand/glove and the hand rim
- to apply maximum propulsion forces over an optimal propulsion path in shortest time in order to maximise propulsion momentum
- to transfer muscle forces directly onto the handrim in order to minimise loss of energy
- to position the athletes' center of gravity well in front of the point of force application for optimum energy transfer and to keep the front wheel on the ground

METHODS AND PROCEDURES: Eighteen national A-, B-Level and junior athletes representing classifications T4 (n = 11), T3 (n = 5) and T2 (n = 2) took part in the investigation. The twofold purpose of the study required differentiated methods.

Startdiagnostics: The wheelchairs were positioned with once the left and once the right rearwheel on a Kistler force platform (60 cm x 120 cm) which was build level into an indoor artificial track. From their preferred start position the athletes had to perform a start push as fast and as strong as possible. The force plates registered the horizontal drive forces at a sampling frequency of 1 kHz. Two genlocked and synchronised video cameras (50 fps) filmed the start actions. Reflecting markers were attached to the head, hand, wrist, ellbow, shoulder and neck (C7) of the athletes for better identification. Selected movement parameters (see Table 1) were analysed after semiautomatic video digitising (Peak-Performance® Motus 4.3) of the marker points. The coordinates were filtered digitally through a Butterworth 4th order low pass filter to remove the noise. Joint angles were calculated from the filtered coordinate data.

Table 1 Parameterdefinitions of startdiagnostics (see also Figure 1).

parameter	definition
A_{init}	initial drive angle – angle between the line between the hand and the rear axle of the wheelchair and a vertical line through the axle at initial contact at the handrim
A_{weg}	angle distance of drive – angle between A_{init} and A_{fin}
A_{fin}	End of drive = A_{weg} + A_{init}
$\Delta v_{antrieb}$	Change of velocity during the push from start of push until release of the hand rim

Identification of potential push performance: The wheelchairs were connected to a unidirectional force transducer (Biovision®, Germany, sample frequency = 500 Hz) which was fixed with its opposite end to a wall. The athletes had to perform maximum isometric contractions with their hands in four different positions at the hand rim. From the force time history the parameters F_{max} (maximum force value), Δt (time interval from start of force production to F_{max}) and S_{ind} given as the ratio $F_{max} / \Delta t$ were identified.

RESULTS: The athletes started with the hands 42.2° (± 13.6°) in front of the vertical through the rear wheel axle. Release occurred at 125.6 (± 21.2°), the average range of propulsion was 83.4° (± 20.1°). Mean acceleration ($v_{max}/\Delta t$) reached 2.3 m/s² (± 0.73 m/s²). Respective values for the best five performers were: A_{init} = 65°, A_{fin} = 125°–185°, A_{weg} = 37°-117° and $v_{max}/\Delta t$ reached values up to 4.3 m/s². Significant differences ($p < 0.05$) in initial hand rim position between performance levels A and B + Juniors could be identified. There was a moderate correlation ($r = .46$, $p < 0.1$) between the range of propulsion and the mean acceleration (Figure 1).

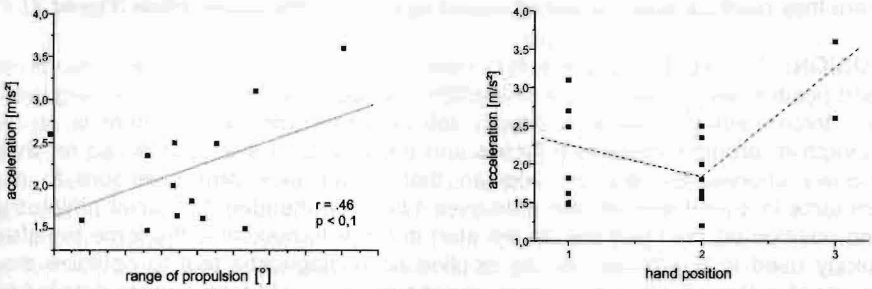

Figure 1 Acceleration vs range of propulsion graph for the start in wheelchair racing with regression line inserted (left graph) and acceleration hand position relation after grouping hand positions as 1 < 22,5°, 2 < 45° and 3 > 45° and polynomial fit over 3 points (right graph).

After grouping the initial hand rim positions into groups with hand positions below 22.5°, between 22.5° and 45° and above 45°, hand positions below 22.5° and above 45° result in higher changes of velocity compared to those between 22.5° and 45°.
In order to estimate the muscular contribution to the start action we investigated the isometric force potentials of the athletes in an experimental setup described above. The hand positions prescribed by the protocol were at app. 15°, 90° and 170° relative to the vertical through the rearwheel axle. Additionally the athletes could use their preferred hand position for the start, which always lay between 15° and 90°. In the lowest position (170°) push force was lowest, and in the first (15°) and the preferred position push forces were highest. The smallest power index was also reached in the lowest hand position. With the preferred hand position the athletes produced the highest power index. Maximum forces correlated significantly with power index values.

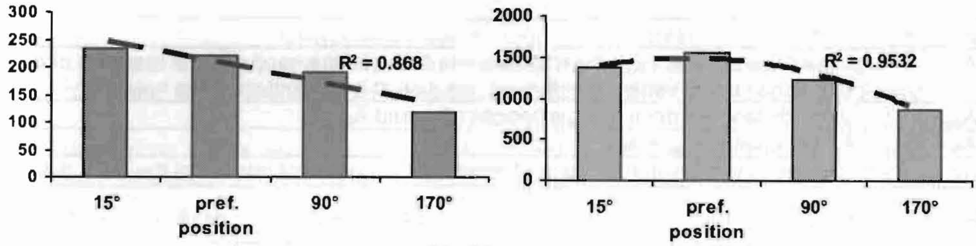

Figure 2 Force [N] vs hand position (left graph) and power index vs hand position (right graph) with regression line inserted.

DISCUSSION: There is a clear distinction between performance levels in wheelchair racing. Top level athletes are well adapted to the demands of their sport. Their propulsion technique is much more effective. Though they use a shorter range of propulsion the change of velocity they achieve is much higher. The initial hand position appears to be decisive for an effective transfer of muscle forces onto the hand rim with the hand position above 45° from the vertical through the rear wheel axle representing an advantage over smaller angles.
As the trunk positions of the athletes during start is almost identical the hand position at the same time is a measure of muscle length and the relation between force and handposition thus can be regarded as an approximation of the force vs length relation for the arm extensors. It is remarkable though that the athletes unconsciously choose a hand position for the start push where they produce superior power output as given by the power index (Figure 2).

CONCLUSION: This study identified important factors for the start in wheelchair racing. Initial hand position on the hand rim was identified as a crucial factor for producing maximum propulsion forces. Hand position is directly related to muscle length. There is an optimal muscle length to produce maximum forces and the athletes have adapted so far that they unconsciously choose a hand rim position that allows their arm extensors to develop maximum force in a minimum of time. However it is recommended that junior athletes adjust their hand position on the hand rim for the start in order to maximize the force transfer. The methodology used in this study can be applied as a diagnostic tool to optimize the start performance of individual athletes. Future investigations should take a more detailed look at the muscles involved and their individual contribution to force production.

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