Differences in wheelchair propulsion technique between trained and untrained subjects

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Preface

The XIIIth Congress on Biomechanics is an official biennial meeting of the International Society of Biomechanics (ISB) whose primary purpose is "to promote and stimulate development of all areas of biomechanics at the international level". This publication is testimony to the successfulness of that mandate. Contained herein are almost 400 two-page abstracts of original research being conducted by scientists from 30 different countries. Both the quality of that work and the diversity of topic are indicative of a very vital discipline, and one which we are honoured to be able to serve as Congress organiser and host.

In 1989 the ISB departed from its tradition of publishing its Congress Proceedings as a monograph series, preferring an immediately available prēcis of current research in the form of a Book of Abstracts. It is nevertheless our belief that this volume will make a valuable contribution to the research literature and also serve to document the progress of the field of biomechanics. We thank all those contributors whose work has made this possible, and hope that readers will be stimulated by their efforts. The strict deadline that was required for the pre-Congress printing of this volume has inevitably meant that a few abstracts contained herein were ultimately not presented at the Congress. Furthermore, the contents reflect the opinions of the contributors and not necessarily those of the Organising Committee nor the International Society of Biomechanics. Considerable effort has been devoted to the correction of obvious errors and omissions, as well as in producing a consistent presentation format, and the organisers are very indebted to the Scientific Sub-Committee and the clerical staff of the Department of Human Movement Studies for their help in this regard.

In addition to this book of abstracts a special issue of the *Journal of Biomechanics* will be published in 1992 containing the full-length communications of the keynote and young investigator award-winning presenters. The clinical biomechanics award-winning paper will be published in the *Clinical Biomechanics* journal. These publications will provide easily accessible reading of state-of-the-art discourses on biomechanics ranging from morphology to movement; athletic to abnormal; shoes to simulations. These writings too will reinforce for readers the broad perspective of biomechanics and the quality of the work of members of the International Society.

Graeme A. Wood, PhD

On behalf of the XIIIth Congress Organising Committee

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Notes

MAXIMUM PERFORMANCE OF WHEELCHAIR TRACK ATHLETES

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INTRODUCTION

Maximum performance capacity of wheelchair athletes has been determined mainly for physiological parameters (1,2). Limited data are available however, regarding biomechanical indices of performance. The study of biomechanics may help clarify the low, gross mechanical efficiency in wheelchair arm work, whereas analysis of elite wheelchair athletes renders insight in both the summit which may be attained in sports training and rehabilitation and in the propulsion technique employed.

METHODOLOGY

Performance of wheelchair track athletes in a maximum aerobic wheelchair exercise test was determined on a special purpose wheelchair simulator (3) during the 1990 World Games and Championships for the Disabled (Assen, The Netherlands). Preliminary results of the maximum performance of 23 male athletes (ISMGF/ISOD class T-4; mean+SD:age= 27yrs+5.4 and body weight=59.8kg+11.8) are presented. The athletes conducted a progressive maximum exercise test (+10W.min-1; V=1.39m.s-1; rim radius:0.26m) to exhaustion. Mean and peak values of the forces applied to the hand rims were determined for the right hand side. Net torque and power output parameters were determined for left and right sides. Parameters were sampled (65Hz) for 5 second periods during each workload and low-pass filtered. Physiological measures were taken continuously and maximum performance values were evaluated. Special attention was given to inter-individual variation and left to right differences (Students T-test; Pearson correlation; $P<0.05$).

RESULTS

A selection of data is given in Table 1. Values for mean external power output (Po(W), peak power output (Pp(W)), peak torque (Mp(Nm)) and peak forces (Fx,Fy,Fz(N)) within the push phase are presented in conjunction with maximum heart rate (HF(b.min-1)) and oxygen uptake (Vo(l.min-1)) during the final minute of the test. Po varied between 1.19 and 2.83 W.kg-1 (mean= 1.82+0.41).

Table 1. Peak Values Maximum Exercise Test (N=23)

	HF	Vo	Po	Pol	Por	Mp	Pp	V	Fx	Fy	Fz	FEF
Mean	183	2.25	105.7	51.7	54.0	86.5	384.4	1.31	123.6	17.5	188.5	69
SD	12	0.39	15.5	8.8	8.2	9.5	67.7	0.12	24.6	11.9	31.4	7
min	163	1.58	82.4	36.4	37.7	66.9	268.8	1.10	74.5	-1.9	135.7	56
max	208	3.18	141.3	68.7	72.5	107.5	500.6	1.55	172.6	39.1	262.6	80

The efficiency of torque production, defined as the mean value over the push phase of the ratio between the total force vector and the effective force (torque/rim radius), is indicated by FEF. A similar ratio for peak values within the push phase varied between 65 and 90%.

No clear relations were found with the test parameters presented here and the performance times in the track events. Mean values for left and right side (Pol,Por(W)) did show small differences which were statistically significant for the constituents of power output, the mean torque and velocity (V(m.s-1); $P<0.05$).

DISCUSSION

Performance values (Vo, Po) were, as far as comparison was possible, in line with previous data of wheelchair athletes (1,4,5). Implicit variability in functionality and unspecificity in wheeling expertise may explain part of the wide variation in performance capacity and technique parameters (i.e. FEF) as shown in this specific maximum test.

Determination of FEF in a previous study (6) showed a more or less similar mean value of 69%, however this was under submaximal conditions with a group of non-wheelchair users. Despite clear differences in wheelchair experience, the FEF values stress the less than optimal direction of the total force component during the wheelchair push. In general, the required motion of the hand and arm is complex and will influence efficiency of force production. In the current experiment the overall resistance against which subjects had to propel was chosen fairly high, since velocity of the wheels was not to be the limiting factor of performance (coordinative problems). High resistive forces do require considerable compressive forces for a sufficient amount of friction between hand and hand rim and may consequently explain the FEF range.

The limited correlation between maximum power output and cardio-respiratory parameters seems to be associated with a number of factors. Obviously, an anaerobic contribution is involved in the power production. When correlating test performance with times in racing events the mechanics and ergonomics of the wheelchair and the environmental conditions serve as unknown factors influencing track performance between subjects.

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DIFFERENCES IN WHEELCHAIR PROPULSION TECHNIQUE BETWEEN TRAINED AND UNTRAINED SUBJECTS

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INTRODUCTION

In previous studies on able-bodied subjects propulsive forces on wheelchair hand rims were found to be ineffectively directed (1). The force vector was directed too much towards the wheel axle. This apparently non-optimal force direction may have been the cause of an imperfect tuning of the wheelchair-user system. However, since subjects had little wheelchair propulsion experience, the effect might also be the result of an insufficient wheelchair technique. To determine whether this ineffective force direction was a consequence of using an able-bodied, untrained subject group or was a generally occurring effect, a comparison was made between wheelchair athletes, non-athletes and able-bodied subjects on a 30 sec. sprint test.

METHODOLOGY

28 male subjects participated. Subjects were divided in three groups: wheelchair athletes (WA, N=9), non-athlete wheelchair users (NWA, N=9) and able-bodied subjects without wheelchair propulsion experience (AB, N=10). Wheelchair users were paraplegics with a lesion level at T8 or lower. Subjects performed a 30 sec. sprint test on a stationary wheelchair ergometer (2) against a normalised resistance level of 0.50, 0.75 or 1.00 $N.kg^{-1}$. Resistance level was chosen such that peak velocity was expected to stay below 3 $m.s^{-1}$. Torque and three dimensional forces applied on the handrim (rim radius r_r=0.26m) and velocity of the wheel (r_w=.31m) were measured over the full 30 sec. period (Fs=65Hz). Ergometer data were processed for the right handrim. For determination of stroke parameters tests were recorded on video.

From ergometer data the following parameters were determined: Power averaged over 5 s periods P5, peak power output Pp, peak velocity Vp and peak torque Mp, averaged over the three strokes showing the highest peak power output within the 30 s. sampling period; effective force Fm, calculated as $M.r_r^{-1}$; Force vector Ftot; and FEF being the ratio between both force parameters averaged over the push. From video stroke parameters begin angle BA and end angle EA were determined (Figure 1). Moreover trunk angle TA at the end of the push phase was calculated as the angle of vector C7 - wheel axle with the vertical.

Determination of group differences comprised Analysis of Variance ($p < 0.05$).

RESULTS

Table 1 lists anthropometric data diagram of wheelchair and results for the three groups. The WA group was able to produce a considerably higher power output P5, mainly because they attained a higher propulsion velocity Vp (Table 1). Examples for the total and effective force curves are illustrated in Figure 2. Despite a higher propulsion velocity WA's showed a higher FEF than AB's. Stroke parameters BA and EA and trunk angle TA did not differ between both groups. The NWA group had a lower P5 than the WA group. However NWA subjects showed a considerable variation in P5 and in FEF values while stroke parameters EA and TA were different from those for WA and AB.

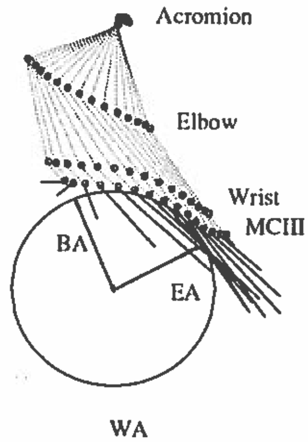

Figure 1: Stick diagram of wheelchair push.

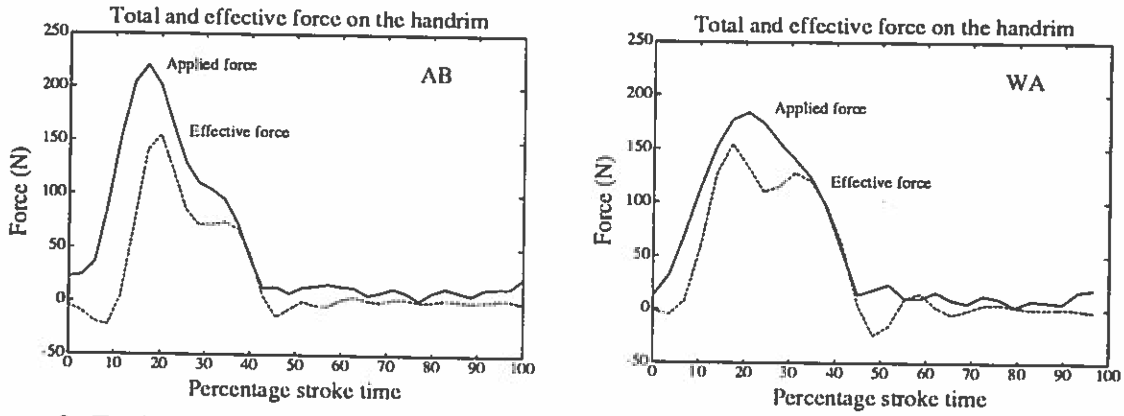

Figure 2: Typical examples of forces applied on the handrim.

DISCUSSION

For all three groups effectiveness of forces in terms of the optimal force vector direction was lower (±60%) than for submaximal values in a previous study (±70%, 1). Wheelchair athletes had a higher mean power output than both non-wheelchair athletes and able-bodied subjects. However peak power output and torque (Pp and Mp) did not differ (Table 1). FEF values for WA and AB seem to suggest that WA directed their propulsive force more effective than AB. This despite the higher propulsion velocity which is assumed to be detrimental to co-ordination. It is expected that under equal velocity conditions FEF values will differ significantly. Results for the NWA group showed a deviating stroke pattern from both AB's and WA's. The large inter-group differences in P5 and FEF may have been caused by within-group differences in training experience. It is possible that the deviating stroke parameters are related to training experience, in particular their trunk motion control.

It is concluded that WA's can produce considerably more power. They possibly direct their propulsive force better than AB's. FEF for WA is however also low. The relation between FEF and wheelchair design will be subject of further research.

TABLE 1: Anthropometric data and wheelchair ergometer results measured on the right hand rim (* $p < 0.05$).

	WA	NWA	AB	ANOVA
age (yrs)	32.0 ± 6.7	29.2 ± 12.5	23.8 ± 2.2	
weight (kg)	60.2 ± 8.0	73.2 ± 18.1	73.0 ± 4.6	
P5 (W)	69.2 ± 9.8	57.7 ± 16.2	55.9 ± 4.5	*
Mp (W)	37.4 ± 3.4	38.7 ± 9.6	40.9 ± 7.7	NS
Pp (W)	322 ± 36	289 ± 44	306 ± 52	NS
Vp ($m.s^{-1}$)	2.8 ± 0.4	2.5 ± 0.4	2.4 ± 0.2	*
Ftot (N)	100 ± 15	101 ± 18	101 ± 18	NS
FEF (%)	62.5 ± 7.3	59.7 ± 14.4	57.0 ± 4.0	NS
EA (deg)	68.0 ± 11.7	44.3 ± 6.7	64.8 ± 12.1 *	
TA (deg)	7.7 ± 9.2	-4.1 ± 3.9	8.0 ± 3.4 *	

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CENTRE OF PRESSURE PATHS FOR NORMAL SUBJECTS AND A DROP-FOOT PATIENT

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INTRODUCTION

The path of the centre of pressure beneath the plantar surface of the foot during the stance phase of gait permits an objective assessment of foot pathology. This paper presents a comparison of the centre of pressure locus between a drop-foot patient and a group of normal subjects while walking barefoot over the Musgrave Footprint pressure measuring device.

REVIEW OF RELATED LITERATURE

Lord et al. (1) elaborate on the developments in foot pressure measuring systems with a particular focus on the conditions of diabetes and rheumatoid arthritis. Grundy et al (2) illustrated the forces and centre of pressure paths in a normal subject walking barefoot and in shoes, and in a patient with hallux valgus and metatarsalgia and suggested that the function of the foot may be altered by footwear or appliances. Cavanagh (3) pointed out the need for centre of pressure averaging due to step to step variability and the loss of information which ensues from conventional averaging techniques. Motriuk and Nigg (4) later challenged this technique claiming that it did not allow for different abduction angles nor indeed did it conform to the conventional definition of average.

METHODOLOGY

Seven normal adult males and one drop-foot male participated in this study. The subjects had previously given their written informed consent. The subjects walked barefoot at a freely chosen speed along a ten metre walkway which incorporated a pair of the pressure plates of the