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Technical note—a wheelchair ergometer for assessing patients in their own wheelchairs

W. M. MOTLOCH and M. N. BREARLEY*

Center for Orthotics Design Inc, Redwood City, California
**RAAF Academy, University of Melbourne, Victoria, Australia*

Abstract
There is a need in Physical Therapy Departments of hospitals for an inexpensive ergometer which can be used to gauge the improvement in the physical performance of a wheelchair occupant in his or her own chair. This technical note describes such a device.

Introduction

In response to a request from the staff of the Physical Therapy Department of the Ralph K. Davies Rehabilitation Center in the Franklin Hospital, San Francisco, for an inexpensive ergometer for use by patients in their own wheelchairs, the authors of this article devised and made the device here described.

The requirement was for an ergometer which could be used to make a quantitative judgement of the improvement with time of the power output of each patient while operating his or her wheelchair. To prepare patients for the hilly terrain of San Francisco, the fore and aft inclination of the chair while on the ergometer was to be variable so as to simulate operation on slopes ranging from 6° upwards to 6° downwards.

Other required features were continuous read-outs during the test of the equivalent distance travelled by the wheelchair, and of the pulse rate of the patient.

The mechanical system

At the front of the ergometer is a short steep ramp (Fig. 1) up which the wheelchair must travel backwards, the aid of an attendant usually being required. The main wheels of the chair come to rest between two pairs of rollers 15 cm (6 in) in diameter, which are mounted on two parallel horizontal shafts supported on self-aligning ball bearings. The attendant locks the chair in this position by clamping the castor wheels between two restraining bars and then tightening wing nuts which hold the ends of these bars down on the ramp (Fig. 2).

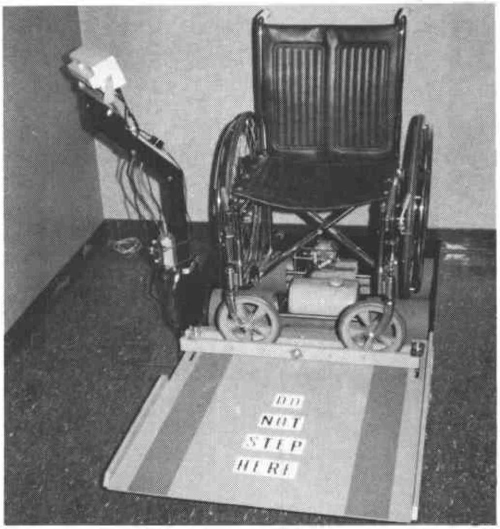

Fig. 1. Front view of the ergometer.

When the occupant of the chair pushes forward on the main wheels or their hand rims, the rollers and their supporting shafts rotate. The front shaft revolves freely in its bearings, and the rotation of the rear shaft is resisted by a closed hydraulic system consisting of a reservoir, a pump and a regulator valve. By rotating the valve, the resistance to the rotation of the rollers can be varied over a large range.

To save expense, the hydraulic system from a commercial exercise cycle was used in its entirety. The drive from the rear roller shaft to the pump is by way of a polyurethane timing belt

All correspondence to be addressed to Mr. W. M. Motloch, Center for Orthotics Design Inc, 1629 Main Street, Redwood City, California 94063, USA.

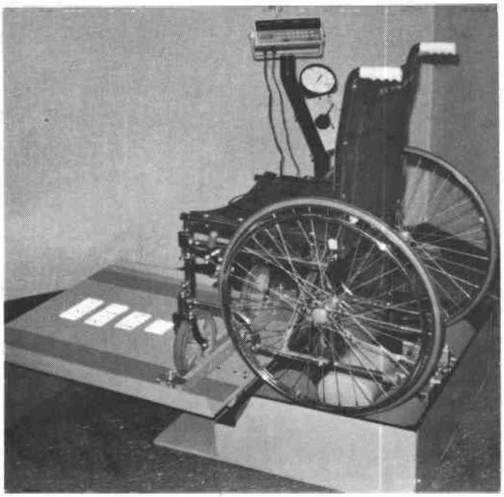

Fig. 2. Side view of the ergometer, ramp raised to horizontal position.

and aluminium sprockets. The gear ratio was chosen so that one complete revolution of the wheelchair main wheels produces the same number of revolutions of the pump axle as did one complete revolution of the bicycle pedals. This quite arbitrary choice was unimportant, as indeed was any calibration of the system, since the wheelchair ergometer is to be used only to compare the performance of each patient with his or her own performance on successive days. Likewise it was considered unnecessary to take any account of the inertia and resistance of the rollers and their axles, and of the additional tyre resistance due to indentation by the rollers.

The fore and aft inclination of the wheelchair may be varied between the limits $\pm 6°$ by altering the angle of the ramp on which the castor wheels rest. The ramp is hinged at its top edge, and a mechanical jack beneath the ramp enables the ramp to be rotated up about this edge. When the ramp is horizontal, so is the wheelchair under test. The castor wheel locking device should be released from the ramp while a change is made in the angle of the ramp. To make the ergometer more compact for storage purposes, the ramp can be raised past the vertical, where it rests against a stop, and the arm carrying the instrument display can be rotated inwards.

The equivalent distance travelled by the wheelchair during the test is determined by the rotation of a small wheel which rests on one of the supporting rollers. This device was also part of the exercise cycle equipment.

The display console

The hydraulic system includes a gauge which registers the power output of the chair occupant in the units of kilopon metres per minute. Since a kilopon is the weight of a mass of one kilogram, this power unit is a gravity-dependent one; it is approximately equal to 1/6 watt. Because of the intermittent nature of the effort applied to the wheels of a chair by the occupant, the power gauge reading also pulsates; it is easy, however, to observe the peak value of the power at each stroke, and this is a suitable measure for daily comparisons. The gauge of the regulator valve carries marks listed as '30,60,90,120,150 pedal revolutions per minute'; the pointer of the valve is turned to the number appropriate to the capacity of the patient; the smaller the number, the greater the resistance.

The instrument console gives a digital display of the equivalent distance travelled by the wheelchair, and of the pulse rate of the patient. The latter information comes via a colour-sensing light cell which is clipped to the ear lobe of the patient, and is also part of the exercise cycle equipment.

Conclusion

The wheelchair ergometer here described is very simple in concept, and because it is based on the hydraulic and electrical components of a commercial exercise cycle it is inexpensive. A final verdict on its value must wait on the results of a programme of patient testing by the hospital staff who are using it, but it appears promising enough to be reported at this stage.