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technical note*

Technological and physiological characteristics of a newly developed hand-lever drive system for wheelchairs

P. ENGEL AND K. SEELIGER

Institute of Occupational Physiology and Rehabilitation Research, School of Medicine, Phillips-University, Marburg and Department of Mechanical Engineering, University of Kassel, Federal Republic of Germany.

Investigations with hand-lever propelled wheelchairs

In the European market, hand-lever drives are usually found on outdoor wheelchairs, except for one indoor model for single arm use (ARNAS, Poirier). Outdoor wheelchairs equipped with hand-lever drives weigh about 50 percent more than standard indoor chairs that are propelled by handrims (1). The disadvantages of most hand-lever drive systems are the fixed action range of the lever movements and the absence of a free wheel. From a psychological point of view, the conspicuous movements required to propel the wheelchair with these hand-levers has discouraged many users (1).

A new lever drive has been developed at the Institut fuer Arbeitsphysiologie und Rehabilitationsforschung that has better force transmission characteristics than those with handrim drive. Comparisons of physiological performance of active wheelchair propulsion on a treadmill ergometer have shown that, despite their greater weight, the physical strain of driving a hand-lever propelled wheelchair is less than driving a wheelchair with handrims (1,4). On the other hand, the larger front wheels on lever propelled chairs result in lower rolling resistance when compared with the handrim driven wheelchairs (1).

During recent years, the lever drive concept has received further testing by other research teams (2,7, 9). While the net efficiency of driving a wheelchair with handrims is less than 10 percent (1,3), it was found to be significantly higher for the lever drive system (2,4).

New design of hand-lever drive system

A project under contract with the Federal German Ministry of Research and Technology in Bonn has developed and tested a new lever drive system for wheelchairs that has been named "Swing-Turn-gear" (8,12). This new system has fundamental advantages over present lever drive systems. For example, the drive system can be attached as an alternative drive system together with the handrim drive in one chair. The hand-levers are attached and function between the frame and the back wheels **(Figure 1).** This requires somewhat greater distance between wheels, which is compensated for through inward shiftable handrims. Testing of the prototype took place on a newly developed lightweight wheelchair (8).

The new lever drive system **(Figure 2)** is characterized by the following qualities (8):

- constant transmission via the lever angle without sinusoidal function and dead points;
- switchable neutral and reverse gear;
- gear change;
- any desired angle of actuation of the hand-lever;
- hand-lever steering which acts on the steering wheels;
- hand-lever braking which acts on the drive wheels.

With this new hand-lever drive system, the wheelchair also can be driven at higher speed by using the free wheel.

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Figure 1
Indoor and outdoor wheelchair with a hand-lever drive system and handrims, used during field driving. (Klosner, et al. 1985)

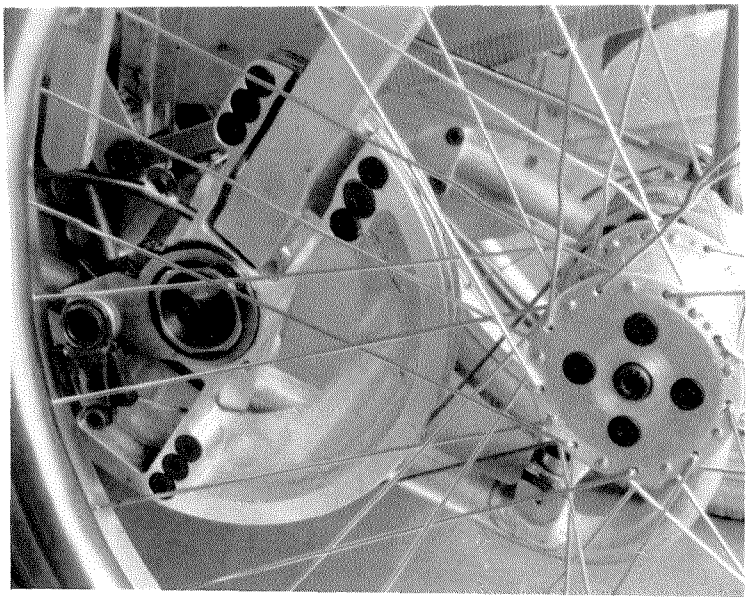

Figure 2
Newly developed Swing-Turn-gear hand-lever drive system. (Klosner, et al. 1985; Seeliger 1984)

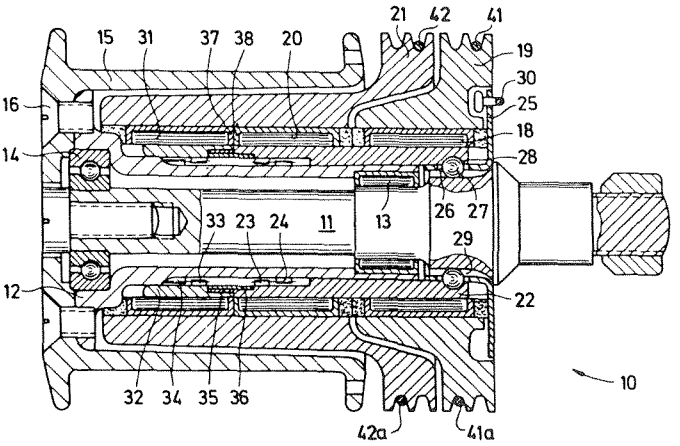

Figure 3
Cross section of the hub of the hand lever transmission unit. (Seeliger, K: Transmission Unit, US Patent application 656,923, 1985)

Figure 3 shows the hub of the wheelchair wheel, which is rigidly mounted on the hollow shaft [12]. Via spline clutches [23,24,33,34], the hollow shaft is engageable with the forward drive tube [22] or with the reverse drive tube [32] by shifting both tubes via balls [27], grooves [29] of the stub shaft [11], and the slanting slots [26] of the shift bushing [25] with the rod [30] to the gear lever. Via freewheeling devices [18,20,31], the rope pulleys [19,21] drive the tubes. The rope pulleys work in an oscillating manner driven by the hand-lever via ropes [41,41a, 42,42a]. Because two of the four ropes are crossed, they drive the forward drive tube always forward and the reverse drive tube always backward.

The basic transmission ratio results from the diameter ratio of the hand-lever pulley to the hub pulleys. The gear change takes place by telescopic elongation or shortening of the hand-lever.

Comparison of alternative use of handrims or hand-lever drive

A spiroergometric comparison of the new lever drive system with the handrim drive on the newly developed wheelchair was undertaken. Ten able-bodied persons test-propelled the wheelchair with both drive systems on a treadmill ergometer with 2-degree incline, at speeds from 2 to 5 km/h, for over 3 minutes without rest.

The results are summarized in **Figure 4.** They indicate a marked decrease in circulatory strain and energy consumption when the new lever drive system is used. The propulsion efficiency of the lever drive system can be calculated more accurately than with the handrim system. The frequency of lever motions required per minute is

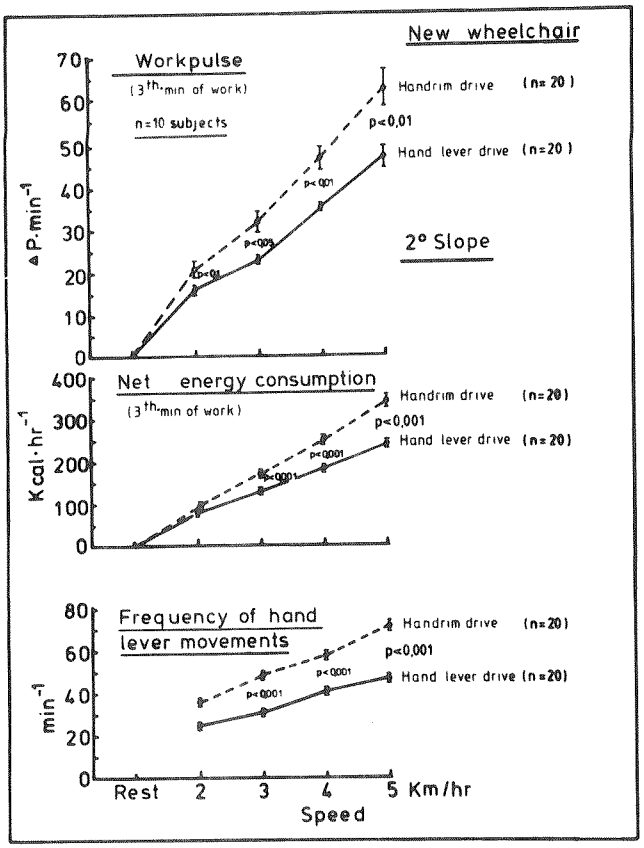

Figure 4
Comparison of the mean course of circulatory strain, energy consumption, and frequency of lever motions of 10 subjects during driving the new wheelchair on a treadmill ergometer (2-degree slope, speed 2-5 km/h) between the new hand-lever drive and handrim drive. Brackets=standard error. (Engel and Henze 1984)

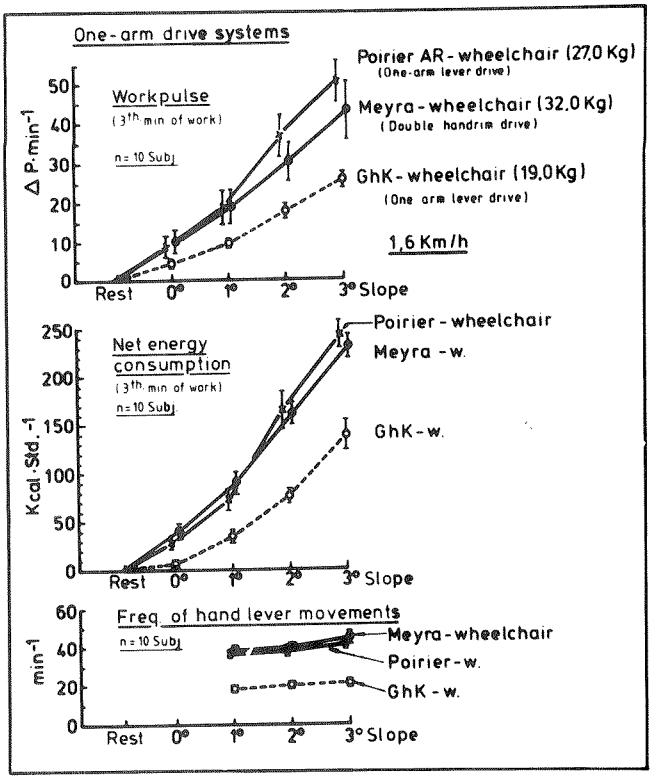

Figure 5
Mean course of circulatory strain, energy consumption, and frequency of lever motions of 10 subjects during active wheelchair driving on a treadmill ergometer (1.6 km/h, slopes from 0-3 degree) and three different wheelchairs for single arm use. The test wheelchairs are characterized by different drive systems. Brackets=standard error. (Engel and Henze 1984)

lower in a useful range than the frequency of movement required to propel handrims. In a standard indoor wheelchair the comparison of both drive systems would be clearer still because the cross section of the handrims in the test wheelchair is two and one-half times larger (9).

Comparison of hand-lever drive systems for single arm use

A further application of the new lever drive system is for one arm use. A comparative ergometric study was done using two currently marketed models: one with a hand-lever drive system (ARNAS, Poirier); the other outfitted with a double handrim (Meyra). The results during active propulsion of these wheelchairs and the new lever drive system (GhK) on the treadmill ergometer is illustrated in **Figure 5.** A higher speed than the given 1.6 km/h on an incline was possible using the new hand-lever drive, but not possible using the other two systems.

A further ergometric comparative study between the new drive system and the hand-lever drive of currently available outdoor wheelchairs is needed using the same wheelchair or on a wheelchair ergometer. However, preconditions for this test will first have to be created.

Summary

It may be concluded that, by use of the newly developed Swing-Turn-gear system, mobility of the disabled person using wheelchairs outdoors can be improved. The qualities of the drive gear in push and pull action, the free wheel, the full selection of frequency, and the range of moving the hand levers represent important progress in wheelchair engineering research. The handrim drive is an alternative, especially for indoor use. But, for the first time, an indoor wheelchair can be offered as a combination vehicle for both indoor and outdoor use.

The acceptance of the new wheelchair integrated Swing-Turn-gear is much better than the conspicuous

hand-lever drive in standard outdoor wheelchairs. At present, the German wheelchair manufacturer, MEYRA Vlotho, is preparing the new hand-lever drive system for production. Initially, the drive system will be adapted to a standard indoor wheelchair made by this company. Development of a lever drive system is also in progress in the United States (11), which employs force transmission characteristics in one direction.

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