LONG-TERM SPIROERGOMETRIC STUDIES OF PARAPLEGICS DURING THE CLINICAL PERIOD OF REHABILITATION

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A CERTAIN minimal rate of physical ability is necessary to activate paraplegics during rehabilitation. Increases in the individual activity are strictly correlated to a corresponding increase in physical fitness. Already in the early phase of the clinical treatment, physiotherapy must be undertaken in order to prevent the contracture of muscles and joints and muscle atrophy, and to provide a way of sustaining body mobility and the cardio-circulatory system in as fit a condition as possible. A very important chapter begins for the patient when he sits for the first time in a wheelchair. He is now mobile, but his field of motion is somewhat limited by his own fitness.

Our laboratory tests have shown that the physical preconditions involved in active wheelchair propelling are insofar unfavourable since the total muscle mass engaged is too small, thus leading to a faster local muscle fatigue. Furthermore, no training effect in the circulatory system can be obtained (Hildebrandt *et al.*, 1970; Engel & Hildebrandt, 1971; Bennedik & Engel, 1972).

Under these circumstances, the testing of whether, as a link during the clinical period of rehabilitation, an increase in the power of the patient's muscles and circulatory system through systematic physical training would be possible, appeared to us to be of some importance. Our opinion is that, in the future, the central and objectifying of these developments in the course of paraplegic rehabilitation through systematic long-term studies will be of even more necessity.

For this purpose, methods must either be found or further developed in order to obtain a standardised and objective test, which controls the physical capacity of the patients (cf. Engel & Hildebrandt, 1972). In our studies in paraplegics and other disabled patients, we used a special treadmill-ergometer (fig. 1) (Voigt *et al.*, 1968; Berendes, 1970; Hildebrandt *et al.*, 1970; Berendes, 1971; Engel & Hildebrandt, 1971; Kröger, 1971; Bennedik & Engel, 1972).

Over a period of more than 16 weeks' duration, 13 male paraplegics, aged between 13 years and 42 years, were tested. From the first time of wheelchair usage, measurements of heart rate and gaseous exchange were taken during active wheelchair propelling on the treadmilling-ergometer once or twice weekly. The tests were made under steady-state conditions at a speed of 2 km./hour (1.24 mph) and at different elevations, the latter increasing stepwise. Between the different runs the patients had a 3 minutes recovery period. For about 14 days previous to the tests, the patients had practiced driving their own wheelchairs on the treadmill-ergometers enabling them to adjust to the procedure. The results of 20 of the total of 252 test runs had to be interpolated as a result of temporary illnesses.

Figure 2 shows the mean course of heart rate at rest and at three different slopes of elevation. In each case, the 4th minute of work was calculated. It is evident that all four curves show a significant decrease during the 16 test-weeks.

At the higher elevations particularly, the progress in adaptation becomes more conspicuous, being much greater during the first 9 weeks of observation than during the later period. Parallel results were found by measuring the respiratory volume. It is also shown that the resting values of heart rate become smaller. This indicates that not only the muscles engaged in propulsion of the wheelchair are trained and

FIG. 1

Laboratory set up to continuously measure circulatory and respiratory effort during active wheelchair propelling on the treadmill-ergometer.

adapted, but that the whole circulatory system becomes more efficient during the test period. These results however are not exclusively produced by the wheelchair propelling (Engel & Hildebrandt *et al.*, 1971).

Figure 3 shows the average O_2 -uptake per kg. body weight (1 kg. approx. 2 lbs.) at rest and on the various slopes during the 16-week test period. Whereas the O_2 -uptake at rest did not change, the O_2 -consumption at work exhibited a significant decrease at all elevations. This means that the efficiency has been improved, partially perhaps through the additional increase of open-air driving in the wheelchair. These curves are somewhat uneven and sometimes oscillating.

FIG. 2

Fig. 2.—Mean course of heart rates of 13 paraplegic patients at rest at slopes of 0, 1 and 2 degrees during active wheelchair propelling on the treadmill-ergometer (speed: 2 km./hour). Brackets indicate the range of standard error.

Fig. 3.—Mean course of O_2 -uptake (per kg. body weight) of 13 paraplegics at rest and during active wheelchair propelling at different slopes on the treadmill-ergometer. Brackets indicate the range of standard error.

FIG. 3

FIG. 4

Fig. 4.—Mean course of O_2 -pulse of 13 paraplegics at different conditions during active wheelchair propelling, 14 weeks after first beginning wheelchair driving.

Fig. 5.—Mean course of cortisol-excretion of three paraplegics from urine samples taken during the night before the test day averaged over a month. Brackets indicate the range of standard error.

FIG. 5

Obviously, adaptation is not simply a steady process. Since the training in wheelchair driving also increases the demands on the circulatory system, the increment in physical capacity ought to be controlled by the relationship between O_2 -uptake and heart rate. This quotient indicates how much O_2 is transported in each heart beat.

Figure 4 shows the mean course of this parameter in our 13 paraplegics at rest and during wheelchair driving under the different conditions. All curves show clear ascendent tendencies, even at rest. This verifies our concept, based on the decrease of resting values of the heart rate, that physiotherapy with all its different exercise procedures is able to improve the physical fitness of the patients, not only through an increase in muscle power but also through an improvement in the efficiency of the cardio-pulmonary system.

Finally, Figure 5 shows the adaptation of hormonal activity in the average of three paraplegic patients. The diagram shows the mean cortisol excretion measured within 14 weeks. The tests were made from urine samples taken the night before the test. There is a significant increase in the rate of cortisol excretion, which also points to an improved state of physical fitness.

The curves of the O_2 -uptake per heart beat are slightly oscillating, again showing that the training processes do not proceed continuously. On the one hand, these variations are caused by temporary illnesses in the patients which lead to inactivity and to corresponding lack of physical fitness. Purgative treatment, necessary on certain days as well as other prescribed drugs, may affect the circulatory system. On the other hand, it can be derived from recent findings of spa and climatic cure treatment that adaptation itself is accompanied by certain non-specific periodic reactions in the vegetative system, so-called reactive periods, which normally recede in the course of the adaptation process (cf. Hildebrandt, 1962).

The results show that the training and adaptation process in the rehabilitation of paraplegics depends upon a great number of factors, only controlled by systematic and continuous long-term studies.

SUMMARY

In a group of 13 adult paraplegics, the circulatory and respiratory effort involved in actively driving a wheelchair on a special treadmill-ergometer once or twice weekly, was observed, from the first time the chair was used, up to the departure of the patient from the clinic (about 4 months). Measurements were taken under steady-state conditions, at different slope elevations and at a speed of 2 km./hour (1.24 mph). In three cases, it was possible to determine the urinal cortisol excretion during the night.

In general, a significant process of adaptation to wheelchair propelling could be observed in the course of 14 weeks through the decreasing of heart rate (also under resting conditions), respiratory volume and O_2 -uptake. Disturbances in this adaptional process, which occurred in some cases as a result of longer, concomitant illnesses, came to light in a temporary increase of the controlled parameters. The cortisol excretion in night urine increased with rising efficiency.

Above all, the observed training effect must be referred to the intensive physiotherapy running parallel since, according to our experience, the daily drive in the wheelchair was insufficient to train the respiratory and circulatory system.

RÉSUMÉ

Un groupe de 13 paraplégiques adultes a été étudié, en ce qui concerne les répercussions circulatoires et respiratoires, au cours d'une activité consistant à mouvoir un fauteuil roulant, sur un ergomètre spécial, une ou deux fois par semaine, ceci depuis la première fois que le fauteuil roulant a été utilisé jusqu'au moment de leur départ, environ 4 mois.

Les mesures ont été effectuées sous différentes inclinaisons et à une vitesse de deux kilomètres par heure.

Dans trois cas, il a été possible de déterminer l'excrétion du cortisol urinaire pendant la nuit.

En général, le processus d'adaptation de la manipulation du fauteuil roulant a été observé au cours des 14 semaines, par la diminution du rythme cardiaque, du volume respiratoire et de la consommation d'oxygène.

Des perturbations dans ce processus d'adaptation dues à des maladies concomitantes se sont révélées par des augmentations temporaires des paramètres contrôlés. L'excrétion du cortisol urinaire était en augmentation.

Il a été noté que la propulsion dans une chaise roulante est insuffisante pour entraîner le système respiratoire et circulatoire si l'on ne se réfère pas à rééducation intensive effectué en parallèle.

REFERENCES

- BENNEDIK, K. & ENGEL, P. (1973). Technische und physiologische Aspekte bei Benutzung handbetriebener Krankenfahrstühle. *Die Rehabilitation*, **11**, 94-108.
- BERENDES, B. (1970). Methodische Untersuchungen zur Prüfung der Leistungsfähigkeit bei körperbehinderten Rollstuhlfahrern. *Med. Inaug. Diss. Marburg/Lahn*.
- BERENDES, D. (1971). Spiroergometrische Untersuchungen an körperbehinderten Rollstuhlfahrern. *Med. Inaug. Diss. Marburg/Lahn*.
- ENGEL, P. & HILDEBRANDT, G. (1971). Zur arbeitsphysiologischen Beurteilung verschiedener handbetriebener Krankenfahrstuhlmodelle. *Z. phys. Med.* **2**, 95-102.
- ENGEL, P. & HILDEBRANDT, G. (1972). Belastbarkeitsprüfung des Kreislaufs bei Körperbehinderten. *Z. ges. Hyg.* (In press).
- HILDEBRANDT, G. (1962). Biologische Rhythmen und ihre Bedeutung für die Bäder- und Klimaheilkunde. In: W. Amelung u. A. Evers: *Handbuch der Bäder- und Klimaheilkunde*. Schattauer, Stuttgart, S. 730-785.
- HILDEBRANDT, G., VOIGT, E.-D., BAHN, D., BERENDES, B. & KRÖGER, J. (1970). Energy costs of propelling wheelchair at various speeds: cardiac response and effect on steering accuracy. *Arch. Phys. Med. u. Rehab.* **51**, 131-136.
- KRÖGER, J. (1971). Vergleichende Untersuchungen von Körper- und Kreislaufbelastung beim Fahren zweier Standard-Rollstuhlmodelle unter besonderer Berücksichtigung der Lenksicherheit. *Med. Inaug. Diss. Marburg/Lahn*.
- VOIGT, E.-D., BERENDES, B. & HILDEBRANDT, G. (1968). Energieumsatz und Kreislaufbelastung von Körperbehinderten beim Fahren im Krankenfahrstuhl. *Arbeitsmed., Sozialmed., Arbeitshyg.* **3**, 135-138.