# CLINICAL USE OF GAIT ANALYSIS WITH FOOTSWITCHES

L.-E. Larsson, P. Odenrick, B. Sandlund.

Department of Clinical Neurophysiology, University Hospital
Department of Biomedical Engineering, Linköping University,
S-581 85 Linköping, Sweden.

## SUMMARY

"Barefootgait" has been recorded in different velocities with the aid of footswitches under heel and ball. The recording gives a wealth of data which, however, can be reduced to simple diagrams describing 1/ velocity, 2/ the relation between stride frequency, and 3/ the relations between the feet and the ground during the stride.

The relations between the feet and the ground thus recorded give rise to a number of phases which are defined by the status of the switches. The changing relations between the phases inform about the distribution of the bodyweight and about the compensation of gait disturbances

## INTRODUCTION

Gait recording with footswitches gives a possibility to measure the time relations between the feet and the ground during the stride. Although the method has several obvious limitations when it comes to describing total gait it gives a lot of basal information. With suitable technique the method is fast and also simple for the patient. In addition it is easy to combine with other methods as EMG, forceplate recording, and goniometry.

We have used a variant of switchrecording for several years. We have described its application in two papers on normal children and grownups (1,2). These papers demonstrated the dependence of the measurements on velocity and also the interdependence between measurements.

In a clinical setting this interdependence expresses the compensatory functions resulting from a primary gait disturbance. It is therefore of prime importance for the understanding of pathological gait.

In the present paper we intend to illustrate and to discuss this interdependence.

## METHOD

The patient is asked to walk on a metal net of 10 meters. If not otherwise stated he uses socks with a thin plastic sole, thus simulating barefoot walking as much as possible. Electrically condustive tape is fastened under the heel and ball on each foot (Fig. 1.).

Fig. 1. Metal tape under heel and ball.

The tape is connected to the recording apparatus through a light cable following the patient via a rail in the roof. Since the results of the measurements change systematically with velocity the patient is asked to walk with five different velocities. They are what he himself considers as ordinary, very slow, slow, very fast, and fast. No other instructions are given.

In combination with the metal net the tapes under the feet make four switches, which open and close during the stride. The current combination of switches describes for each moment the relation between the feet and the ground. It is therefore possible to measure average velocity and stridelength, stridefrequency, and the different phases of the stride.

The measurement is done with the aid of a computer and a special program package. The results are described in three diagrams for 1) velocity, 2) stridefrequency vs stridelength, and 3) phase relations.

In these diagrams the results from the patient are compared to control values from individuals of the same sex and age.

During the whole recording the patient is videotaped with two TV-cameras. One of them is shooting along the walkway while the other is drawn at the side of the patient.

Control and patient groups

The present paper will exemplify the clinical use of the switch recording method. The patient examples are therefore selected from our total patient material (120 individuals) which mostly consists of patients with spasticity, orthopaedic disorders and neuromuscular diseases.

The control group covers an age range from 3-65 years and has been described in two previous papers (1,2).

Velocity

The real velocities as related to the requested for grown up patients and controls are shown in fig. 2.

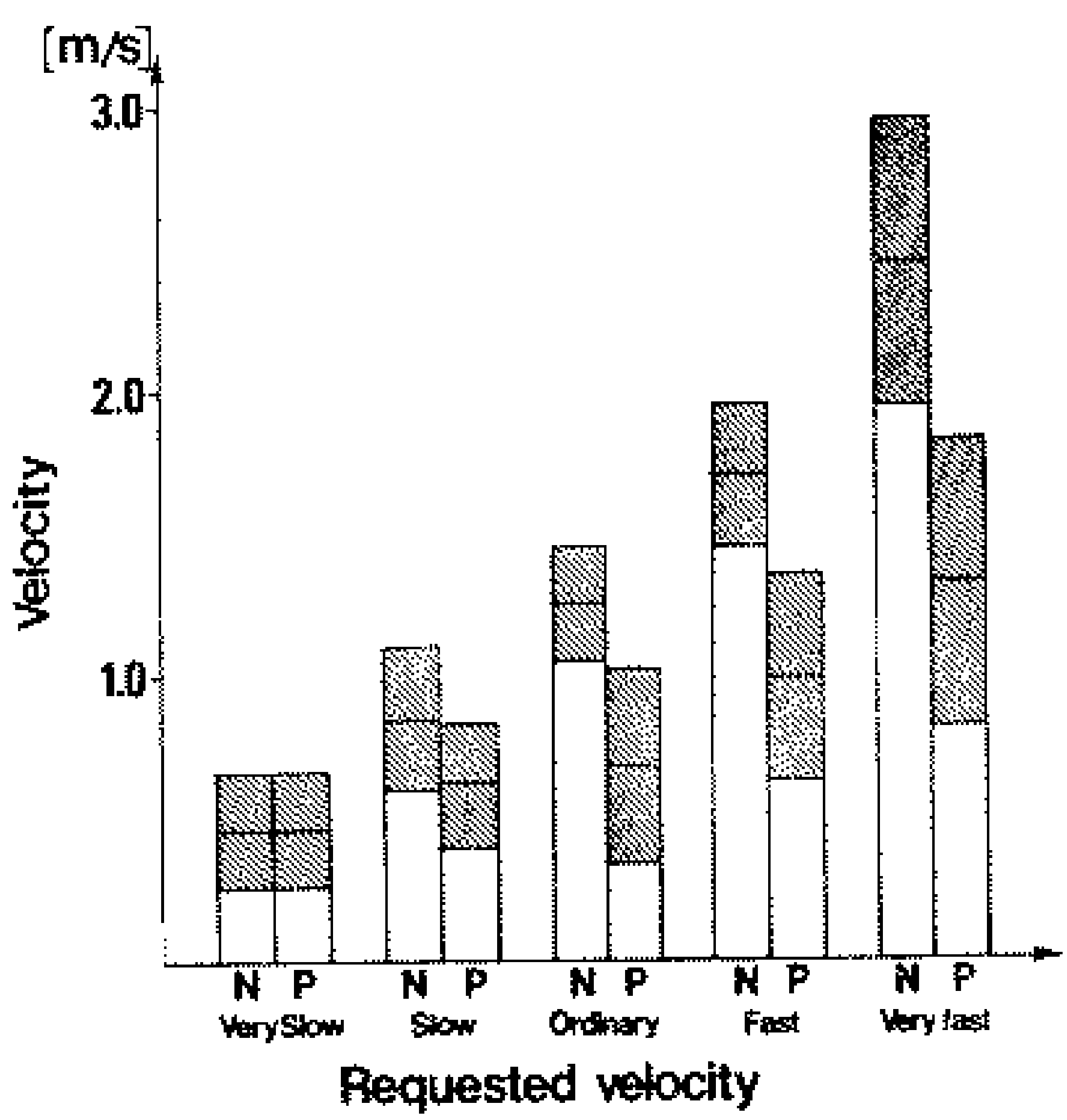



Fig. 2. Actually recorded velocities in relation to requested in grown up patients and controls. The right bars represent the patient group.

It is seen that the patients walk slower not only in their maximum velocity, but also in the lower velocitites requested. The most obvious decrease is, however, seen when the patient is asked to walk as fast as possible. With decreasing gait function the velocity range will therefore be more and more narrow until eventually only one possible velocity is left.

Stride frequency vs stride length

Velocity is the product of stride length and stride frequency. The relation between these variables will therefore tell in which way a certain velocity is reached. For most individuals it is linear within the whole velocity range (1,2). It is affected by many factors such as e.g. a slippery floor, and carrying a weight. A subject with shoes tends to walk with slightly longer and slower strides (Table I) than without.

In clinical gait analysis it is important to know that grown up women takes shorter and faster strides than men and the same applies to children in relation to grown ups (1,2).

In disease the relation between stride frequency and stride length is often changed, so that patients tend to walk with short and fast strides in comparison to controls, especially in low velocities. This is illustrated in fig. 3 for female grown up patients.

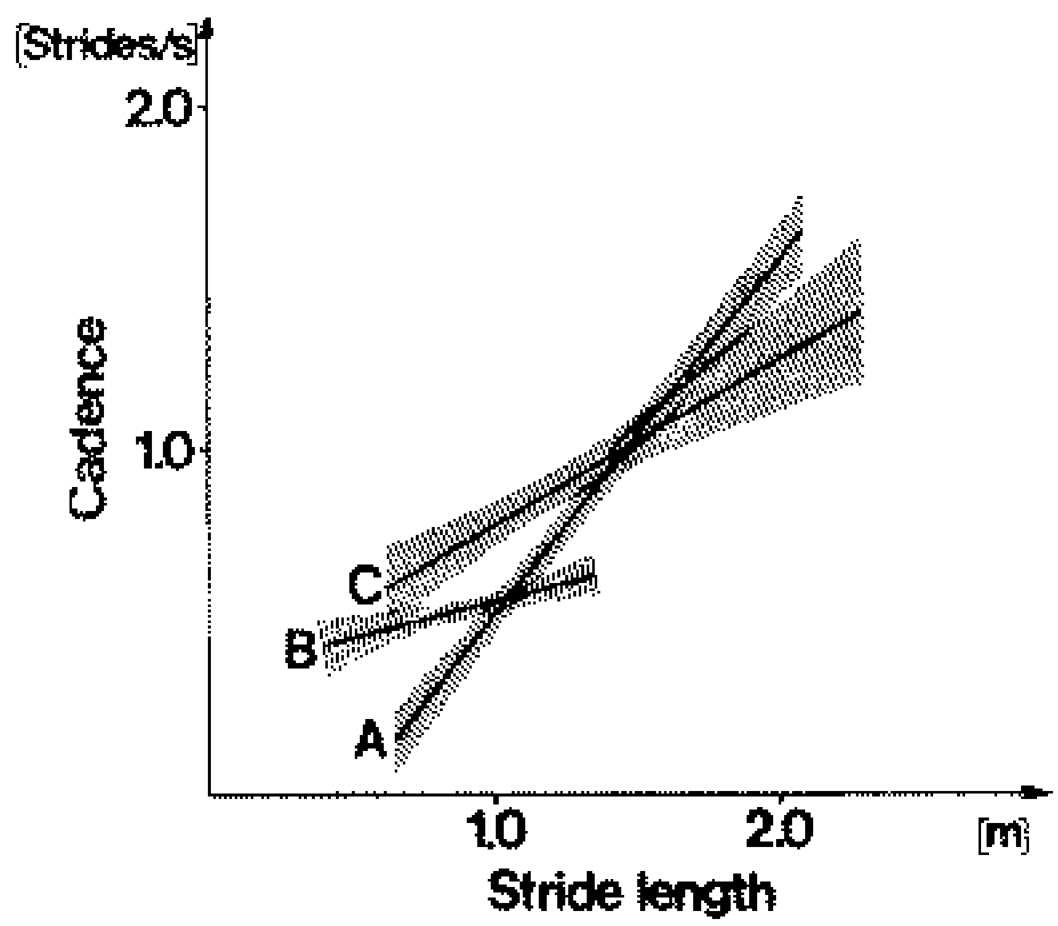



Fig. 3. The relation between stride frequency and stride length in controls (A) and in two patient groups walking with a maximum velocity higher (C), and lower (B) than 1.08 m/s respectively.

The tendency to walk with short and fast strides is so common among patients that it seems to represent a general compensatory mechanism. Short strides are clearly less risky when postural and stepping functions are at stake. To keep velocity it is then necessary to increase stride frequency.

Relations between phases

With the aid of footswitches the stride (S) can be divided in several phases, (Figs. 4 and 5), stance (ST); swing (SW); and double support (DS). Stance may be divided in the time for heel on to ball on (HOBO), the time for foot flat (FF), and the time for heel up to ball up (HUBU).

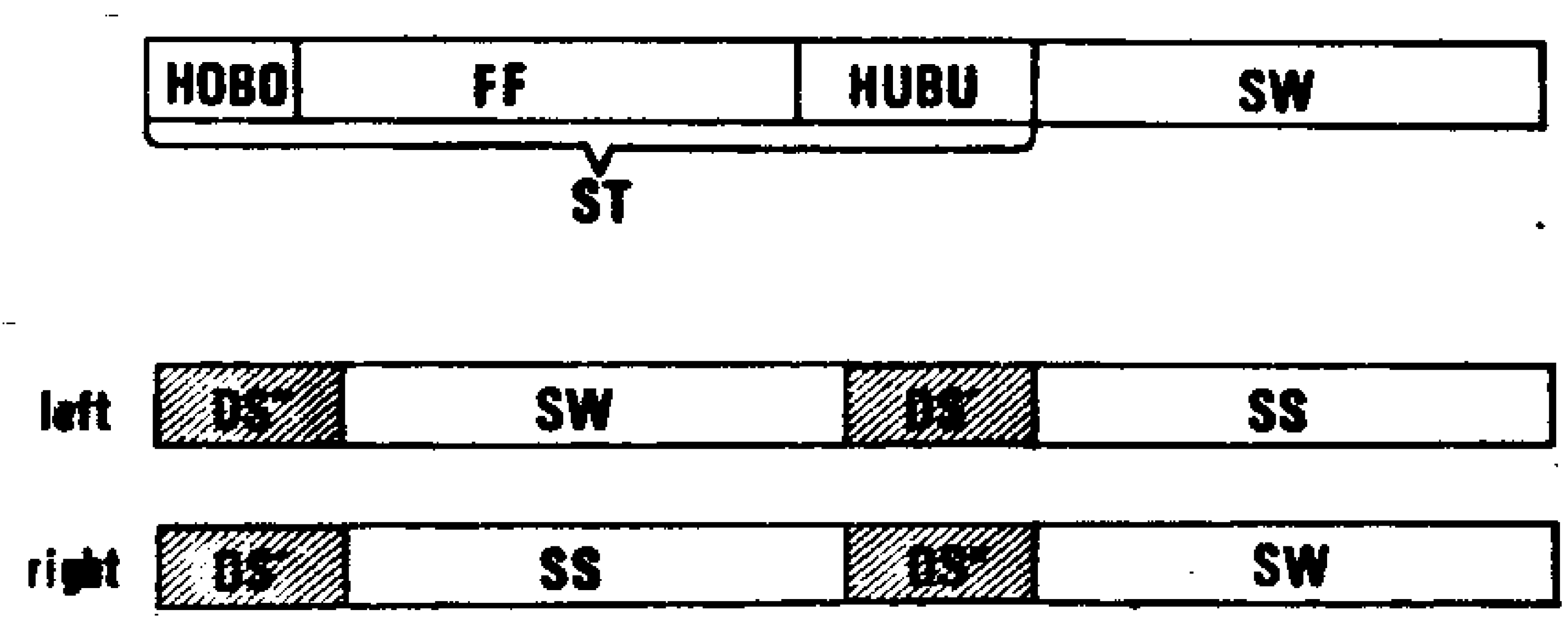



Fig. 4. The phases of the stride as defined by the status of the footswitches.

Stance (ST), Swing (SW), Double support (DS' + DS" = DS)

Heel on to ball on (HOBO)

Foot flat (FF)

Heel up to ball up (HUBU)

Single heel support (SHS)

Single ball support (SBS)

Double support foot flat (DSFF)

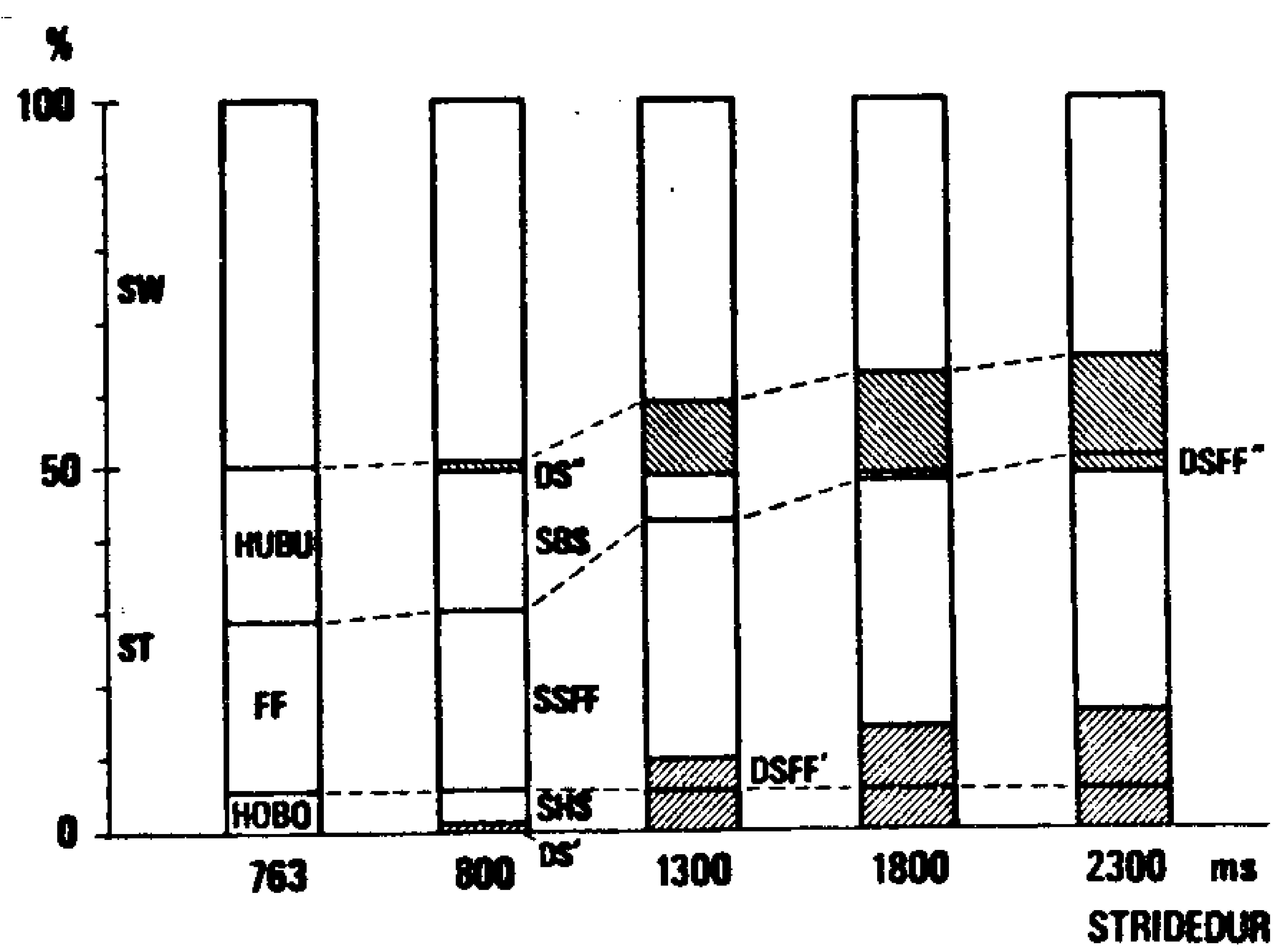



Fig. 5.
The percentage relations between the phases of the stride duration at different velocities.

$ST = HOBO + FF + HUBU$ (1)

The relation between phases will change with velocity and the equation above may then be used to describe the changing relations within stance for one leg. Stance is, however, also the sum of single support (SS), and double support (DS).

Thus

$ST = DS' + SS + DS''$ (2)

where DS' and DS" stand for those parts of double support which preceed and follow single support (Fig. 4). Since single support is the same as contralateral swing ($SW_1$) the equation (2) may also be written

$ST = DS' + SW_1 + DS''$ (3)

This equation may be used to describe the relations between two legs. When the equations (1) and (3) are considered together, it will be observed that new phases appear within stance, some of them only at certain stride durations. The changes with stride duration are illustrated in fig. 5.

In the transition from walking to running double support is zero and stance has the same duration as swing. In the control group this corresponds to an average stride duration of 763 msec (Fig. 5). With lower velocity - increasing stride duration - double support will take an increasingly large part of stance (hatched parts in fig. 5). Thus heel on to ball on (HOBO) will be divided into DS' and single heel support (SHS), i.e. the phase when one heel is the single support of the body. In the same way heel up to ball up (HUBU) will be divided into single ball support (SBS), and DS". With still more decreasing velocity first DS' and then DS" will grow longer than HOBO and HUBU respectively. They will then start to invade foot flat (FF). We call the new phases DSFF', DSFF", and SSFF (double support foot flat and single support foot flat).

It may be questioned if this detailed subdivision of the stride has any meaning. We consider it to be of descriptive value. Changes in gait are more easy to describe. In addition the transitions of the phases into each other represent changes in the contact forces against the floor, and they therefore have a functional meaning. The relation between phases are strongly influenced by pathological conditions, but also by changes in everyday gait such as using shoes instead of walking barefoot (Table I), carrying a weight, supporting oneself with a stick or leaning forward.

A change in one phase will always be compensated for in one or more of the others in accordance with the equations above. A change in one leg will for instance always tend to influence the other and it is necessary to evaluate both legs at the same time. Due to these compensatory relations the healthy leg in a onesided lesion is never healthy in functional sense, and it can never be used as a control.

Table I. Average stride variables in 6 normal subjects walking with and without shoes. The corresponding velocity was 0.87 m/s, the stride length was 1.26 m and the stride duration was 1458 msec.

| | | | Without shoes | Diff with shoes | p |
|---|---|---|---|---|---|
| Cadence | CAD | Strides/s | 0.761 | -0.073 | 0.01 |
| Stance | ST | msec | 922 | -19 | 0.01 |
| Swing | SW | msec | 532 | 18 | 0.01 |
| Double support | DS | msec | 195 | -20 | 0.05 |
| Heel on - ball on | HOBO | msec | 94 | 41 | 0.001 |
| Foot flat | FF | msec | 604 | -54 | 0.01 |
| Heel up - ball up | HUBU | msec | 224 | -6 | n.s. |

## Case examples

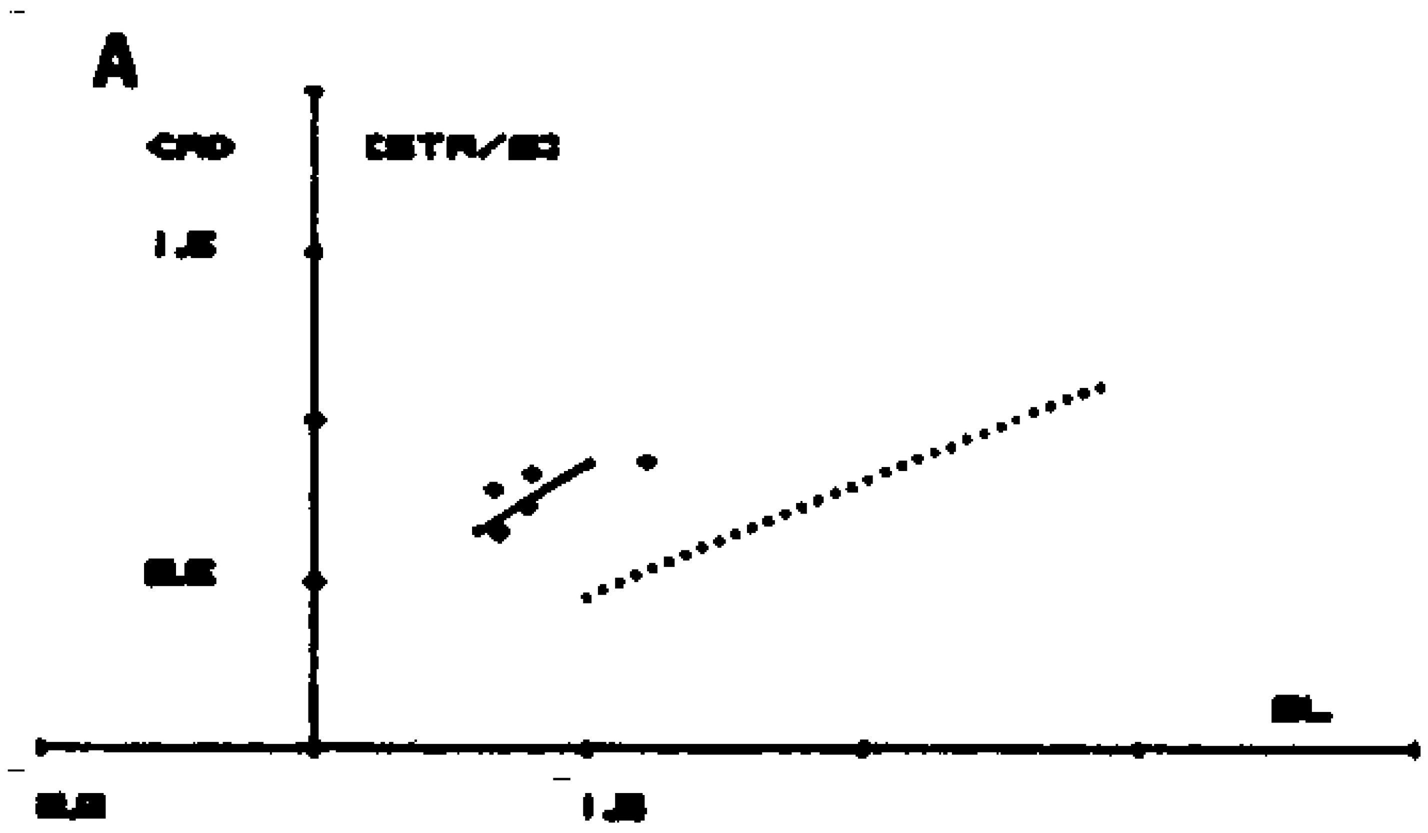
### Case 1.

A 47-year-old man with a right sided spastic hemiparesis following an accident. He walks at a very slow pace, the maximum velocity is lower than 1 m/s (fig. 6B). In all velocities he takes comparatively short strides, and he compensates for that by increasing the stride frequency (fig. 6A).

The clinical inspection shows that he walks on a broad base. During left stance the trunk moves more than usual to the left. The right leg is stiff. The knee is very little flexed, and it is slightly overstretched during deploy. There is a slight tremor in the right foot during swing, it is flat and slightly pronated when put down and it is stiff during deploy.

If we look on the phase diagram (fig. 6C) it shows obvious asymmetries between right and left. They are explained by the right hemiparesis, which makes right single support difficult, and which forces the patient to rely as much as possible on the left healthy side. Stance is therefore long and swing short on the left side. (Remember that SW is the same as contralateral SS).

The DS" to the right which is the same as DS' to the left has comparatively long duration. During these phases the weight of the body is transferred from right to left. The early start of right DS" therefore shows the patient's need to bring the weight from right to left as soon as possible. Of the other phases heel on to ball on (HOBO) is missing to the right, an expression of the patient's tendency to set this foot flat on to ground. Heel up to ball up is longer on the right than on the left. This may be due both to his increased extensor tendency and to his need to bring the body weight from right to left as soon as possible.



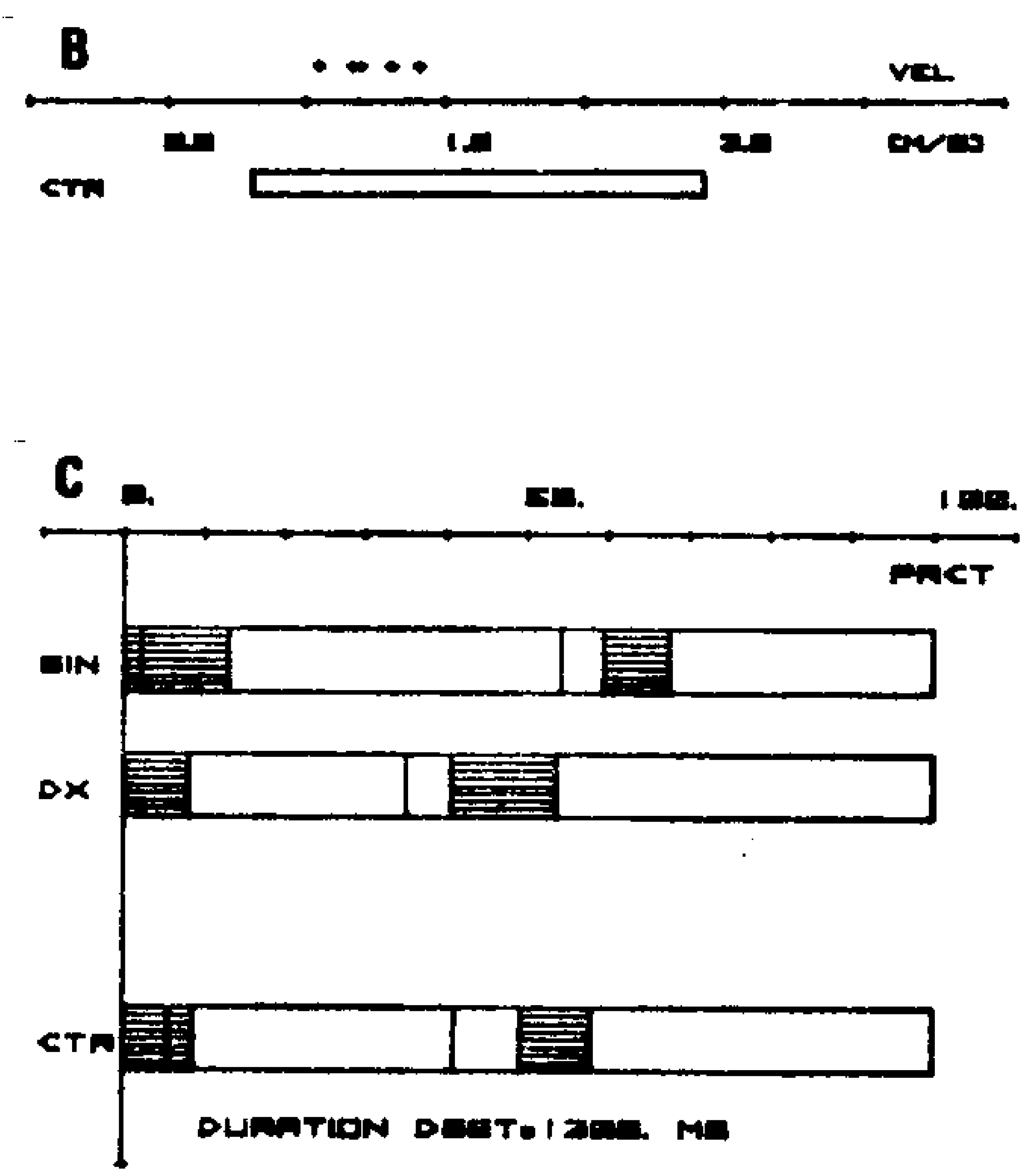




Fig. 6. Gait diagrams from a patient with spastic rightsided paresis.

A. Relation between stride frequency (CAD strides/s) and stride length (SL m/s).

B. Velocities (VEL m/s).

C. Phase diagram. For designation of phases see also figs. 4 & 5.

Case 2.

This case exemplifies how gait is influenced by shoes and by the use of bilateral peroneal stimulators.

The patient is an 11-year-old boy with a bilateral spastic paraparesis. The clinical observation showed that he walked with flexed knees and with an obvious adductor spasticity. He had a tendency to scissors gait and toe-walking.

He was equipped with bilateral peroneal stimulators. (Fig.7A-C). Fig. 7B shows that velocity is low as compared to his age group. The relation between stride frequency and stride length is ordinary, (Fig. 7A). The phase diagram (Fig. 7C) shows asymmetry of heel up to ball up (HUBU), and of single ball support (SBS), which is a part of HUBU. Heel on to ball on (HOBO) is longer than in the control group - the effect of peroneal stimulators is to dorsiflex the feet.

The stimulators were then switched off (Fig. 7E-F), and the duration of heel on to ball on now decreases on both sides (Fig. 7F). Heel up to ball up increases likewise on both sides, as well as single ball support while the asymmetry remains. This means that the feet are set down more flat and that there is an increased tendency to toe gait.

Finally when the patient walks without shoes and stimulator (Fig. 7G-H) the tendency to toe gait increases still more, i.e. the duration of heel up to ball up increases still more and especially so the single ball support. The duration of heel on to ball on is now very short on both sides.

The investigation therefore shows how the patient's tendency to walk on his toes is favourably influenced both when he wears ordinary shoes and also when he uses peroneal stimulators.

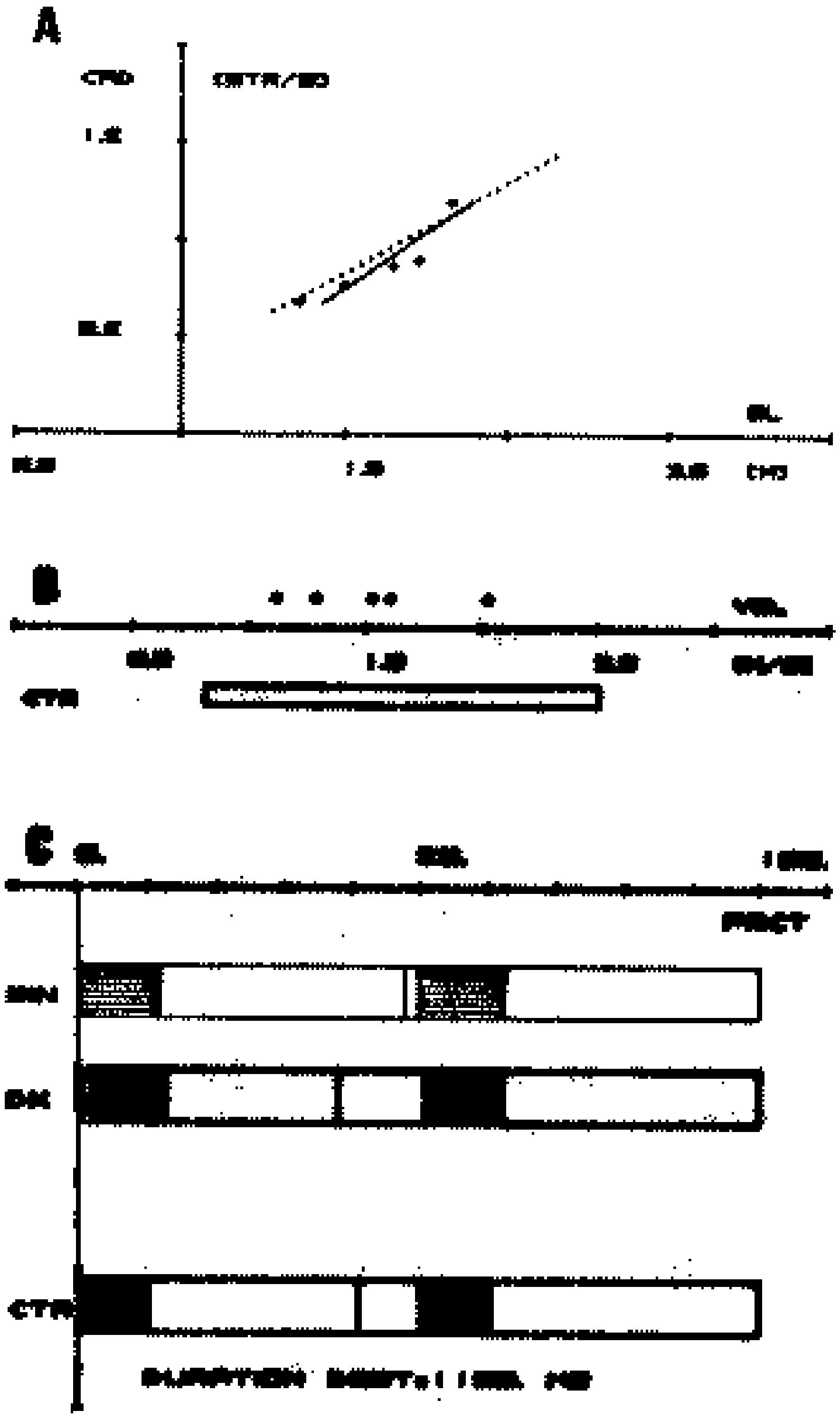


Fig. 7. Gait diagrams from a patient with bilateral spastic pareses.

ABC. With shoes and bilateral peroneal stimulators.

For fig. 7 D - I, see next page.

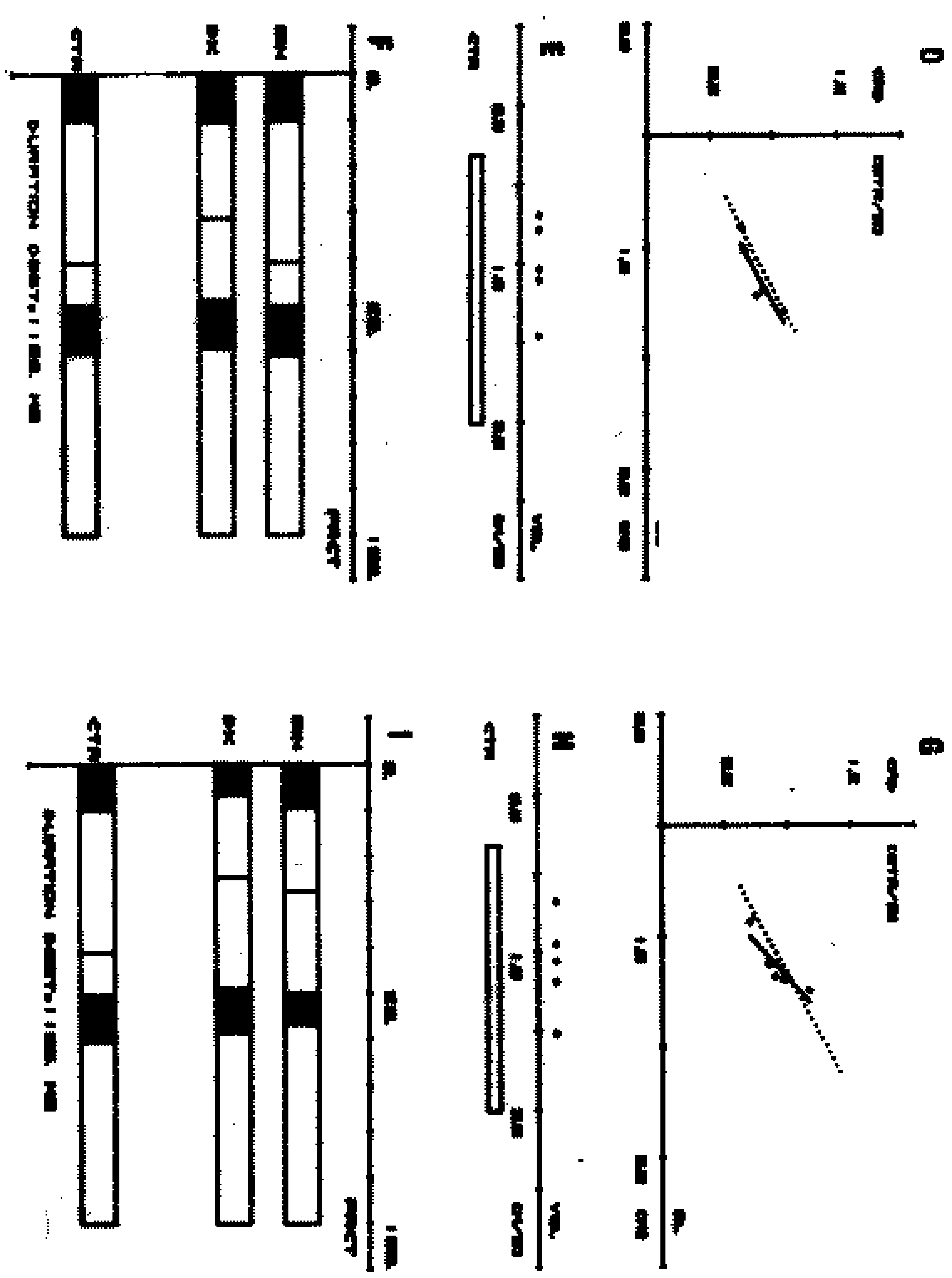


Fig. 7. DEF. With shoes.
Stimulators switched off.

GHI. Without shoes and stimulators.

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