GAIT ANALYSIS

A COMPARISON BETWEEN OBSERVATIONAL ANALYSIS AND TEMPORAL DISTANCE MEASUREMENTS.

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INTRODUCTION

If patients suffering from neurological deficits resulting from diseases such as stroke or Parkinson's disease are asked what is the most important aspect of their rehabilitation, the majority of them will reply that independent walking is their main goal. For the elderly the ability to walk independently, or with minimal assistance, to the toilet may mean the difference between being able to live at home or having to go into a care centre. For young patients the ability to be independently ambulant allows them to participate again in activities with their friends and families and often to return to work or studies[1].

As gait retraining is such an important part of rehabilitation, accurate evaluation and measurement of gait is crucial for proving the effectiveness of treatment. While many computer-based systems are now available for the collection of data related to walking patterns[2], the majority of physiotherapy departments are unable to justify the cost of such equipment and subjective evaluation is usually the main form of gait evaluation. The question arises as to how accurately we can judge improvement or the degree of impairment in our patient's gait?

With this question in mind, a study was undertaken in which six temporal distance measurements were analysed objectively from ink footprints. Observational analysis of the same six temporal distance factors was then compared to the objective data to show whether accuracy could be achieved observationally.

ABSTRACT

The purpose of this study was to compare observational analysis of gait to six temporal distance measurements in order to rate the accuracy of the observational analysis.

Ten hemiparetic and ten parkinsonian patients were asked to walk along a paper walkway with ink pads attached to their normal footwear. Measurements of velocity, cadence, step length, stride length, base width and foot angle were taken.

Ten normal subjects were also evaluated on the paper walkway to give normal values as a baseline for comparison with the hemiparetic and parkinsonian patient's measurements.

Observational analysis was recorded on a gait assessment form and a video recording was made of each patient. Comparison was made between the results recorded on the gait assessment form and the objective data.

Observational analysis was found to be fairly reliable for the assessment of some gait parameters but as no accurate data are produced it cannot be used to give scientific proof of the effectiveness of treatment.

Step length was the most difficult parameter to evaluate observationally in the hemiparetic patients, whereas cadence, foot angle and base width were the most difficult in the parkinsonian patients. As velocity was an easy value to record objectively it should be used in all gait assessments.

METHOD

Subjects

- Normal Subjects

Ten normal subjects were selected from the staff and students working at the Johannesburg Hospital. Eight female and two male subjects were selected with ages ranging from 20-74 years (mean 45.8 years). The age range of the normal subjects was matched as closely as possible to that of the hemiparetic patients.

- Hemiparatic subjects

Ten hemiparetic subjects were selected from the wards, clinics and physiotherapy department of the Johannesburg Hospital, these being the first ten patients who met the inclusion criteria. There were seven female patients and three male patients. Ages ranged from 21-73 years (mean 48.5 years).

- Parkinsonian Subjects

Ten parkinsonian patients were selected from the wards, clinics and physiotherapy department of the Johannesburg Hospital, these being the first ten patients who met the inclusion criteria and who were willing to participate in the study. There were seven female patients and three male patients. Ages ranged from 59-84 years (mean 69.3 years). All patients were taking L-Dopa in the form of Sinemet.

- Inclusion Criteria
  - To understand what was required during testing.
  - The ability to walk at least ten metres three times using any type of walking aid (except parallel bars) and requiring assistance from no more than one person.
- Testing (Data Collection)
  - Each patient was allowed to read (or had read to him) an explanation of the project and was asked if he understood what was to take place and whether he was happy to take part in the trial.
  - Ink pads were attached to the patients' shoes, red on the right and blue on the left, with a triangular pad at the toe and a square pad at the heel. Each patient was then asked to walk at his most comfortable speed along a paper walkway placed over a measured fourteen metre length of corridor leaving ink footprints from which measurements were later taken. Measurements were taken over the central ten metres, with the first two metres being allowed for acceleration and the last two metres for deceleration. Data from six temporal distance measurements were collected. The measurements started with the first heel strike over the starting marker and ended with the first heel strike over the finishing marker. The patient wore his usual footwear.
  - The patient's gait was evaluated by observational analysis recorded on a gait assessment form. Observational analysis

of the six temporal distance measurements was rated as being either less than normal, normal or more than normal. The observational analysis was considered to be accurate when these values were seen to correspond with variations from normal shown by the temporal distance measurements. Normal values were obtained from the literature and from the ten normal subjects evaluated (Table I).

* A Video recording was taken as each patient walked towards the camera. This was then kept so that future viewing could confirm the observational data recorded on the gait assessment form.
* A comparison was made of observational analysis evaluation and temporal distance measurements of the hemiparetic and parkinsonian subjects.

DATA ANALYSIS

Velocity – or speed of walking – was measured in metres per second and was calculated by dividing the ten metre data collection section by the time taken in seconds to walk along it.

Cadence – steps per minute – was calculated by counting the number of steps taken over the ten metre data collection section, dividing by the time taken in seconds to cover this section and then multiplying by 60 to bring this to steps per minute.

Step length is the distance from the initial contact of one foot to the initial contact of the successive step of the opposite foot. Right step length and left step length were measured. (Fig 1).

Stride length is the distance from initial contact of one foot to the next initial contact of the same foot. It therefore includes both stance and swing phases. (Fig 1).

Base width at heel is the width between the heel markers on each foot. Measurements were taken from the centre point of the heel squares to the edge of the walkway and the smaller distance was subtracted from the larger. Base width at toe was calculated in the same manner using the apices of the triangular pads as reference points for measurements. (Fig 2).

Foot angle – refers to the amount of toe-out or toe-in of each foot. (Fig 3).

RESULTS

Fig 4 shows that observational analysis was most accurate in the hemiparetic patients, with seven or more patients being accurately assessed for velocity (7 patients), cadence (8 patients), stride length (9 patients), foot angle (9 patients) and base width (9 patients).

Observational analysis among the parkinsonian patients showed accuracy for velocity (8 patients), step length (9 patients), and stride length (9 patients).

Tables I, II and III show the objective measurements obtained for the normal, hemiparetic and parkinsonian subjects and are referred to in the discussion.

DISCUSSION

Velocity - Normal walking velocity has been described by Robinett and Vondran[3] as being approximately 89 metres per minute (1.48 metres per second) for men and 74 metres per minute (1.23 metres per second) for women. This was confirmed by measurements from the normal subjects which ranged from 12.5 to 1.56 metres per second at comfortable walking speed (Table I). For this study a velocity of over 1 metre/sec was considered normal. Timing by stopwatch showed that all the hemiparetic patients walked at velocities of less than 1 metre per second (Table II). The velocity of seven patients was correctly evaluated observationally, whilst three were thought to show normal velocity.

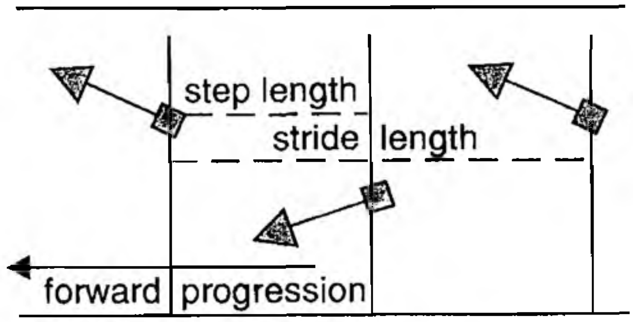

Figure 1: Step length and stride length

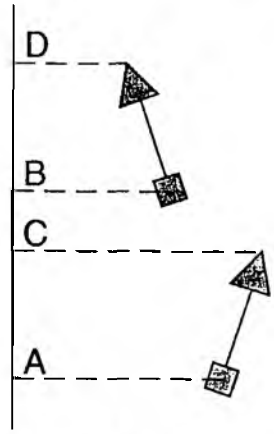

Figure 2: Base width

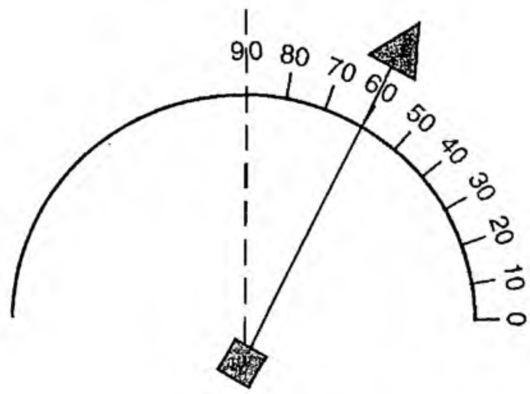

Figure 3: Foot angle

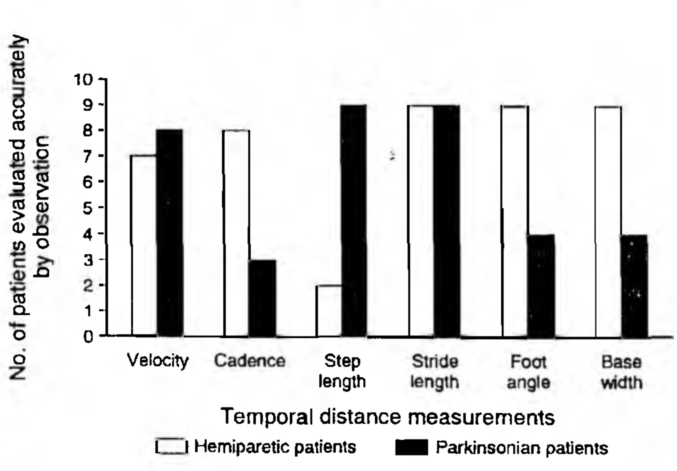

Figure 4: Comparison of observational analysis with temporal distance measurements

Table I: Gait measurements of ten normal subjects

Subject No	Velocity (m/sec)	Cadence	Step Lenth	Stride Length	Base Heel	Base Toe	Foot Angle ° R	L
1	1.41	127	666	1 332	84	106	3	3
2	1.45	123	714	1 428	117	181	6	9
3	1.32	119	666	1 332	59	107	9	2
4	1.25	121	625	1 250	-6	61	13	7
5	1.25	127	588	1 176	0	-6	-2	2
6	1.29	132	588	1 176	-48	71	2	5
7	1.36	123	666	1 332	30	62	6	3
8	1.56	132	714	1 428	20	84	10	3
9	1.36	114	714	1 428	39	106	8	6
10	1.36	123	666	1 332	81	91	2	1

Table II: Gait measurements of hemiparetic patients

Patient No	Velocity	Cadence	R Step length	L Step length	R Stride Length	L Stride Length	Base Heel	Base Toe	Foot Angle ° R	L
1	0.8	97	514	535	1 105	1 108	114	151	6	6
2	0.14	35	189	257	454	453	196	239	10	20
3	0.24	48	160	315	487	482	115	202	22	5
4	0.7	102	413	463	874	870	134	225	19	9
5	0.36	61	389	469	858	860	227	272	9	6
6	0.9	92	611	492	1 103	1 125	80	226	32	13
7	0.57	79	429	461	894	888	113	163	13	3
8	0.29	61	260	238	501	498	164	217	3	13
9	0.62	75	431	565	983	987	238	342	6	24
10	0.55	80	435	482	908	910	139	161	3	6

Table III: Gait measurements of parkinsonian patients

Patient No	Velocity	Cadence	R Step Leangth	L Step Length	R Stride Length	L Stride Length	Base Heel	Base Toe	Foot Angle ° R	L
1	0.21	125	70	91	172	173	80	181	13	20
2	0.79	100	553	507	1 066	1 066	44	103	4	16
3	1.03	118	646	544	1 198	1 190	86	82	-3	1
4	0.74	121	380	341	725	721	54	114	9	7
5	1.18	106	743	699	1 211	1 442	82	158	6	12
6	0.81	118	402	443	856	845	51	65	4	02
7	0.93	96	642	495	1 138	1 137	136	227	8	15
8	0.71	99	471	496	970	966	88	107	10	2
9	0.47	100	252	268	527	524	57	132	17	18
10	0.74	93	462	435	903	897	6	40	9	-4

It is interesting to note that one young stroke patient, whose gait was rated as normal by the physiotherapist, felt that she walked too slowly to keep up with her friends. Robinette and Vondran[3] also found that goals set within rehabilitation departments often were not adequate for a patient to return to his usual daily environment. This shows how important it is for the physiotherapist to plan together with the patient the goal of treatment. This might be walking from the bedroom to the bathroom in an unspecified length of time, achieving sufficient velocity to cross the road safely at traffic lights, or having to negotiate stairs and considerable distances in order to be on time for a lecture.

The parkinsonian patients were mostly in the upper age range, a factor which could influence velocity, however a significant difference in the velocities of the normal subjects of varying ages tested was not found. Only two of the parkinsonian patients walked faster than one metre per second (Table III). The velocity of eight patients was correctly evaluated observationally. Six of the ten patients stated that their walking varied at different times throughout the day according to when their medication was taken. This would present problems if several sets of measurements were to be compared over a time span as the effects of the medication would have to be taken into account. This was not a problem in this study as only one set of measurements was recorded with the parkinsonian patients. As velocity is an easy measurement to obtain objectively, and has been shown by Brandstater *et al*[4] to correlate with improved motor function in hemiplegic patients, it would be preferable to use objective velocity measurements with all gait assessments.

Cadence – Carr and Shepherd[5] relate that "adults walking normally take approximately 100 steps per minute".

For this study 90-100 steps per minute was taken as being normal. In the ten normal subjects measured in our department, cadence was found to be slightly higher than this at a comfortable walking speed, varying between 132 and 114 steps per minute (Table I). Cadence was found to be lower than 100 steps per minute in all except one of the hemiparetic patients (Table II) and normal or higher than normal in all the parkinsonian patients (Table III). This measurement is also easily obtained objectively and as accuracy of observational analysis was poor with the parkinsonian patients it would be better to use objective measurements.

In normal subjects cadence relates to velocity in that velocity is increased by increasing either stride length or cadence and is usually produced by increasing both. This did not apply to the parkinsonian patients in this study. In the ten patients tested velocity was relatively low, with a comparatively high cadence. The patient with the slowest velocity of 0.21 metres per second had the highest cadence of 125 steps per minute (Table III).

Step Length – Step lengths of 0.5 metres and above were considered to be normal. Step length proved very difficult to evaluate observationally in the hemiparetic patients. This was surprising as hemiplegic gait is so obviously asymmetrical in appearance. However, although it is easy to see that the time spent weight bearing on the affected limb is almost always reduced, step length may be decreased on either side and it was found that five of the patients took a longer step with the affected limb while the other five did so with the unaffected limb. The difficulty in assessing step length by observation has also been described by Gaudet *et al* (1990)[6].

The parkinsonian patients, with their more symmetrical gait, were easier to evaluate observationally and could be seen to be taking shorter steps than normal.

Stride Length – This measurement was accurately evaluated in both hemiparetic and parkinsonian patients, with nine out of

ten patients being correctly evaluated in each case. Stride lengths of one metre and over were considered as normal.

Being a combination of two successive step lengths, stride length is directly affected by the step length measurements but does not show an asymmetry of gait as does step length. This made it a much easier gait parameter to judge observationally and nine of the patients in each group were correctly assessed as having either normal or decreased stride lengths. As the asymmetry of gait is not shown this is not such a valuable measurement as step length in the evaluation of hemiplegic gait.

Foot Angle - Variations between right and left foot angles of up to five degrees were considered as normal. Foot angle was accurately observed in nine of the ten hemiparetic patients but was only accurately observed in four of the ten parkinsonian patients.

Foot angle was increased on the affected side in all except one of the hemiparetic patients and foot angle was observed accurately in all patients showing this increase. There was great variability in the foot angle of the parkinsonian patients, with three patients showing toeing-in of the foot. This variable gait pattern made foot angle much more difficult to evaluate observationally.

Base Width - No descriptions of normal base width were found in the literature although this measurement has been described as being useful by Gaudet *et al*[6].

There was a large discrepancy between the base width of the hemiparetic patients and the parkinsonian patients, with much narrower base widths being observed in the latter. Base widths of between 100 mm and 145 mm at the heel and between 100 mm and 170 mm at the toe were considered within normal limits.

Base width was correctly assessed observationally in nine of the ten hemiparetic patients and was easy to see due to the slowness of gait. The more rapid gait pattern of the parkinsonian patients made accurate observation much more difficult and a decreased base width was not always noticeable, although nine of the patients were found to have a decreased base width when objective measurements were analysed.

Video Recording - A video recording was made of each patient walking towards the camera. This was found to be very useful as a record for observational analysis.

CONCLUSION

Temporal distance parameters of velocity and stride length can be judged observationally in both hemiparetic and parkinsonian patients with reasonable accuracy. However, as observational analysis can only provide estimates of whether the parameters are normal or show an increase or decrease from normal, this type of analysis is not sufficient for research purposes.

Measurements of step length, foot angle and base width may be estimated reliably in some patients, but for accuracy objective measurements should be obtained. This can be done by collecting ink footprints on a length of paper walkway and then analysing the measurements. Although this is a rather time consuming procedure, the data produced is reliable enough for research purposes and does not require expensive equipment. This is important in South Africa today as research into effectiveness of treatment is essential but limited funds do not allow the purchase of expensive equipment. This method of data collection has been described in two articles by Holden *et al*[5,6].

As velocity is the easiest measurement to obtain objectively and has been shown by Brandstater *et al*[4] and Holden *et al*[7] to correlate with function in hemiparetic patients, this measurement should be included in all gait assessments.

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IBITAH

The International Bobath Instructors/Tutors Association for Adult Hemiplegia (IBITAH) was founded in 1984 and is an international organisation of therapists who have developed a special interest in the assessment and treatment of adult persons who have suffered a stroke or similar neurological impairment. IBITAH unites physiotherapists and occupational therapists worldwide and at present represents more than 170 therapists in 20 countries.

The objectives of IBITAH are:

- To improve and spread skills in the assessment and treatment of persons with hemiplegia and other allied neurological conditions
- To promote and further knowledge of the Bobath concept related to adult hemiplegia and other allied neurological conditions
- To increase the availability of IBITAH recognised courses worldwide
- To maintain and improve the standards of IBITAH recognised courses
- To improve and standardise the training of instructors throughout the world
- To organise regular meetings and educational programs and to facilitate the exchange of ideas between members.

The Bobath concept is a problem solving approach to the assessment and treatment of individuals with disturbances of tone, movement and function due to a lesion of the central nervous system. It is named for its originators, Drs Berta and Karel Bobath.

IBITAH is responsible for setting the regulations, structure and content of basic and advanced courses in the assessment and treatment of adult hemiplegia and related conditions, as well as stipulating the process for training and qualifying instructors. There are three levels of instructor – instructor, advanced course instructor and senior instructor. In South Africa there are at present one senior instructor, one instructor and two instructors in training. IBITAH recognised courses offered in South Africa are also recognised for certification by the South African Neurodevelopmental Therapy Association.

■ *(Information taken from IBITAH brochure)*