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A method for dynamic measuring with pressure or force platforms

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Abstract

In gait studies with pressure or force platforms researchers try to achieve the recording of a "natural" walking pattern of the subject. They deal with limits in dimension of the platforms, which implies a restricted probability of hitting the sensitive surface and a number of walks with missed steps. Especially for patients with impaired locomotion, repetition of runs could be a challenge to their compliance and endurance. A method which aims at an increase of the probability of hitting, with maintenance of a "natural" gait pattern, is presented as a possible choice. The proposed approach of using a target, two step lengths in front of a hidden platform, is tested on practical feasibility and efficacy and compared with 3 alternative methods. Fifteen patients with ambulation disturbances of different origin walked on a walkway and the number of hits during maximally twenty-five runs was recorded. The results confirm and quantify the extent of the expected difficulties. Methods with a target or starting-point were not effective on patients with a distinct variable step length. The three most promising methods scored equally poor. Respectively 6, 7 and 8 patients were not able to produce three hits for each foot during twenty-five runs. The results form arguments to inquire into another, less frequently avocated method: "first-step" data collection.

Keywords: Biomechanics; Gait analysis; Pressure/force platforms.

Introduction

Measurements of (the distribution of) forces or pressures exerted on the footsole during locomotion are helpful in the quantitative assessment of the biomechanical condition of the musculo-skeletal system. These recordings can lead to an increased insight into the general mechanics of gait[1-10], the mechanical characteristics[1,3,5,7,11-17] and progress of disorders[18,19] and the effects of therapeutic interventions (surgery,[14,17,20-24], footwear[3,7,25,26] and orthoses[7,27,28]).

Several techniques are used: force platforms[9,29-31] (strain-gauge systems[3,5,20,24,17], piezoelectric systems[7,13,29,31-34]) or pressure distribution systems. Pressure distribution could be recorded with the help of pressure platforms (capacitive transducers,[35,36] resistive transducers,[6,37] optical system (pedobarograph),[4,11,14,18,19,21,22,27-29,38-40] Harris foot-printing mat (versions),[15,41,23,30,42-44]) discrete pressure transducers attached to the footsole,[2,16,45,46] or pressure insoles.[25,47,48] In practice every choice appears to have specific problems.

Since measurement of more than one step in a "natural" rhythm is preferable[8,29] and most people wear shoes, recordings with insole systems seem to be ideal. However these insoles are also characterized by some technical problems.[2] The technique is susceptible to effects of bending, temperature and humidity.[49] The sensors have to be placed in relation to the relevant foot structures and must not interfere with the normal gait pattern as a result of unfavourable pressure changes by the insole or sensors in itself.[45,47] Different sizes of the insoles are required.

With regard to platforms the measure of the sensitive area varies from 12.5 × 25 cm [5] till 61 × 61 cm,[7] according to the literature we have read.[10,24,50] In particular the pressure platforms have rather small sensitive areas. In that case the chance to hit the platform while walking is restricted and the test subject has to repeat his walk a number of times.[29,33] Manufacturers make such restricted measures of pressure platforms not without a reason. The larger the number of pressure sensitive sensors in a platform, the more time it takes to scan all the sensors and the smaller the sample frequency will be.

To compose an average value of the analysed parameter, as a reliable representative of the "natural" gait of the test subject, it is necessary to repeat the measurement of the step (possibly for both the right and left side).[17,29,51] In a study with 10 healthy volunteers Hughes et al. calculated that an excellent level of reliability (coefficient of reliability= .9) was achieved when the data of 3 or 4 walks of one measurement session were used for the force and pressure variables and the contact area. "Measurements related to time were more variable."[50]

The minimal number of recorded steps with reliable average values of the selected parameters depends on the ability of the equipment to record accurately, the method used to extract data and the ability of the subject to walk repeatably.[50]

Especially for patients with impaired locomotion the repetition of walks could be a challenge to the compliance and endurance of these persons.[33] Another factor depends on the individual characteristics and is illustrated by the observation of patients who show, in the laboratory, an excessive tendency to perform their task well, which can result in an abnormal gait pattern.

Reports previously published have described instrumentation and techniques to measure forces or pressures exerted on the footsole during locomotion. Several of these publications do not give complete information about the followed measurement protocol which describes the (standard) measurement conditions, whereas every researcher had to deal with a choice of the study situation. We assume that a "natural" gait pattern and thus repeatability is influenced by several factors which should be described in the measurement protocol (length of the walkway, possible use of a camouflaged platform, warm-up trials, the control of walking speed and frequency, ...).

A visible platform can result in a greater hit percentage, but also in an aberrant step if the subject adjusts his step length to hit the platform anyway. Hughes stated in her thesis: "Alterations in gait of this kind can be observed by a trained operator and those results discarded.[52]. Camouflage of the plate[5,10,17] is probably only necessary where the equipment is to be used by a number of inexperienced people".[52]

To achieve a "natural" gait pattern researchers let their test subjects perform a "free walk" at their preferred comfortable or "normal" speed.[5-7,9,13,14,18,21,35,53] A complete free walk results in many steps which miss the platform[29] or, with a visible platform, in an unnatural step when the subject adjusts his stride length in order to hit the platform.[33,54] These restraints are met more extremely in studies with running subjects.[1,32]

The accomplishment of a greater chance to hit the sensitive area could be helped by using an adjusted starting position some step lengths away from the platform.[3,5,7,10,35,43] This method requires a number of test walks to determine the correct starting position for the individual[33] and could lead to problems with mimicking the "natural" cadence if subjects make deliberate effort to achieve a good hit.[9,10]

A test situation without missed steps could be achieved by starting to walk at one step length away from the platform: "first-step" measurement.[12,42,43,49] Disadvantages of this method, as opposed to "mid-gait" data collection, are the lower peak pressures (especially in the heel region)[12,43] and a walking pattern with lesser balance during the first step(s).

While working with a pressure platform in a preceding non-published clinical study on pre- and postoperative hallux valgus patients, the above described restraints were met. In order to achieve the combination of a "natural" walk with a good probability of hitting a new method was developed.

The purposes of the present study are to quantify the practical feasibility and the efficacy (probability of hitting) of this new method and to make a comparison with three alternatives.

Methods and materials

A new method

The new method, which is presented in this article, corresponds with a method used by long jumpers in athletics, who want to end with their steps just on the push off bar. They measure out a predetermined number of steplengths in front of the bar, and place there a mark which will be used as a target. During the first part of the run, the athletes make one step with one particular foot just next to the mark and continue their run in a way they can reach the bar at the end of the walkway with the predetermined foot.

The measurement protocol which was used in the mentioned clinical research is as follows. The pressure platform (EMED-F system, Novel GmbH, München) was mounted in the floor and camouflaged by a thin carpet which covered the whole length of the 7 meter walkway. This carpet (cotton on a rubber base) was fixed to the floor with adhesive tape and did not fold or shove away during walking, nor did it significantly change the pressures recorded by the platform sensors. The subjects were asked to walk barefoot between two parallel lines (at 25 cm mutual distance) on the walkway as normal as possible, at a comfortable free speed and frequency, while looking straight forward to a cross on the wall. While doing this they had to hit, with one foot, a rubber sheet (25 × 25cm) which was positioned approximately two step lengths in front of the sensitive area of the platform and continue their walk till the end of the walkway (Fig. 3). After observation of approximately 3 warm-up runs the position of this rubber "target" was eventually adjusted to a changed step length and meanwhile an optimal starting-point was determined and indicated on the carpet with a piece of adhesive tape.

In this manner the subjects thought that the "target" was the measurement device and they were not conscience of the real location of the pressure platform. Furthermore, sometimes the subject showed a visible deviation of his normal step length at the moment of hitting the target. Two steps later, when the platform was hit, the gait pattern looked normal again.

The observer (APS) made the decision if the hits were good enough for data storage and analysis. An "acceptable hit" was performed if the sensitive area of the platform was hit by the whole plantar surface of the foot, if

Table I. Patient characteristics

Nr	Sex	Age	Primary diagnosis	Impairments with regard to walking	Orthopaedic appliances
1	M	40	N. tibialis lesion (right)	Pain in foot	Orthopaedic shoes
2	F	19	Traumatic lesion tendons and nerves of foot flexors (right)	Pain in foot, hammer toes, diminished range of motion of ankle	Orthopaedic shoes
3	F	72	Reumatoid arthritis: multiple foot operations	Bilateral: hallux valgus and claw toes, left: ankle in valgus	Orthopaedic shoes
4	M	21	Bilateral congenital leg deformities, Syme amputation (right)	Fatigue and pain in legs	Bilateral prostheses
5	M	27	Motor accident, lower-leg amputation (left)	Fatigue and pain in legs	Foreleg-prosthesis
6	M	18	Meningitis + Waterhouse Friedrichsen Syndrome, lower-leg amputation (left)	Fatigue and pain in legs	Foreleg-prosthesis
7	F	62	Conus syndrome, extirpation meningeoma Th10-12	Paresis left leg	Semi-orthopaedic shoes
8	F	44	Burned left leg, multiple operations knee and ankle	Leg-length discrepancy, left: diminished range of motion of ankle, pes varus, missing toes, painful hip	
9	M	46	Buerger's disease, lower-leg amputation (left)	Wide trace	Foreleg-prosthesis
10	F	68	Caudal neurinoma, 2x surgery	Paresis left leg	Dynamic ankle orthosis
11	M	20	Traumatic upper-leg amputation (left)	Fatigue and pain in legs	Prosthesis
12	M	35	Multiple trauma's, through-knee amputation (left)	Fatigue and pain in legs	Prosthesis
13	M	58	Buerger's disease, partial amputation digit 1-5 (left)	Pain in hallux, walking on lateral aspect of footsole	Orthopaedic shoes
14	M	61	Diabetes mellitus, amputation digit$_2$ (right)	Impaired sensibility	Orthopaedic shoe
15	M	23	Motor accident, crush lesion right foot, surgical amputation digit$_1$ and part of first metatarsal	Pain in foot	Orthopaedic shoes
	sum: 5F 10M	mean: 41 range: 19-68			

the step on the platform looked "normal" and if the step on the target deviated at most slightly from the regular pattern.

In the present study the above described method was tested on practical feasibility and efficacy (probability of hitting) and compared with 3 alternative methods.

Patient population
Eighteen patients visiting the "foot disorder consulting hour" at the department of Rehabilitation, of the University Hospital Rotterdam, Dijkzigt, were invited to cooperate in the present study. These patients were estimated to have enough endurance to walk for approximately 500 m without crutches or other walking aids. Three of the eighteen participating patients were not able to perform the task completely as a result of increasing tiredness or poor postural balance with fear to fall, and were excluded from statistical analysis.

The remaining group of patients consisted of 5 females and 10 males. The average age of these women was 53 (range: 19-72), of the men it was 35 (range: 18-61). Sex, age, primary diagnosis, impairments with regard to walking, and orthopaedic appliances of the fifteen studied patients are presented in Table I.

Study design
After informed consent the patients walked, without practice trials, two successive series on a walkway with two different conditions each (Fig. 1-2). The patients, wearing their regular footwear, were asked to walk between two parallel lines (at 25 cm mutual distance), as normal as possible and at their own comfortable velocity and frequency. Futhermore they had to aim at the target or the visible platform. The patients were asked to give priority to the maintenance of their "normal" cadence if this aim was in conflict with targetting.

Series 1:
- condition A; the starting-point was adjusted to the step length of the subject and a target was placed two step lengths in front of a camouflaged platform (fig. 3);
- condition B; the starting-point was adjusted to the step length of the subject and the platform was visible;

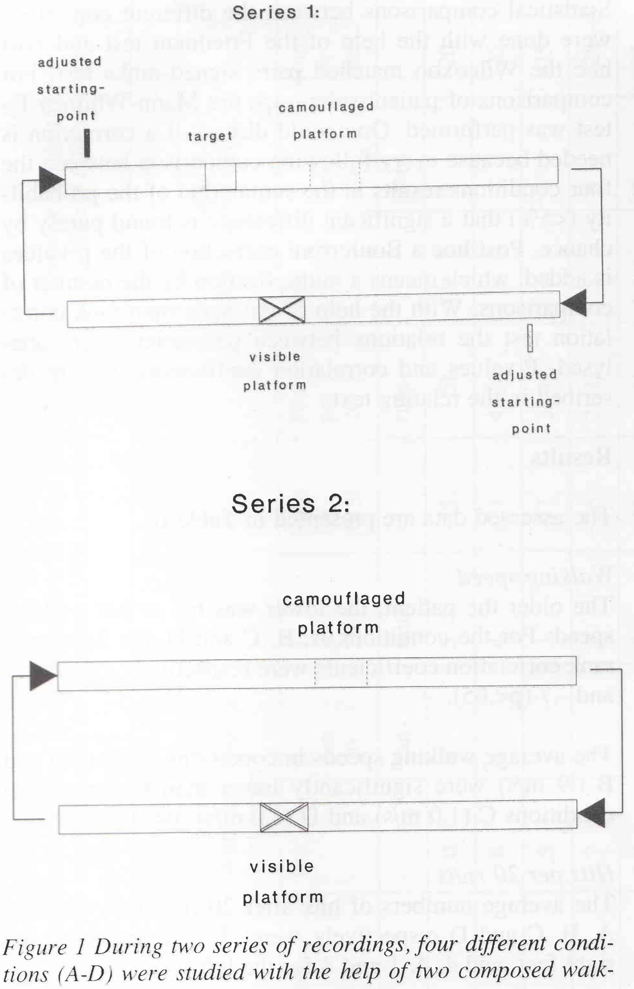

Figure 1 During two series of recordings, four different conditions (A-D) were studied with the help of two composed walkways.

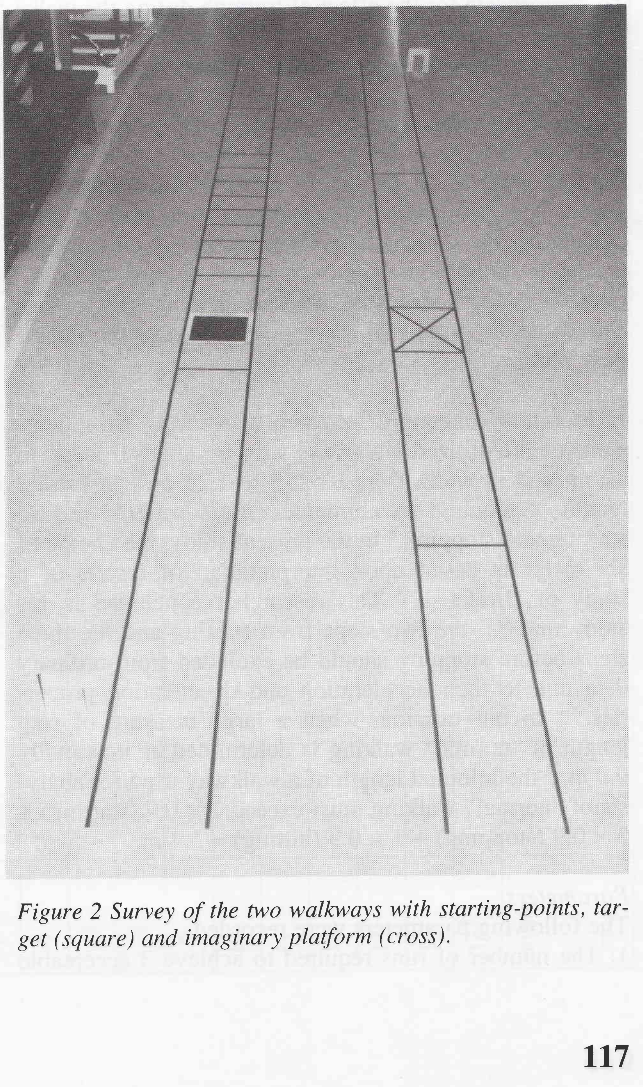

Figure 2 Survey of the two walkways with starting-points, target (square) and imaginary platform (cross).

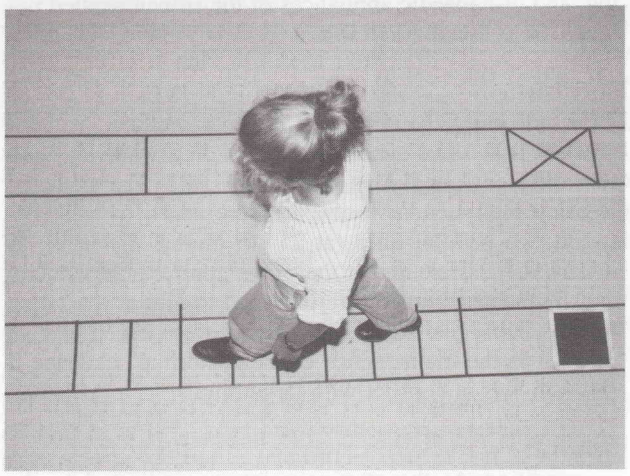

Figure 3 In condition A the subject hits the camouflaged imaginary platform (between two of the visible transverse lines) two steps behind the target (square).

series 2:
- condition C; without a predetermined starting-point and the platform was camouflaged for the patients;
- condition D; without a predetermined starting-point and the platform was visible for the patients.

To compensate for the effect of training during the walks the two conditions with a greater expected number of hits (with determined starting-point or target) were used first.

The platform was imaginary and not really mounted in the floor. By means of pieces of adhesive tape on the floor a walkway (6 m length, 25 cm width) was composed. The position of the platform was made recognizable for the patient (condition B and D), or only for the tester (condition A and C), at 3.5 m from the start, with the help of pieces of adhesive tape at the margins. The complete outline of the sensitive area of the imaginary platform was 35 × 25 cm.

In literature concerning research of walking the dimensions of the utilized walkways vary in length from 4[6] to 10 m[7] and in width from 0.525[55] to 1.25 m.[39] Sufficient length is required to eliminate erratic patterns due to starting and stopping.[8] In the present study, the choice of six meter is based upon interpretation of results of a study of Hirokawa.[54] This researcher concluded in his study that "... the two steps from starting and the three steps before stopping should be excluded from ordinary data due to their acceleration and deceleration properties."[54] In our opinion, when a large measure of step length in "normal" walking is determined as maximally 0.9 m,[54] the minimal length of a walkway used for analysis of "normal" walking must exceed 2 × 0.9 (starting) + 3 × 0.9 (stopping) + 1 × 0.9 (hitting) = 5.4 m.

Parameters
The following parameters were recorded:
1. The number of runs required to achieve 3 acceptable hits for each foot. If a patient did not achieve this goal after the standard 20 runs, five additional runs were made.
2. The number of acceptable hits for each foot after 20 runs on the walkway.
3. The number of times the starting-point was adjusted to the steplength of the patient.
4. The number of times the target was adjusted to the steplength.

The used definition of an "acceptable hit" was the same as mentioned in the section "a new method".

In an attempt to describe the level of functioning of the participating patients the primary diagnoses, impairments with regard to gait, and the possible use of orthopaedic appliances were looked up in the medical records. For the same reason the walking speed was measured. With the help of a digital stop-watch the time used to walk a distance of three meter of the middle of the walkway was recorded twice. This was done in all the study conditions. A digital watch was chosen because a simple study organization was pursued and other techniques may have restricted reliability as well. With the average time the walking speed was calculated.

Statistics
Statistical comparisons between the different conditions were done with the help of the Friedman test and post hoc the Wilcoxon matched pairs signed-ranks test. For comparisons of patient subgroups the Mann-Whitney U-test was performed. One could discuss if a correction is needed because every following comparison between the four conditions results in the summation of the probability (<5%) that a significant difference is found purely by chance. Post hoc a Bonferroni correction of the p-values is added, which means a multiplication by the number of comparisons. With the help of the Spearman rank correlation test the relations between parameters were analysed. P-values and correlation coefficients (rs) are described in the relating text.

Results

The assessed data are presented in Table II.

Walking speed
The older the patient, the lower was his or her walking speed: For the conditions A, B, C and D, the Spearman rank correlation coefficients were respectively -.5, -.6, -.7 and -.7 ($p<.05$).

The average walking speeds in conditions A (.9 m/s) and B (.9 m/s) were significantly lower than the speeds in conditions C (1.0 m/s) and D (1.0 m/s) ($p<.05$).

Hits per 20 runs
The average numbers of hits after 20 runs for condition A, B, C and D respectively were: 3, 3, 2 and 3 for the right feet, and 4, 4, 1 and 4 for the left feet.

Table II Assessed data

The average walking speed [m/s], the number of times that the position of the starting point (S) or the target (T) was adjusted to the steplength, during twenty runs, and the number of runs necessary to obtain three hits for each foot (3R3L) are shown. Several patients did not achieve this aim after twenty or even after five additional runs (>25). For every foot the number of hits per twenty runs is presented.

	Series 1									Series 2					
	Camouflaged platform With starting-point With target					Visible platform With starting-point				Camouflaged platform Free walk			Visible platform Free walk		
Nr	m/s	S per 20 runs	T per 20 runs	Runs for 3R3L	Hits per 20 runs	m/s	S per 20 runs	Runs for 3R3L	Hits per 20 runs	m/s	Runs for 3R3L	Hits per 20 runs	m/s	Runs for 3R3L	Hits per 20 runs
1	1.0	2	5	>25	5L	1.0	1	20	3R5L	1.1	>25	0	1.1	22	4R2L
2	.8	1	4	>25	4R2L	.8	4	>25	4R2L	.9	>25	3R	.9	14	4R4L
3	.5	2	3	17	3R4L	.4	3	>25	2R3L	.7	>25	1L	.8	>25	1R4L
4	.7	3	3	>25	2R3L	.8	6	>25	3L	.9	>25	1R2L	.9	25	4R1L
5	1.3	2	5	>25	4L	1.4	2	>25	2R1L	1.4	>25	1R1L	1.4	>25	1L
6	1.1	1	3	20	5R3L	1.0	1	18	4R5L	1.2	>25	0	1.3	>25	2R2L
7	.8	3	1	19	6R3L	.8	2	11	3R5L	.9	>25	1R5L	.8	>25	4L
8	.8	0	1	17	3R5L	.8	0	9	7R8L	1.0	>25	1R1L	1.0	17	4R5L
9	1.0	0	0	20	4R3L	1.0	0	19	5R3L	1.0	>25	6R1L	1.1	8	9R7L
10	.5	0	1	13	3R5L	.5	2	16	4R5L	.6	18	3R5L	.6	17	4R7L
11	1.0	4	2	>25	1R2L	1.1	2	>25	2R4L	1.1	>25	1R	1.1	>25	1R3L
12	.9	0	4	18	3R4L	1.0	1	8	3R7L	1.0	>25	4R	1.1	>25	2R11L
13	.8	1	3	19	3R5L	.8	1	15	7R4L	.9	>25	2L	.9	>25	7R1L
14	.9	0	3	>25	4L	.7	5	>25	0	.8	>25	1R	.8	>25	1R
15	1.2	3	0	17	3R4L	1.3	1	>25	3L	1.3	>25	1R2L	1.5	11	5R5L
mean:	.9	1	3	160/9=18 and 6x>25	3R4L	.9	2	116/8=15 and 7x>25	3R4L	1.0	18/1=18 and 14x>25	2R1L	1.0	114/7=16 and 8x>25	3R4L
range:	.5-1.3	0-4	0-5			.4-1.4	0-6			.6-1.4			.6-1.5		

For the left feet the average number of hits during twenty runs in condition C was statistically significantly lower than in condition A, B or D ($p<.01$). The results of the other comparisons of this parameter in the four conditions were not significant.

Number of runs for 3 right and 3 left hits

At least 2/5 of the patients (6/15 in condition A) did not achieve to obtain three hits for each foot during twenty or even after five additional runs (">25" in table II). In condition B, C and D respectively 7/15, 14/15 and 8/15 of the patients scored ">25" runs.

In order to be able to compare the average scores of the different conditions the following method was performed. For every patient and in every condition the number of runs required to obtain the desired score of 3 right and 3 left hits (=6) were counted. The fourth or following hits at one side were ignored. If the desired six hits were not made after 25 runs, the highest number of hits for both sides (<6) were noted. The scores of the patients are represented in a graph with the number of runs (≤25) on the horizontal axis and the cumulated number of hits (≤6) on the vertical axis. The nature of the relation between both parameters is determined by means of a regression line (hits = regression coefficient × runs) (fig. 4). The value of the regression coefficient (slope) forms a parameter which, in a simple way, can represent the course of increase of hits during the observed runs.

In order to make a comparison between the group scores in the four specific conditions, the mean regression lines are composed (fig. 5). The regression coefficient of the line belonging to the average score in condition C is statistically significantly smaller than that of condition A, B or D ($p<.01$). With regard to the average regression coefficients no statistically significant differences were established between conditions A, B and D.

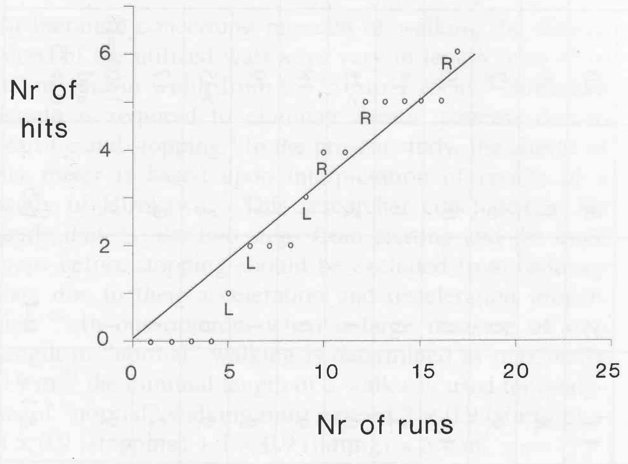

Figure 4 An example (patient 8) of the relation between the number of performed runs (≤25) and the cumulated number of acceptable right (R) and left (L) hits (≤6), which is represented by a regression line.

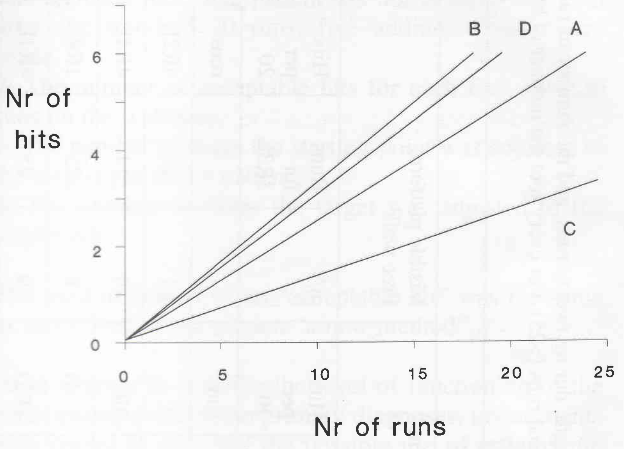

Figure 5 Relation between number of runs and cumulated number of acceptable hits (see fig. 4). Average of the regression lines obtained from four different conditions: A, with starting-point, target and camouflaged platform; B, with starting-point and visible platform; C, free walk with camouflaged platform; and D, visible platform without starting-point.

With the help of the four regression lines a rough estimation of the average number of runs required to obtain three hits at both sides of the four specific conditions could be made. The estimated average runs of conditions A, B, C and D respectively are 24, 18, 47 and 19.

Adjustments of target or starting-point

The mean number of adjustments of the target in condition A was three. The starting-point on an average was adjusted once in condition A and twice in condition B. In some cases poor scores (small slopes of regression lines) occurred in spite of frequent adjustments of the target. In condition B the starting-point was statistically significantly more frequently adjusted if the slopes of the regression lines were smaller ($r_s=-.6$ and $p<.02$), or the number of hits during 20 runs was smaller (right feet: $r_s=-.6$ and $p<.03$, left feet: $r_s=-.6$ and $p<.04$).

No statistically significant correlations were found between age or walking speed and: 1. the number of adjustments of the target or the starting-points or 2. the number of runs to obtain three hits for both feet, represented by the regression coefficients. Also the number of 3 hits per 20 runs did not correlate significantly with the walking speed. Only in condition A was it found that the older the patient, the larger was the number of hits during twenty runs ($r_s=.5$ and $p<.05$). This moderate correlation was only found with regard to the left feet.

Amputee patients

Five of the 15 analysed patients had undergone a lower limb amputation and walked with an above-knee or below-knee prosthesis. The average age of these 5 male amputee patients was 29 years (range: 18-46) but statistically did not differ significantly from the average of 47 years of the non-amputees (range: 19-72). In all four conditions, the amputee patients on an average walked significantly faster than the other patients ($p<.05$). After

Bonferroni correction the differences were not significant anymore (p>.05).

No statistically significant differences between the amputees and non-amputees were established with regard to: 1. the number of hits per twenty runs and 2. the slope of the regression lines.

Discussion

A new method, which aims at an increase of the probability to hit the platform with maintenance of a "natural" gait pattern, is presented. For that purpose a starting-point and a target were used as expedients. In order to maintain the "natural" cadence of the patient the platform was camouflaged.

This method was tested on practical feasibility and efficacy (probability of hitting) and compared with three alternative methods. Simple and appropriate study techniques (observation and stop-watch) were used and fifteen patients with disturbances of gait were analysed.

The values of the parameters "hits per 20 runs" (1-4 hits on an average) and the "(estimated) number of runs for 3 right and 3 left hits" (18-47 runs on an average) numerically confirmed the problem of hitting with maintenance of a natural gait pattern, which was encountered in former research[3,5,7,9,10,12,24,33,35,43,49]. One result was not surprising but is quantified now: Condition C (a free walk on a walkway with camouflaged platform) scored poorly and is, as a useful alternative method, out of the question.

Of course, from the presented study can not be excluded that a repetition of the performed recordings on a group with more than fifteen patients might result in statistically significant differences between conditions A, B and D. If such differences are clinically relevant as well is doubtful: some hits more or less, on a total of twenty runs or even more, is meaningless.

The present study produced a number of observations which are not found again in literature about the studied subject. Although these aspects were not assessed numerically and analyzed statistically, they possibly are relevant, are described below and could be taken into account in future research.

Observation suggested that a great shoe-size, a great step length, an involuntarily irregular step length, limited physical or motivational endurance, and disturbed postural balance influenced the score negatively.

In a number of patients gait patterns with a distinctly variable step length were observed. In these cases methods with a target or starting-point did not work satisfactorily.

Patient number ten, a female of sixty-eight years, scored well, even in condition C. She walked slowly with small steps, which could be an explanation for her score: the smaller the step length, the greater is the probability of hitting the platform with one or, unfortunately, with both feet.

Patients five and eleven walked with leg prostheses. In relation to the others they were young and walked fast. In spite of these characteristics these patients scored poorly. They told to prefer a longer walkway in order to obtain their usual comfortable cadence. This difficulty may have interfered with the task to adapt their step length to the location of the platform.

In several cases the adjustments of the target or the starting-point did not result in the expected increase of number of hits. Our optimism was based upon the promising experience in a study with pre- and postoperative hallux valgus patients. The impairment of walking of the patients in the present study had an essentially different character. In particular the coordination and postural balance was more severely impaired than in the hallux valgus patients. In particular at the moment of hitting the target or the platform, disturbance of postural balance and gait pattern was provoked.
The underestimation of the difficulties of the present specific patients in performing more than one task simultaneously, could explain the disappointing results of the newly presented method in these study group. These observations correspond to research of Geurts who emphasized that in "... subjects with gross motor-skill deficiencies, the performance of routine acts (such as walking) may only be possible at the cost of considerable information processing capacity, resulting in the inability to perform these acts simultaneously with other, even non-motor, attention-demanding tasks (such as memorizing)".[56] In the present study the attention-demanding task was to hit a target or a platform.

Furthermore, the adjustments consume some time, may divert the attention of the researcher, and may bring the test subject out of balance. Besides, patients often establish their own starting-point (for example the start of the walkway in condition D) and possibly adjust it themselves after feed-back of the preceding result.

Summarizing it can be said that we looked for the best method to perform mid-gait data collection with platforms, developed a new method, tested four alternatives on specified patients and established equally poor results in the three most promising methods. These results form arguments to review the method of "first-step" data collection, which is avocated and in a protocol described by Cavanagh et al[49].

Conclusions

Based upon literature the minimal length of a walkway, used for analysis of "normal" walking was computed. The walkway must exceed 2 × 0.9 (starting) + 3 × 0.9 (stopping) + 1 × 0.9 (hitting) = 5.4 m. This study has shown that methods with a target or starting-point did not work on patients with a distinctly variable step length. With regard to the probability of hitting no significant differences were found between conditions A, B and D. In conditions A, B and D, respectively 6/15, 7/15 and 8/15 of the patients did not obtain three hits for each foot during 25 runs. Furthermore, on an average, 18 or more runs were required to obtain 3 hits at both sides.

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