From gait disorders to gait analysis

Bernard Auvinet*
Rheumatology - Polyclinique du Maine, Laval

Preliminary results

Medical scholarship about gait disorders blossomed in the nineteenth century: locomotor ataxia in tabetic neurosyphilis (Romberg, Gowers, and Charcot); the festinating gait of Parkinson's disease, and so many others. In the same time appeared the measurement of locomotion in the modern sense: firstly by applying photography (Muybridge), and secondly by combining kinematic and kinetic locomotor measurements (Marey). In the middle of the twentieth century the Berkeley group led by Saunders, Inman and Sutherland launched a Biomechanics Laboratory dedicated to clinical applications (prosthesis). Gait laboratories are now worldwide available using simultaneously kinematic, kinetic and myoelectric measurements; they deal with clinical applications of gait analysis, but they are still expensive and time consuming. There is a lack in an ambulatory gait analysis system suitable in routine practice for clinicians.

Figure 1 : The Locometrix apparatus
This gait analysis system is based on technology which used the measurement of acceleration

Gait analysis method

Gait Analysis System

The gait analysis system used in this study (Locometrix-2™, figure 1) includes in a very small box three accelerometers, a microprocessor and a data logger. The apparatus is incorporated into a semi-elastic belt, which is fastened around the subject's waist, so that sensors are over the L3-L4 inter-vertebral space. Signals were recorded with an acquisition frequency of 100 Hz. The recorded signals are transferred to a laptop computer and analyzed by a specific software developed by Centaure-Metrix.

Figure 2 : The walking test

The apparatus which is incorporated in an elastic belt is attached around the waist of the patient who has to walk along a 40 m straight corridor.

* With the collaboration of:

Pr. Yves Maugars
Rheumatology
Centre Hospitalo-Universitaire
Nantes, France

Mr. Denis Chaleil
Université d'Angers,
Service de Pharmacie Clinique,
Angers, France

Gait Analysis Test

Walking tests (figure 2) were carried out on each subject and patient walking down and back along a 40 m straight hospital corridor at preferred. The 40 m distance was long enough to ensure that sufficient stable walking was recorded between the start and the end of the test. All subjects wore their usual walking shoes avoiding high heeled or hard-soled shoes. The walking speed was measured with a stopwatch.

Data Processing

Two periods of steady state walking of 20.48 s were selected from the recording of each subject (there and back), which provided accurate data on gait variables [1].

Gait Variables

- Walking velocity (V, m/s);
- Stride Frequency or Cadence (SF, Hz): number of gait cycle per second;
- Stride Length (SL, m) was calculated from the average speed (m/s) divided by the SF (Hz);
- Symmetry (SYM, dimensionless): an overall index of symmetry between right and left step;
- Regularity (REG, dimensionless), named variability in the literature, describes the similarity of vertical movements over successive strides;
- Cranio-caudal power (W/kg) measure the kinesia of the movement according to the cranial-caudal axis;

Validations

Mechanical validations were done versus force plate and opto-electronic gait analysis systems, there is a good estimate of the vertical motion of the body centre of mass [2].

Intra-tester and inter-testers reproducibilities have been previously validated for clinical applications [3].

Control database: A large control database including more than 400 healthy subjects, men and women, from 20 to 90 year old, has been measured in order to determine the distribution mean and standard deviation for each variable according to gender and age [4].

Main validated clinical applications (Table Annexe)

Five main clinical pathologies were previously validated: hip osteoarthritis (HOA, [5]), knee osteoarthritis (KOA, [6]), Parkinson's disease (PD, [7]), obesity (Ob, [8]), elderly fallers (EF, [9]).

Jennifer Glass, Yves Mainguy, Bernard Auvinet, Francis Blotman

The Study: Gait Analysis in Fibromyalgia patients

The overall aim of this observational study was to characterize gait disorders in fibromyalgia (FM) patients, in comparison to matched control subject.

The secondary objective was to investigate whether these patients could be subgrouped on the basis of there:

- pressure pain threshold,
- psychological factors,
- gait variables.

Study design

This study was a multicentre French (Nantes, Paris, Lille, Grenoble, Toulouse), open trial on outpatients with FM and matched controls subjects. Control subjects were matched in each centre as closely as possible for age, height, and weight.

Study procedure

Two visits were planned:

- **V1:** selection/screening visit; Mini International Neuropsychiatric Inventory was carried out in order to drop out patients with psychiatric disorders.
- **V2:** baseline assessment/gait test visit

Between V1 and V2, patients had to discontinue CNS-active therapies of which antidepressants, anticonvulsives, mood stabilizer therapies, opioids, drug substances (wash-out period 1 to 4 weeks if necessary).

V1

Patients

- Physical examination including the diagnosis of FM by ACR criteria,
- Laboratory assessment.

Patients and controls

- Vital assessment,
- Scale assessing current pain and average pain during the previous week (VAS),
- Screening for depression and anxiety:

- Mini International Neuropsychiatric Inventory (MINI)
- Beck's Depression Inventory (BDI)
- State-Trait Anxiety Inventory (STAI)

V2

Patients

- FM symptoms and signs

Patients and controls

- Baseline vital signs
- Baseline status testing

- Scales assessing current pain and average pain during the previous week (VAS)
- Short Form – McGill Pain Questionnaire (SF-MPQ)
- Short Form-36 (SF-36)
- Fibromyalgia Impact Questionnaire (FIQ)
- Coping Strategies Questionnaire (CSQ)
- Chalder Fatigue Scale (CFS)
- Pittsburgh Sleep Quality Index (PSQI)
- Pressure pain threshold algometry (PPT): PPT assessments will be performed (according to the 1990 ACR criteria) using the Somedic Sales pressure algometer (1 cm?, 30 kP/s).
- Pain drawing

Gait test

- Each participant will be asked to walk down and back a straight 40m hospital corridor, first at their own pace (Self-Selected Speed).

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A/ Material

Following the blind-review meeting (November 6, 2006). 104 subjects having completed the study in conformity with the protocol had been selected (52 pairs valuable).

(Age: 45±7y., height 164±6cm, BMI 24±4Kg/m²).

Every patient fulfilled the ACR 1990 criteria :

- Widespread pain: 7±3y.
- Tender points: 16±2

B/ Blind analysis on gait variables

According to the statistical analysis plan, blind cluster analysis was performed from gait variables measured at self-selected speed into the 104 subjects using k-means, cluster analysis limited to two clusters.

No variable is more discriminant than Cadence (73% patients and controls were detected), the best being combination is Cadence and Cranio-caudal power, which detects 39 FM and 34 Controls.

C/ Open analysis

1. gait variables (table 3 and 4) walking speed was significantly diminished as reductions of stride length and cadence. Steps symetry was not affected. Futhermore there were a hudge decrease of stride regulatory and cranio-caudal power which measures hypo and bradibenesia.

According to a muticentre study (variance analysis was carried out to detect center effort) a center effect was noticed for walking speed, stop length and symetry. Three main variables were without any centre effect : cadence, regulatory and cranio-caudal power.

(Table 1 and Tables 2 and 3 page 54 and Table 4 page 55 and Table 5 page 56)

Table 1 : **Gait variables in patients and controls at baseline assessment**

	Self Selected Speed		
	Patients	**Controls**	**p value**
Walking Speed (m/s)	1.18 (0.19)	1.32 (0.17)	0.00007
Cadence (Hz)	0.93 (0.07)	0.99 (0.07)	0.000008
Symmetry (WD)	213 (39)	227 (38)	NS
Regularity (WD)	267 (38)	293 (39)	0.0007
Cranio-caudal power (W/kg)	2.59 (1.45)	3.63 (1.51)	0.0005

WD: Without Dimension

D/ Cluster Analysis

Taking into account the following variables:

- Gait variables: regularity, cadence, Cranio-caudal power
- Psychometric variables: CFQ (physical, mental), CSG (catastrophysing), FIQ (score), PSQI, SF-36 (physical and mental component summaries), VAS weekly
- BDI, and STAI (trait).

A first cluster analysis was done providing the following results:

(Table 6 page 57)

Table 2 : **Gait variables, patients and controls, and center effects. Variance analysis**

	Walking speed	Cadence	Step Length	Symmetry	Regularity	Cranio-caudal power
SSS (Self Selected Speed)	F= 3.14 **p< 0.03**	F= 1.13 NS	F= 6.31 **p< 0.0004**	F= 3.20 **p< 0.03**	F= 2.03 NS	F= 1.93 NS

Table 3 : **Psychological and behavioural assessments**

	Controls	FM Patients	P Value
BDI	3,8 (3,7)	15,8 (8,2)	< 0,0001
STAI Y-A	29,6 (8,4)	37,3 (13,6)	0,02
STAI Y-B	35,6 (9)	44,1 (12,6)	0,02
CFS total	11,3 (2,2)	20,8 (5,6)	<0,0001
CFS physical	7,3 (1,8)	14,8 (4,5)	0,02
CFS mental	4 (0,5)	6 (1,5)	0,02
CSQ Catastrophizing	4,6 (5,7)	14,5 (9,2)	0,0003
PSQI	4,3 (2,7)	11,3 (4,3)	<00001
Mac bill total	1,3 (3,3)	24,5 (9,1)	<0,0001
Sensory descriptors	1,1 (2,5)	19 (7)	<0,0001
Affection descriptors	0,2 (0,9)	5,6 (3)	<0,0001
SF 36			
Physical component summary	56 (4)	34 (4)	<0,0001
Mental Component summary	50,9 (6,7)	40,6 (10,5)	<0,0001
VAS Currently	2,4 (9)	63 (22)	<0,0001
FIQ score	4,46 (8,33)	56,63 (15,09)	<0,0001
physical function	0,22 (0,54)	4,12 (1,97)	<0,0001

Table 4 : **Baseline assessment - Psycho-comportemental variables, patients and centre effect : variance analysis**	
CFS Physical	F= 0.10 / NS
CFS Mental	F= 0.16 / NS
CFS Total	F= 0.03 / NS
CSQ Catastrophizing	F= 0.94 / NS
Physical function FIQ	F= 2.72 / p< 0.05
FIQ score	F= 1.40 / NS
MPQB weekly pain VAS	F= 0.52 / NS
MPQC PPI	F= 0.21 / NS
Mac Gill score	F= 1.28 / NS
Mac Gill Physical	F= 1.31 / NS
Mac Gill Mental	F= 1.04 / NS
PSQI	F= 1.04 / NS
PCS (SF-36)	F= 0.92 / NS
MCS (SF-36)	F= 0.83 / NS
VAS weekly (SF-36)	F= 0.75 / NS
VAS currently (SF-36)	F= 0.83 / NS
p score: pain drawing	F= 3.84 / p= 0.009
PPT (Somedic)	F= 3.84 / p= 0.009

Pain scores: During V2 pain was measured several times, mainly by McGill score and sub-scores, VAS weekly and currently (SF 36), pain drawing score and SOMEDIC score.
All pain scores were strongly correlated excepted for Pain drawing score and Pressure pain Threshold algometry (SOMEDIC).

Table 5 : **Correlation between gait variables and psychological and behavioural assessments**

		Self selected speed		
		Cadence	Regularity	CCP
Chalder Fatigue Scale (CFS)	Physical			
	Mental			
	Score			
Coping Strategies Questionnaire (CSQ)	Catastrophizing	r= -0.26 p= 0.06	r= -0.34 p= 0.01	
Fibromyalgia Impact Questionnaire (FIQ)	Physical	r= -0.39 p= 0.004	r= -0.29	p= 0.04
	Score	r= -0.37 p= 0.007	r= -0.34 p= 0.01	r= -0.30 p= 0.03
Mac Gill	Sensory descriptors			
	Affective descriptors			
	Score			
SF 36	Physical component summary	r= 0.32 p= 0.02		r= 0.30 p= 0.03
	Mental component summary			
	VAS weekly			r= -0.33 p= 0.01
PSDI				
SOMEDIC				

$p < 0.05$

E/ First Comments

■ Gait variables were linked to physical function in FM's patients:

- Fibromyalgia Impact Questionnaire
- Physical component summary of SF-36.

But gait variables were independent from mental components:

- Mental Chalder Fatigue Scale
- Mental component summary of SF-36
- Including Quality of sleep.

Concerning Coping strategies, the main point was the strong relation between Catastrophizing and gait variables.

But pain was poorly related to gait variables, only pain score, measured by VAS scale, was negatively linked to Cranial-caudal Power which measure hypokinesia.

Recommendations

- Gait analysis can be proposed as an objective method to measure and grade physical function.
- Gait analysis can be proposed to design and evaluate specific physical rehabilitation programs.
- Gait analysis will be of interest to subgroup FM patients but further studies are needed. ■

Table 6 : **Cluster analysis in FM - Patients summary**

	Cluster 3 21/52	Cluster 2 11/52	Cluster 1 20/52
Level of pain	High	Moderate	High
FIQ (Score)	High	Low	Moderate
Catastrophizing	High	Low	Low
Depression level	High	Low	Moderate
Anxiety trait	High	Normal	Normal
Gait:			
Cadence	↘↘	Normal	↘↘↘
Regularity	↘	↘	↘
Crania-caudal power (CCP)	↘	↘	↘↘