Gait analysis: operation of laboratory room and interpretation

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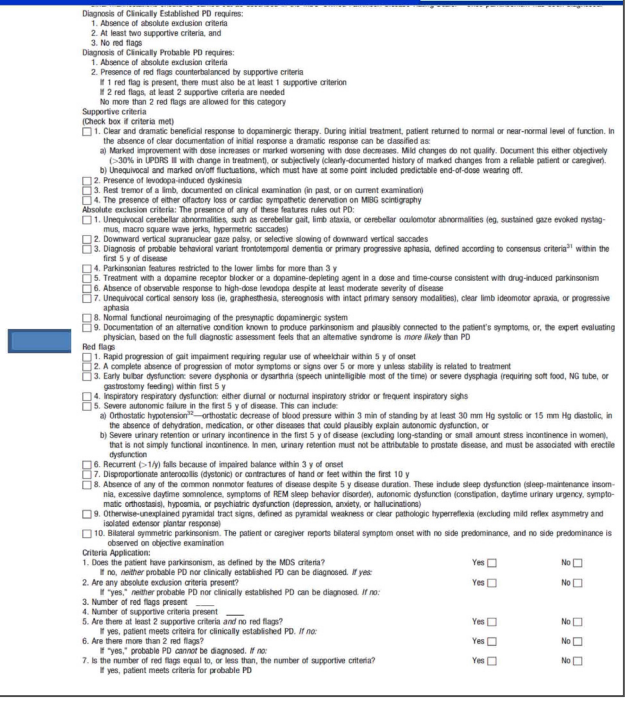
Diagnostic criteria in PD

- Bradykinesia
- At least one of following
  - Rigidity
  - 4-6 Hz resting tremor
  - Postural instability

1993, Ach Neurol



Diagnosis of Clinically Established PD requires:
1. Absence of absolute exclusion criteria
2. At least two supportive criteria, and
3. No red flags

Diagnosis of Clinically Probable PD requires:
1. Absence of absolute exclusion criteria
2. Presence of red flags counterbalanced by supportive criteria
   If 1 red flag is present, there must also be at least 1 supportive criterion
   If 2 red flags, at least 2 supportive criteria are needed
   No more than 2 red flags are allowed for this category

Supportive criteria
(Check box if criteria met)
☐ 1. Clear and dramatic beneficial response to dopaminergic therapy. During initial treatment, patient returned to normal or near-normal level of function. In the absence of clear documentation of initial response a dramatic response can be classified as:
   a) Marked improvement with dose increases or marked worsening with dose decreases. Mild changes do not qualify. Document this either objectively (>30% in UPDRS III with change in treatment), or subjectively (clearly-documented history of marked changes from a reliable patient or caregiver).
   b) Unequivocal and marked on/off fluctuations, which must have at some point included predictable end-of-dose wearing off.
☐ 2. Presence of levodopa-induced dyskinesia
☐ 3. Rest tremor of a limb, documented on clinical examination (in past, or on current examination)
☐ 4. The presence of either olfactory loss or cardiac sympathetic denervation on MIBG scintigraphy

Absolute exclusion criteria: The presence of any of these features rules out PD:
☐ 1. Unequivocal cerebellar abnormalities, such as cerebellar gait, limb ataxia, or cerebellar oculomotor abnormalities (eg, sustained gaze evoked nystagmus, macro square wave jerks, hypermetric saccades)
☐ 2. Downward vertical supranuclear gaze palsy, or selective slowing of downward vertical saccades
☐ 3. Diagnosis of probable behavioral variant frontotemporal dementia or primary progressive aphasia, defined according to consensus criteria[31] within the first 5 y of disease
☐ 4. Parkinsonian features restricted to the lower limbs for more than 3 y
☐ 5. Treatment with a dopamine receptor blocker or a dopamine-depleting agent in a dose and time-course consistent with drug-induced parkinsonism
☐ 6. Absence of observable response to high-dose levodopa despite at least moderate severity of disease
☐ 7. Unequivocal cortical sensory loss (ie, graphesthesia, stereognosis with intact primary sensory modalities), clear limb ideomotor apraxia, or progressive aphasia
☐ 8. Normal functional neuroimaging of the presynaptic dopaminergic system
☐ 9. Documentation of an alternative condition known to produce parkinsonism and plausibly connected to the patient's symptoms, or, the expert evaluating physician, based on the full diagnostic assessment feels that an alternative syndrome is *more likely* than PD

Red flags
☐ 1. Rapid progression of gait impairment requiring regular use of wheelchair within 5 y of onset
☐ 2. A complete absence of progression of motor symptoms or signs over 5 or more y unless stability is related to treatment
☐ 3. Early bulbar dysfunction: severe dysphonia or dysarthria (speech unintelligible most of the time) or severe dysphagia (requiring soft food, NG tube, or gastrostomy feeding) within first 5 y
☐ 4. Inspiratory respiratory dysfunction: either diurnal or nocturnal inspiratory stridor or frequent inspiratory sighs
☐ 5. Severe autonomic failure in the first 5 y of disease. This can include:
   a) Orthostatic hypotension[32]—orthostatic decrease of blood pressure within 3 min of standing by at least 30 mm Hg systolic or 15 mm Hg diastolic, in the absence of dehydration, medication, or other diseases that could plausibly explain autonomic dysfunction, or
   b) Severe urinary retention or urinary incontinence in the first 5 y of disease (excluding long-standing or small amount stress incontinence in women), that is not simply functional incontinence. In men, urinary retention must not be attributable to prostate disease, and must be associated with erectile dysfunction
☐ 6. Recurrent (>1/y) falls because of impaired balance within 3 y of onset
☐ 7. Disproportionate anterocollis (dystonic) or contractures of hand or feet within the first 10 y
☐ 8. Absence of any of the common nonmotor features of disease despite 5 y disease duration. These include sleep dysfunction (sleep-maintenance insomnia, excessive daytime somnolence, symptoms of REM sleep behavior disorder), autonomic dysfunction (constipation, daytime urinary urgency, symptomatic orthostasis), hyposmia, or psychiatric dysfunction (depression, anxiety, or hallucinations)
☐ 9. Otherwise-unexplained pyramidal tract signs, defined as pyramidal weakness or clear pathologic hyperreflexia (excluding mild reflex asymmetry and isolated extensor plantar response)
☐ 10. Bilateral symmetric parkinsonism. The patient or caregiver reports bilateral symptom onset with no side predominance, and no side predominance is observed on objective examination

Criteria Application:
1. Does the patient have parkinsonism, as defined by the MDS criteria? Yes ☐ No ☐
   If no, *neither* probable PD nor clinically established PD can be diagnosed. *If yes:*
2. Are any absolute exclusion criteria present? Yes ☐ No ☐
   If "yes," *neither* probable PD nor clinically established PD can be diagnosed. *If no:*
3. Number of red flags present: ____
4. Number of supportive criteria present: ____
5. Are there at least 2 supportive criteria *and* no red flags? Yes ☐ No ☐
   If yes, patient meets criteira for clinically established PD. *If no:*
6. Are there more than 2 red flags? Yes ☐ No ☐
   If "yes," probable PD *cannot* be diagnosed. *If no:*
7. Is the number of red flags equal to, or less than, the number of supportive criteria? Yes ☐ No ☐
   If yes, patient meets criteria for probable PD

Scales of motion in Parkinson's disease

- **Gait pattern**
  - 0: Normal: No problems.
  - 1: Slight: Independent walking with minor gait impairment.
  - 2: Mild: Independent walking but with substantial gait impairment.
  - 3: Moderate: Requires an assistance device for safe walking (walking stick, walker) but not a person.
  - 4: Severe: Cannot walk at all or only with another person's assistance.
- **Stooped posture**
  - 0: Normal: No problems.
  - 1: Slight: Not quite erect, but posture could be normal for older person.
  - 2: Mild: Definite flexion, scoliosis or leaning to one side, but patient can correct posture to normal posture when asked to do so.
  - 3: Moderate: Stooped posture, scoliosis or leaning to one side that cannot be corrected volitionally to a normal posture by the patient.
  - 4: Severe: Flexion, scoliosis or leaning with extreme abnormality of posture.

3D motion capture

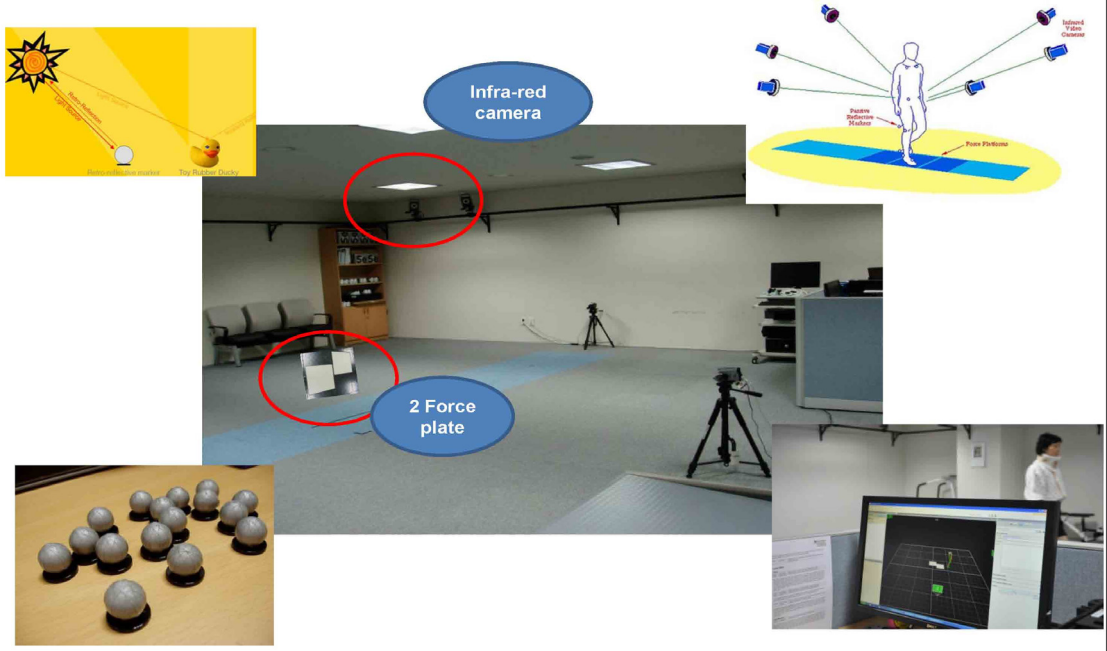
- **Postural instability**
  - 0: Normal: No problems: Recovers with one or two steps.
  - 1: Slight: 3-5 steps, but subject recovers unaided.
  - 2: Mild: More than 5 steps, but subject recovers unaided.
  - 3: Moderate: Stands safely, but with absence of postural response; falls if not caught by examiner.
  - 4: Severe: Very unstable, tends to lose balance spontaneously or with just a gentle pull on the shoulders.

SOT

- **Freezing of gait**
  - 0: Normal: No freezing.
  - 1: Slight: Freezes on starting, turning or walking through doorway with a single halt during any of these events, but then continues smoothly without freezing during straight walking.
  - 2: Mild: Freezes on starting, turning or walking through doorway with more than one halt during any of these activities, but continues smoothly without freezing during straight walking.
  - 3: Moderate: Freezes once during straight walking.
  - 4: Severe: Freezes multiple times during straight walking.

Accelerometer

해운대백병원 동작분석실



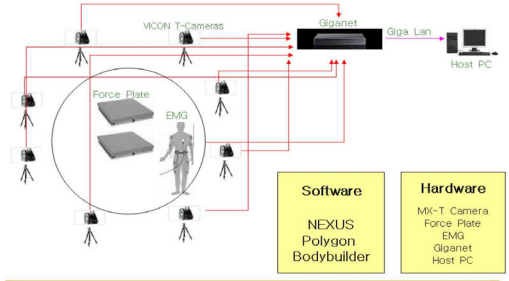
Parameter

Spatiotemporal parameters	Kinematics	Kinetics
• Cadence • Walking speed • Step length • Step width • Stride length • Step time • Stance phase • Swing phase	Joint angles • Flexion/extension • Abduction/adduction	• Joint moments • Joint power
Gait speed	Stooped posture Arm swing	Postural instability

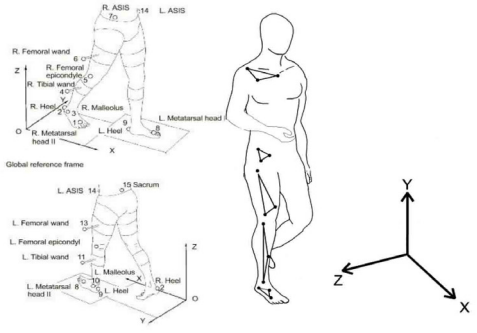
3D motion capture
- gait pattern

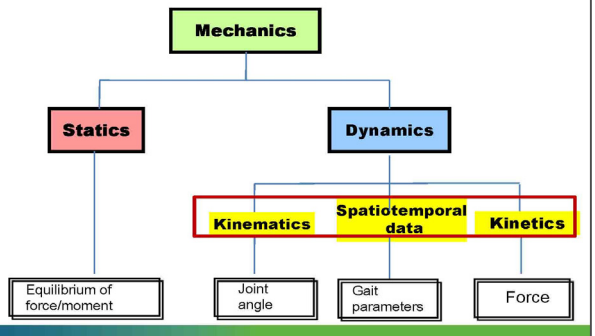
3D motion analysis

VICON System Setup



Retro-Reflective Marker Set
- Plug-in Gait Model





Stride parameters

➢ Stride length & Stride rate

- The most commonly studied linear kinematic parameters
- Stride length: distance covered by one stride
- Stride rate: the number of strides per minute

Walking speed = Stride length x Stride rate

Increase of walking speed

Stride length	Stride rate
Increase	
	Increase
Increase	Increase

Spatiotemporal parameters

➢ Stride & Step

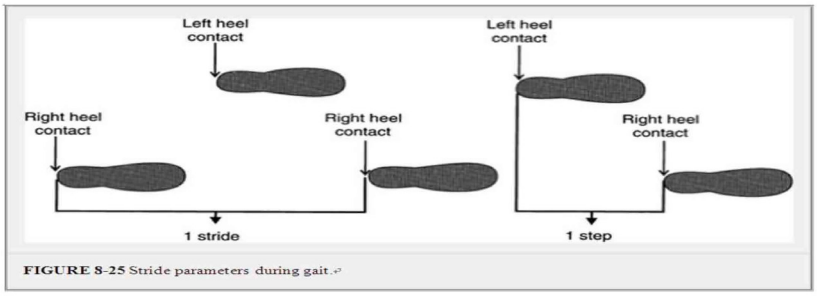
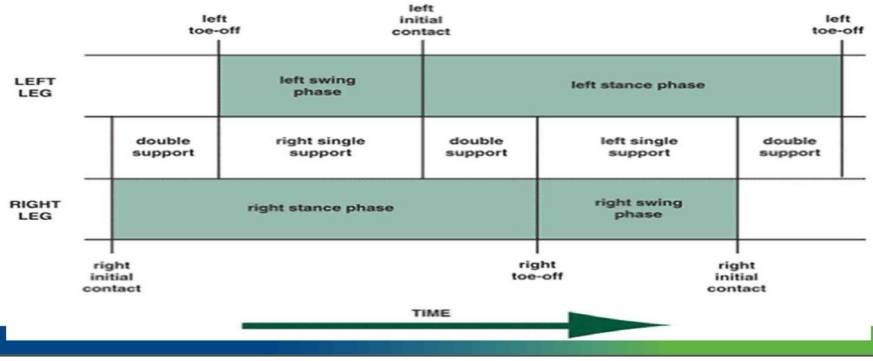


FIGURE 8-25 Stride parameters during gait.



Gait parameters

➢ Support & swing phase

Variable	Walking	Running	Sprint
Speed (m/s)	0.67-1.32	1.65-4.00	8.00-9.00
Stride length(m)	1.03-1.35	1.51-3.00	4.60-4.50
Cadence (steps/min)		79.00-118.00	132-200
Stride rate (Hz)	0.65-0.98	1.10-1.38	1.75-2.00
Cycle time (s) 1.55-1.02	0.91-0.73	0.57-0.50	
Stance (% of gait cycle)	66.00-60.00	59.00-30.00	25.00-20.00
Swing (% of gait cycle)	34.00-40.00	41.00-70.00	75.00-80.00

-Gait Parameters-

	Left	Right	Normal adult
Cadence	**119** steps/min	**118** steps/min	106 steps/min
Double Support	0.20 s	0.22 s	
Foot Off (Stance)	**58.4 %**	**61.8 %**	61.6 %
Opposite Foot Contact	48.5 %	52.0 %	49.9 %
Opposite Foot Off	9.90 %	11.8 %	11.5 %
Single Support	0.39 s	0.41 s	
Step Length	**0.45 m**	**0.46 m**	0.61 m
Step Time	0.52 s	0.49 s	0.51 s
Step Width	**0.18 m**	**0.18 m**	0.17 m
Stride Length	0.91 m	0.91 m	1.23 m
Stride Time	1.01 s	1.02 s	1.02 s
Walking Speed	**0.90** m/s	**0.89** m/s	1.16 m/s

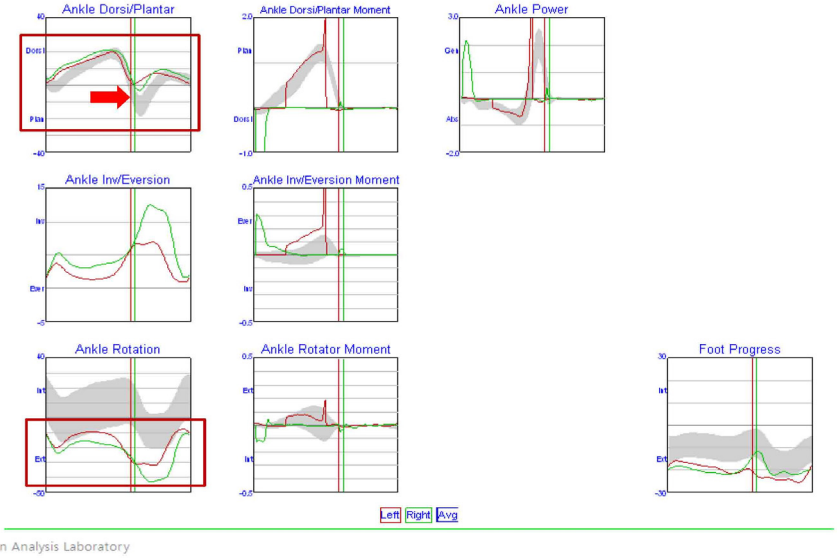
Normal adult

Parkinson's disease

PD patient

INJE University Haeundae Paik Hospital

Ankle

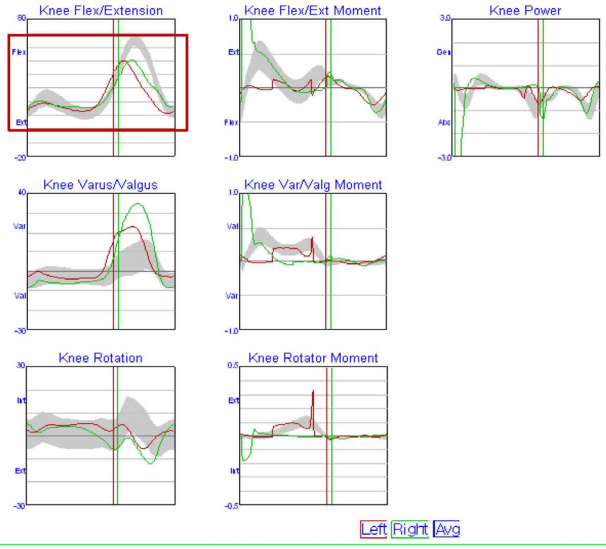


Motion Analysis Laboratory

PD patient

INJE University Haeundae Paik Hospital

Knee

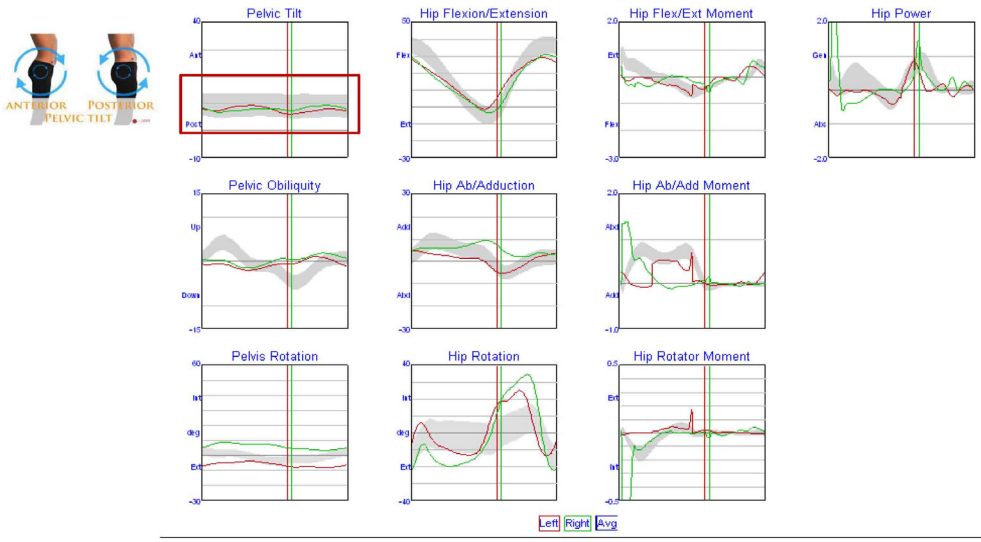


Motion Analysis Laboratory

PD patient

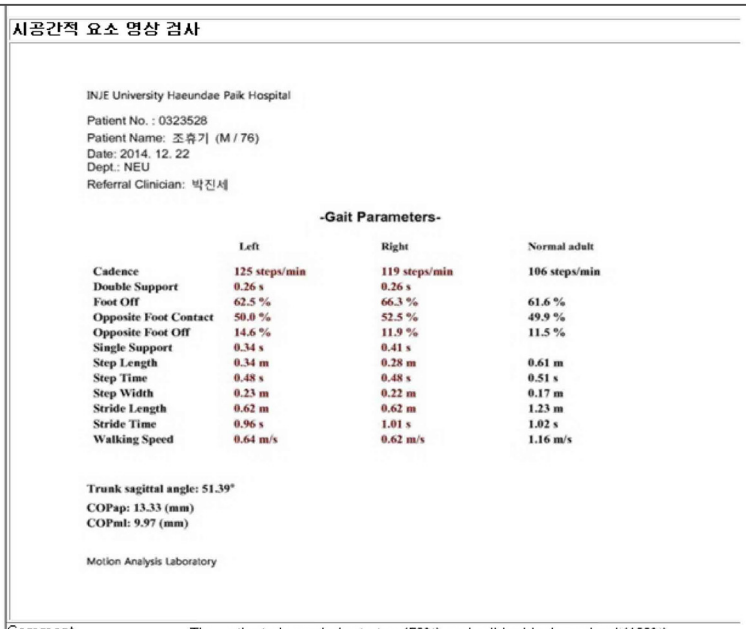
INJE University Haeundae Paik Hospital

Pelvis & Hip



Motion Analysis Laboratory

Parkinson's gait with camptocormnia



시공간적 요소 영상 검사

INJE University Haeundae Paik Hospital

Patient No. : 0323528
Patient Name: 조휴기 (M / 76)
Date: 2014. 12. 22
Dept.: NEU
Referral Clinician: 박진세

-Gait Parameters-

	Left	Right	Normal adult
Cadence	125 steps/min	119 steps/min	106 steps/min
Double Support	0.26 s	0.26 s	
Foot Off	62.5 %	66.3 %	61.6 %
Opposite Foot Contact	50.0 %	52.5 %	49.9 %
Opposite Foot Off	14.6 %	11.9 %	11.5 %
Single Support	0.34 s	0.41 s	
Step Length	0.34 m	0.28 m	0.61 m
Step Time	0.48 s	0.48 s	0.51 s
Step Width	0.23 m	0.22 m	0.17 m
Stride Length	0.62 m	0.62 m	1.23 m
Stride Time	0.96 s	1.01 s	1.02 s
Walking Speed	0.64 m/s	0.62 m/s	1.16 m/s

Trunk sagittal angle: 51.39°
COPap: 13.33 (mm)
COPml: 9.97 (mm)

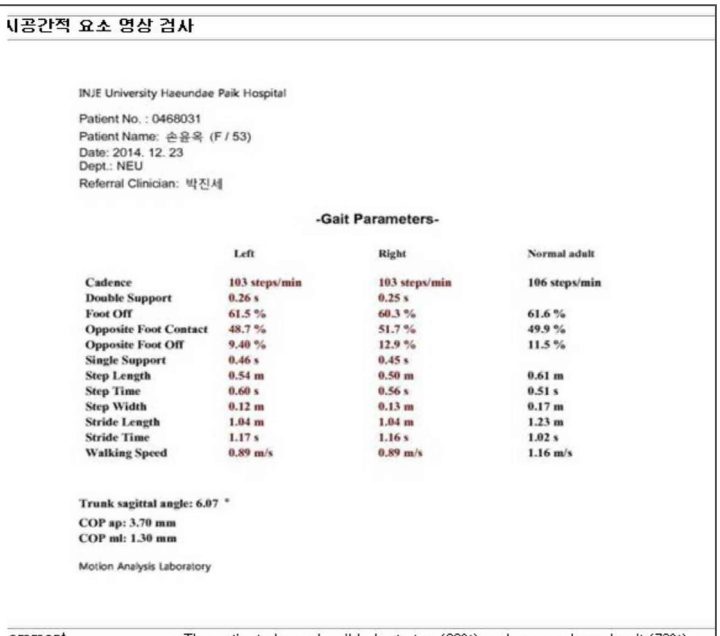
Motion Analysis Laboratory

Comment

The patient showed short step (52%) and mild wide-based gait(129%).
Cadenced is increased (115%) and walking speed is slow (55%).
He showed normal stance phase and swing phase.
Posturogrpahy showed severe stooped posture (51 degree).

Conclusions)
These findings are compatible with Parkinson's gait with camptocormnia

Early Parkinson's gait



시공간적 요소 영상 검사

INJE University Haeundae Paik Hospital

Patient No. : 0468031
Patient Name: 손윤옥 (F / 53)
Date: 2014. 12. 23
Dept.: NEU
Referral Clinician: 박진세

-Gait Parameters-

	Left	Right	Normal adult
Cadence	103 steps/min	103 steps/min	106 steps/min
Double Support	0.26 s	0.25 s	
Foot Off	61.5 %	60.3 %	61.6 %
Opposite Foot Contact	48.7 %	51.7 %	49.9 %
Opposite Foot Off	9.40 %	12.9 %	11.5 %
Single Support	0.46 s	0.45 s	
Step Length	0.54 m	0.50 m	0.61 m
Step Time	0.60 s	0.56 s	0.51 s
Step Width	0.12 m	0.13 m	0.17 m
Stride Length	1.04 m	1.04 m	1.23 m
Stride Time	1.17 s	1.16 s	1.02 s
Walking Speed	0.89 m/s	0.89 m/s	1.16 m/s

Trunk sagittal angle: 6.07 °
COP ap: 3.70 mm
COP ml: 1.30 mm

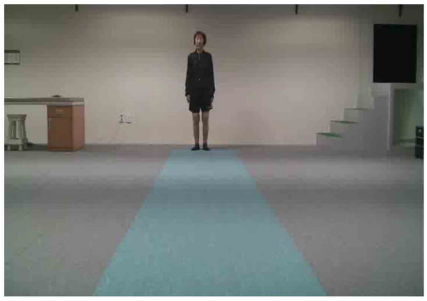
Motion Analysis Laboratory

omment

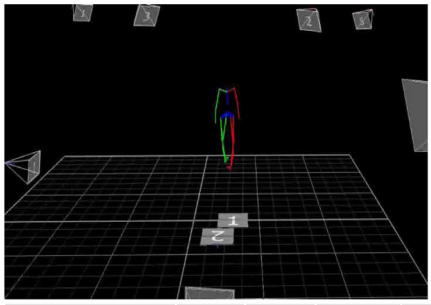
The patient showed mild short step (82%) and narrow-based gait (73%).
Cadenced is normal and walking speed is decreased (76%).
She showed normal stance phase and swing phase.
Posturography revealed upright posture (6 degree).

Conclusion)
These findings are suggestive of hypokinetic gait.

F/68



Normal gait ?

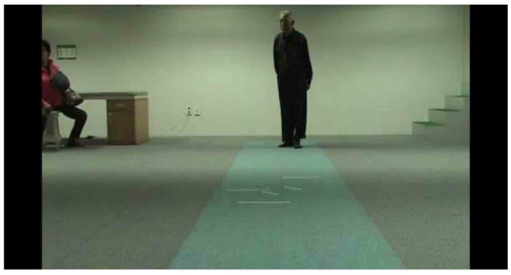


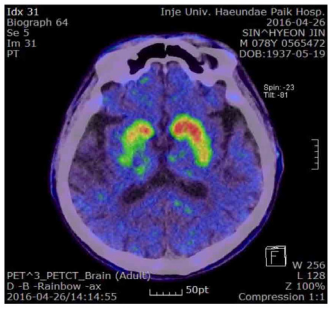
	left	right	Normal	Elderly	
Cadence	103	101	106	99.6	step/min
Double support	0.35	0.31		0.3	
Foot off (stance)	65	60.5	60.5	62.5	%
Opposite foot contact	51.3	47.9	49.9	50.1	%
Opposite foot off	16.2	13.4	11.5	12.6	%
Single support	0.41	0.41		0.45	
Step length	0.45	0.51	0.61	0.50	m
Step time	0.57	0.62	0.51	0.51	s
Step width	0.18	0.15	0.17	0.13	m
Stride length	0.92	0.95	1.23	0.99	m
Stride time	1.17	1.19	1.02	1.21	s
Walking speed	0.79	0.81	1.16	0.82	m/s

→ Senile gait

Early stage of Parkinsonian gait

M/78



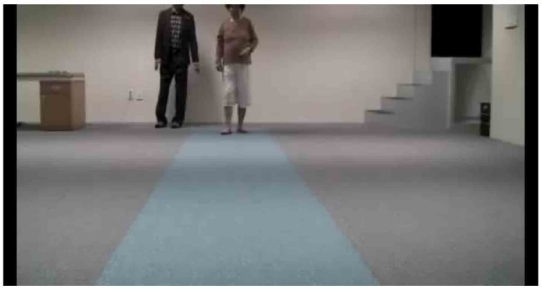


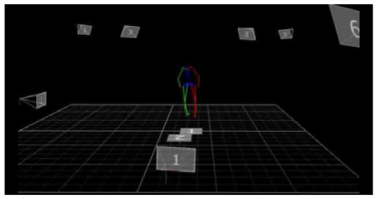
Short step gait

	left	right	Normal	Elderly	
Cadence	120	118	106	99.6	step/min
Double support	0.24	0.25		0.3	
Foot off (stance)	59.0	65.7	60.5	62.5	%
Opposite foot contact	45.0	55.9	49.9	50.1	%
Opposite foot off	10.0	14.7	11.5	12.6	%
Single support	0.35	0.42		0.45	
Step length	0.38	0.40	0.61	0.50	m
Step time	0.55	0.45	0.51	0.51	s
Step width	0.20	0.21	0.17	0.13	m
Stride length	0.79	0.79	1.23	0.99	m
Stride time	1.00	1.02	1.02	1.21	s
Walking speed	0.79	0.78	1.16	0.82	m/s

Increased cadence (19%)
Decreased step length (22%)
Decreased walking speed (5%)

Decreased arm swing





Hypokinetic gait
Short step
Decreased arm swing

	left	right	normal	
Anteversion	9.89	16.07	10	°
Retroversion	2.58	2.90	25	°
Arm swing amplitude	12.47	18.97		
Arm swing asvmmetric index	20.68			

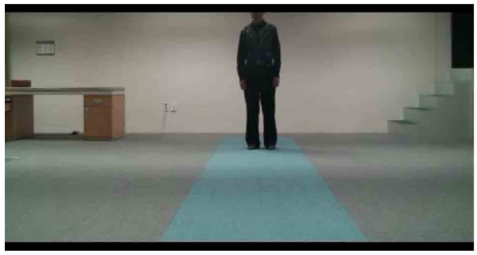
$$I_A = \left| \frac{\text{arm swing}_{left} - \text{arm swing}_{right}}{\text{arm swing}_{left} + \text{arm swing}_{right}} \right| \times 100\%$$

	left	right	normal	
Cadence	52.3	52.6	99.6	step/min
Double support	0.93	0.86	0.3	
Foot off (stance)	69.7	71.1	62.5	%
Opposite foot contact	50.9	49.1	50.1	%
Opposite foot off	21.9	15.8	12.6	%
Single support	0.66	0.76	0.45	
Step length	0.33	0.31	0.50	m
Step time	1.12	1.16	0.51	s
Step width	0.23	0.20	0.13	m
Stride length	0.61	0.62	0.99	m
Stride time	2.28	2.28	1.21	s
Walking speed	0.27	0.27	0.82	m/s

Decreased cadence (47%)
Decreased step length (38%)
Decreased retroversion arm swing (90%)
Decreased walking speed (68%)

Evaluation of L-dopa response

First day, No medication



7 days later, Levodopa 100mg tid

	left	right	normal	
Cadence	87.6	93.7	106	step/min
Double support	0.5	0.4		
Foot off (stance)	67.9	65.6	61.6	%
Opposite foot contact	53.3	50.0	49.9	%
Opposite foot off	21.9	15.6	11.5	%
Single support	0.43	0.44		
Step length	0.42	0.41	0.61	m
Step time	0.64	0.64	0.51	s
Step width	0.16	0.18	0.17	m
Stride length	0.79	0.82	1.23	m
Stride time	1.37	1.28	1.02	s
Walking speed	0.58	0.64	1.16	m/s
Arm swing amplitude	11.6	5.66		

	left	right	normal	
Cadence	96.8	96.0	106	step/min
Double support	0.46	0.47		
Foot off (stance)	69.4	68.0	61.6	%
Opposite foot contact	48.4	51.2	49.9	%
Opposite foot off	16.1	20.8	11.5	%
Single support	0.4	0.38		
Step length	0.47	0.48	0.61	m
Step time	0.64	0.61	0.51	s
Step width	0.18	0.17	0.17	m
Stride length	0.84	0.94	1.23	m
Stride time	1.24	1.25	1.02	s
Walking speed	0.68	0.75	1.16	m/s
Arm swing amplitude	14.8	11.24		

Walking speed 17%, arm swing amplitude 50% increased

Evaluation for DBS

Pre operation "off" state

Freezing of gait, short step gait

POD 4 days "off" state

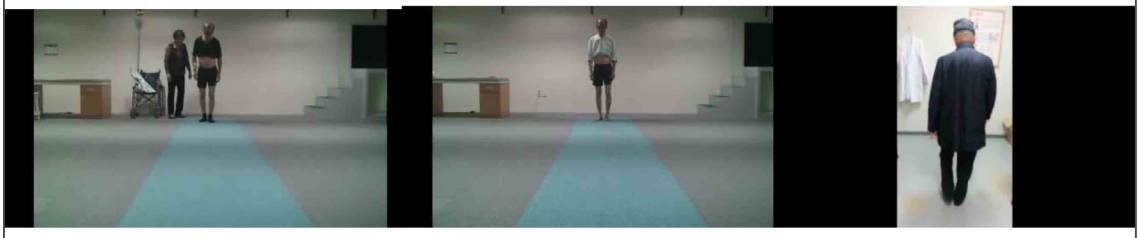
Improved freezing of gait
Improved short step gait

	left	right	normal	
Cadence	138	138	106	step/min
Double support	0.31	0.29		
Foot off (stance)	69.0	64.4	61.6	%
Opposite foot contact	55.2	44.8	49.9	%
Opposite foot off	21.8	13.8	11.5	%
Single support	0.29	0.27		
Step length	0.37	0.26	0.61	m
Step time	0.64	0.63	0.51	s
Step width	0.26	0.25	0.17	m
Stride length	0.63	0.64	1.23	m
Stride time	0.87	0.87	1.02	s
Walking speed	0.72	0.74	1.16	m/s

	left	right	normal	
Cadence	88.9	82.8	106	step/min
Double support	0.36	0.35		
Foot off (stance)	65.2	56.6	61.6	%
Opposite foot contact	41.3	45.7	49.9	%
Opposite foot off	17	8.97	11.5	%
Single support	0.52	0.47		
Step length	0.48	0.58	0.61	m
Step time	0.60	0.85	0.51	s
Step width	0.2	0.16	0.17	m
Stride length	1.1	1.07	1.23	m
Stride time	1.35	1.45	1.02	s
Walking speed	0.81	0.74	1.16	m/s

Increased cadence (40%), Increased step length (36%)
No interval change of walking speed

Pre-op evaluation for DBS



Pre op "Off" state
UPDRS= **44**

	left	right	normal	
Cadence	190	148	106	step/min
Double support	0.28	0.39		
Foot off (stance)	69.8	71.6	61.6	%
Opposite foot contact	41.3	45.7	49.9	%
Opposite foot off	15.9	22.2	11.5	%
Single support	0.16	0.19		
Step length	0.07	0.04	0.61	m
Step time	0.37	0.44	0.51	s
Step width	0.18	0.18	0.17	m
Stride length	0.09	0.12	1.23	m
Stride time	0.63	0.81	1.02	s
Walking speed	0.14	0.15	1.16	m/s

Pre op "On" state
UPDRS=**18**, LEDD= **1035**

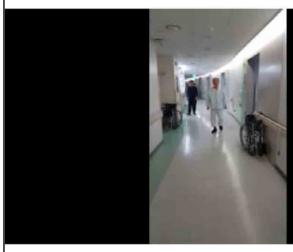
	left	right	normal	
Cadence	109	112	106	step/min
Double support	0.22	0.22		
Foot off (stance)	61.8	59.8	61.6	%
Opposite foot contact	52.7	48.6	49.9	%
Opposite foot off	16.5	16.5	11.5	%
Single support	0.46	0.42		
Step length	0.5	0.47	0.61	m
Step time	0.52	0.55	0.51	s
Step width	0.18	0.18	0.17	m
Stride length	0.95	0.98	1.23	m
Stride time	1.10	1.07	1.02	s
Walking speed	0.86	0.91	1.16	m/s

Post op 1 month "On" state
UPDRS=**18**, LEDD= **390**

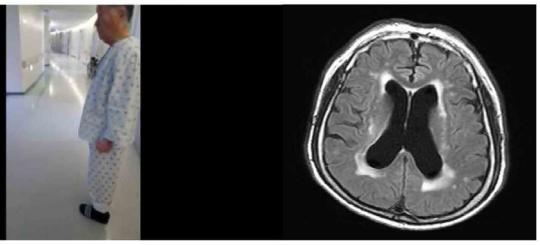
	left	right	normal	
Cadence	101	102	106	step/min
Double support	0.26	0.24		
Foot off (stance)	58.8	61.9	61.6	%
Opposite foot contact	47.9	52.5	49.9	%
Opposite foot off	10.9	11.0	11.5	%
Single support	0..44	0.49		
Step length	0.51	0.48	0.61	m
Step time	0.62	0.56	0.51	s
Step width	0.16	0.16	0.17	m
Stride length	1.01	0.99	1.23	m
Stride time	1.19	1.18	1.02	s
Walking speed	0.85	0.84	1.16	m/s

Normal pressure hydrocephalus

Pre-lumbar drainage



Post-lumbar drainage

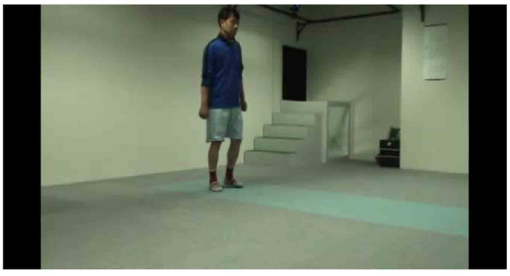


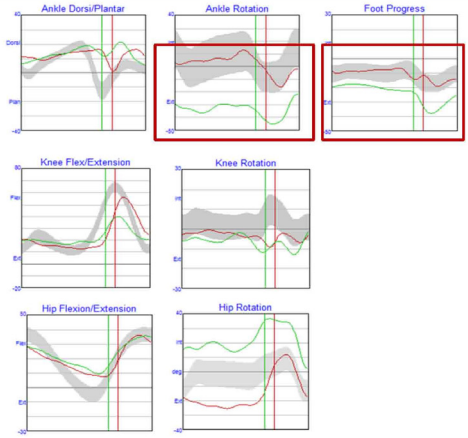
	left	right	normal	
Cadence	102	103	99.6	step/min
Double support	0.44	0.37	0.3	S
Foot off (stance)	64.4	67.5	62.5	%
Opposite foot contact	45.8	54.7	50.1	%
Opposite foot off	18.6	18.8	12.6	%
Single support	0.32	0.42	0.45	S
Step length	0.27	0.25	0.50	M
Step time	0.64	0.53	0.51	S
Step width	0.24	0.23	0.13	m
Stride length	0.54	0.54	0.99	m
Stride time	1.18	1.17	1.21	s
Walking speed	0.46	0.46	0.82	m/s

	left	right	normal	
Cadence	100	100	99.6	step/min
Double support	0.50	0.46	0.3	S
Foot off (stance)	69.2	72.5	62.5	%
Opposite foot contact	48.3	51.7	50.1	%
Opposite foot off	20.8	20	12.6	%
Single support	0.33	0.38	0.45	S
Step length	0.28	0.29	0.50	M
Step time	0.62	0.58	0.51	S
Step width	0.23	0.23	0.13	m
Stride length	0.57	0.58	0.99	m
Stride time	1.2	1.2	1.21	s
Walking speed	0.47	0.48	0.82	m/s

Minimal change between pre and post lumbar drainage

Ataxic gait





	left	right	normal	
Cadence	99.9	92.2	106	step/min
Double support	0.3	0.42		
Foot off (stance)	66.9	61.7	61.6	%
Opposite foot contact	50.9	49.1	49.9	%
Opposite foot off	16.5	16.5	11.5	%
Single support	0.51	0.4		
Step length	0.3	0.28	0.61	m
Step time	0.5	0.71	0.51	s
Step width	0.27	0.32	0.17	m
Stride length	0.62	0.38	1.23	m
Stride time	1.22	1.33	1.02	s
Walking speed	0.52	0.28	1.16	m/s

Research for 3D motion analysis

	Without arm weight	With arm weight	*p*
Cadence (steps/min)	101.78 ± 13.44	109.24 ± 12.94	0.000*
Walking speed (m/sec)	0.62 ± 0.19	0.73 ± 0.22	0.000*
Stride time (sec)	1.21 ± 0.21	1.12 ± 0.15	0.000*
stride length (m)	0.73 ± 0.21	0.81 ± 0.22	0.007*
Double support (sec)	0.35 ± 0.11	0.29 ± 0.10	0.000*
Stance phase (% gait cycle)	64.14 ± 4.02	62.79 ± 3.71	0.004*
Swing phase (% gait cycle)	35.57 ± 4.29	37.12 ± 3.67	0.001*

	Without arm weight	With arm weight	*p*
Arm swing (°)			
Anteversion	10.15 ± 9.63	17.98 ± 9.16	0.000*
Retroversion	6.47 ± 9.08	10.06 ± 8.15	0.000*
Amplitude	16.61 ± 10.19	28.45 ± 12.80	0.000*
Pelvic kinematics (°)			
Pelvic tilt	2.93 ± 1.13	2.84 ± 1.36	0.553
Pelvic obliquity	3.98 ± 1.43	4.12 ± 5.09	0.559
Pelvic rotation	5.78 ± 2.16	6.70 ± 2.63	0.013*

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The effects of additional arm weights on arm-swing magnitude and gait patterns in Parkinson's disease

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HIGHLIGHTS

- Decreased arm swing is a typical gait characteristic in Parkinson's disease.
- Adding weight to the arm facilitates limb movements in Parkinson's disease.
- Additional arm weight improves gait disturbance in Parkinson's disease.

ABSTRACT

Objective: Recently, arm facilitation has been interested in gait rehabilitation. However, there have been few studies concerning arm facilitation in patients with Parkinson's disease (PD). The aim of our study was to investigate the effect of increasing arm weights on gait pattern in patients with PD.
Methods: Twenty-seven patients with PD were enrolled, and they underwent gait analysis using a three-dimensional motion capture system. Sandbags were applied to the distal forearms in all participants. We compared gait parameters including arm swing, pelvic motion, spatiotemporal data, and relative rotational angle between the weighted and unweighted gaits.
Results: The total arm-swing amplitude and pelvic rotation were significantly higher when walking with additional arm weights than without arm weights. Cadence, walking speed, stride length, and swing phase were significantly higher, whereas stride time, double-support time, and stance phase were significantly lower, when walking with additional arm weights than without arm weights.
Conclusion: We conclude that adding weights to the arm during walking may facilitate arm and pelvic movements, which results in changes to gait patterns. The therapeutic use of additional arm weights could be considered for gait rehabilitation in PD to improve gait impairment.
Significance: Arm-swing facilitation using weight load improved gait in Parkinson's disease.

1. Introduction

Gait disturbance and postural instability have been thoroughly described in Parkinson's disease (PD). Slow velocity with shuffling, dragging steps, small stride/step length, forward-stooped gait, and decreased arm swing are typical gait characteristics in PD.

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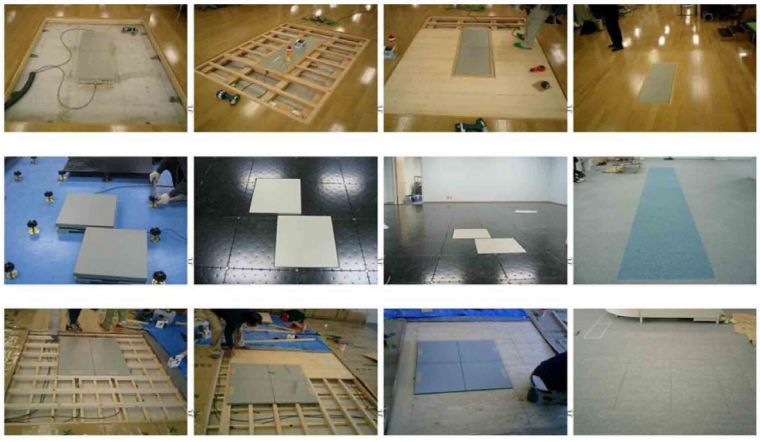
1388-2457/

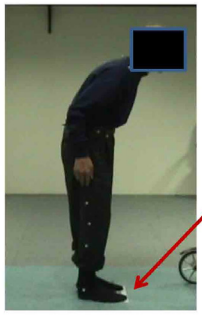
Force plate
Postural instability

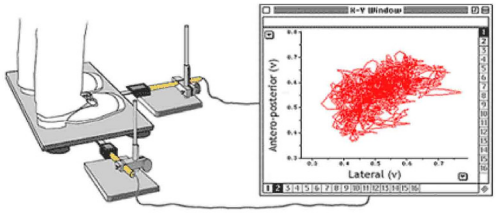
Forceplate - AMTI

- 508*464 size
- 6-axis F/T sensor
- Strain Gauge Type
- Movable Long Rail



Static posturography

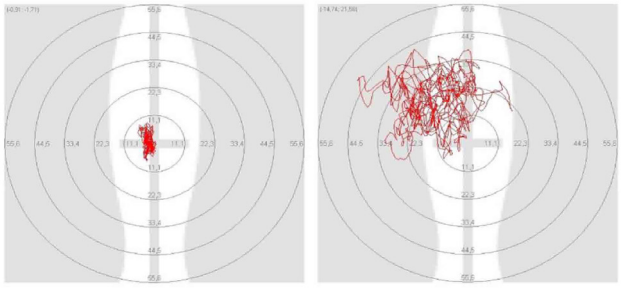




Static Posturography (stabilometry)

- Places the subject in a standing posture on a force plate connected to force and movement transducers, which are able to detect the tiny oscillations of the body.

Static posturography



Healthy control　　Parkinson's disease

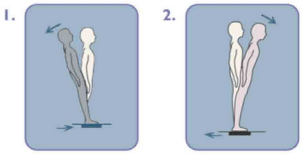
- **Center of Pressure** : point at which pressure of body over the sole if it were concentrated in one spot
  - AP length
  - ML length
  - Area
  - Oscillation (velocity)

Dynamic posturography

- Motor control
  - measurement of sway in response to tilt or translation in the support surface
  - Functional limit of stability, support surface translation, adaptation test
- Sensory control
  - Measurement of sway under various visual and support conditions
  - Sensory organization test, Head-shake sensory organization test

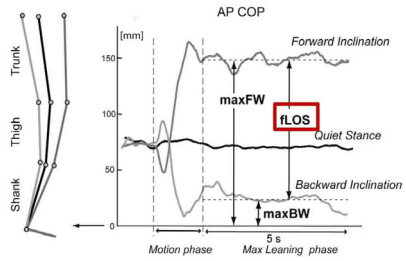
Dynamic posturography –motor control

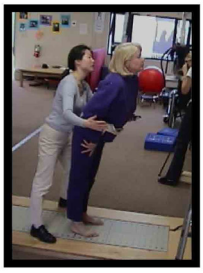
1. Support surface translation

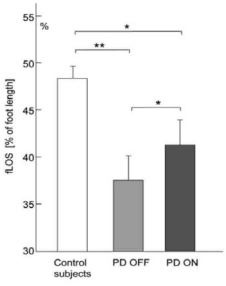


Forward/Backward Translations

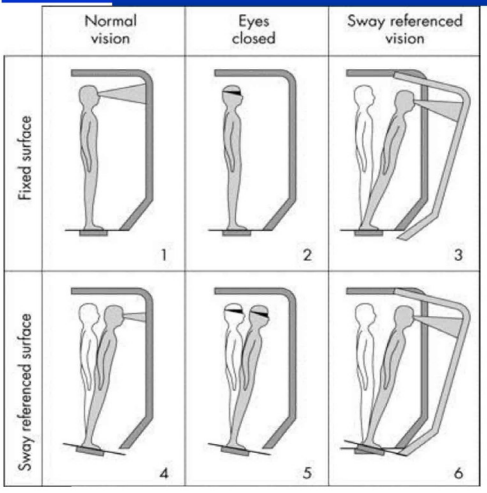
2. Functional limit of stability (fLOS)
= AP COP length in Max(forward)-Max(backward)

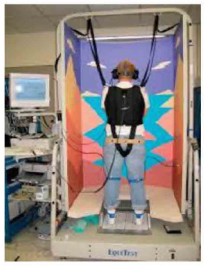






Dynamic posturography –sensory organization test (SOT)





- Tested outcome : COG (center of gravity)

Six sensory condition

(1) Immobile surface, immobile visual surround, eyes open.
(2) Immobile surface, eyes closed.
(3) Immobile surface, mobile visual surround, eyes open.
(4) Mobile surface, immobile visual surround, eyes open.
(5) Mobile surface, eyes closed.
(6) Mobile surface, mobile visual surround, eyes open.

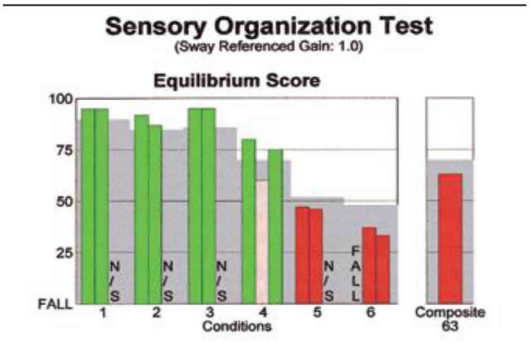
Table 2. Sensory information available during organization tests[10]

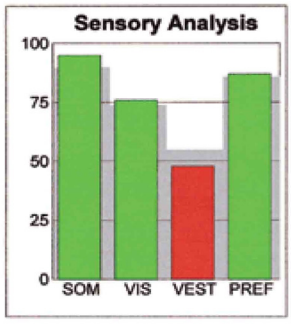
SOT conditions	Visual surround	Platform	Accurate sensory feedback	Altered sensory feedback
1	Fixed	Fixed	Vis, vest, prop	-
2	Eye closed	Fixed	Vest, prop	-
3	Sway-ref'd	Fixed	Vest, prop	Vis
4	Fixed	Sway-ref'd	Vis, vest	Prop
5	Eye closed	Sway-ref'd	Vest	Prop
6	Sway-ref'd	Sway-ref'd	Vest	Vis, prop

vis; visual, vest; vestibular, prop; proprioceptive, sway-ref'd; sway referenced

Sensory organization test (SOT)

- Somatosensory input = condition2/condition1 x 100
- Visual input = condition4/condition1 x 100
- Vestibular input = condition5/condition1 x 100
- Balance score = arithmetic mean of the three individual scores
- Composite score = the weighted average of the scores of all sensory condition





Research for force plate

wedge	vision	AP direction		ML direction	
		range (cm)	velocity (cm/s)	range (cm)	velocity (cm/s)
no wedge	EO	3.17 ± 1.46	37.07 ± 9.73	2.47 ± 1.56	42.71 ± 9.03
	EC	3.51 ± 1.66	36.52 ± 9.46	2.68 ± 1.78	43.53 ± 10.11
wedge	EO	3.32 ± 1.91	34.52 ± 8.35	2.05 ± 1.26	41.67 ± 8.47
	EC	3.27 ± 1.67	33.92 ± 7.89	2.10 ± 1.89	41.89 ± 8.13
two-way ANOVA	wedge effect	p=0.627	p=0.002*	p=0.002*	p=0.008*
	vision effect	p=0.805	p=0.059	p=0.529	p=0.026*
	interaction	p=0.264	p=0.925	p=0.559	p=0.232

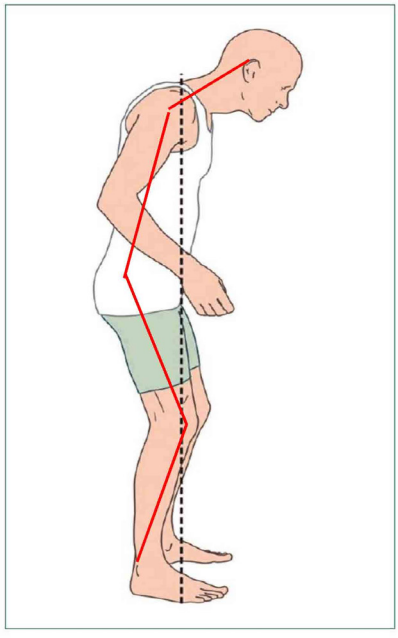
Haeundae paik hospital

3D motion capture -stooped posture

Stooped posture

- Postural deformity is inevitable in advanced PD
- Complication
  : pain, swallowing difficulty, shortness of breath, visual disruption, radiculopathy

- Camptocormia
  At least 45 degree thoracolumbar flexion
- Antecollis
  Forward flexion of the head and neck
- Pisa syndrome or scoliosis
  Lateral flexion of the trunk

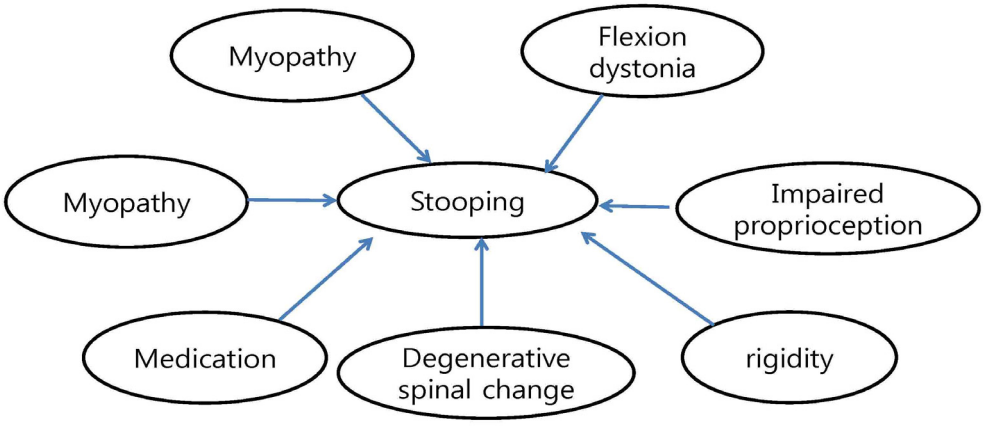


Stooped posture

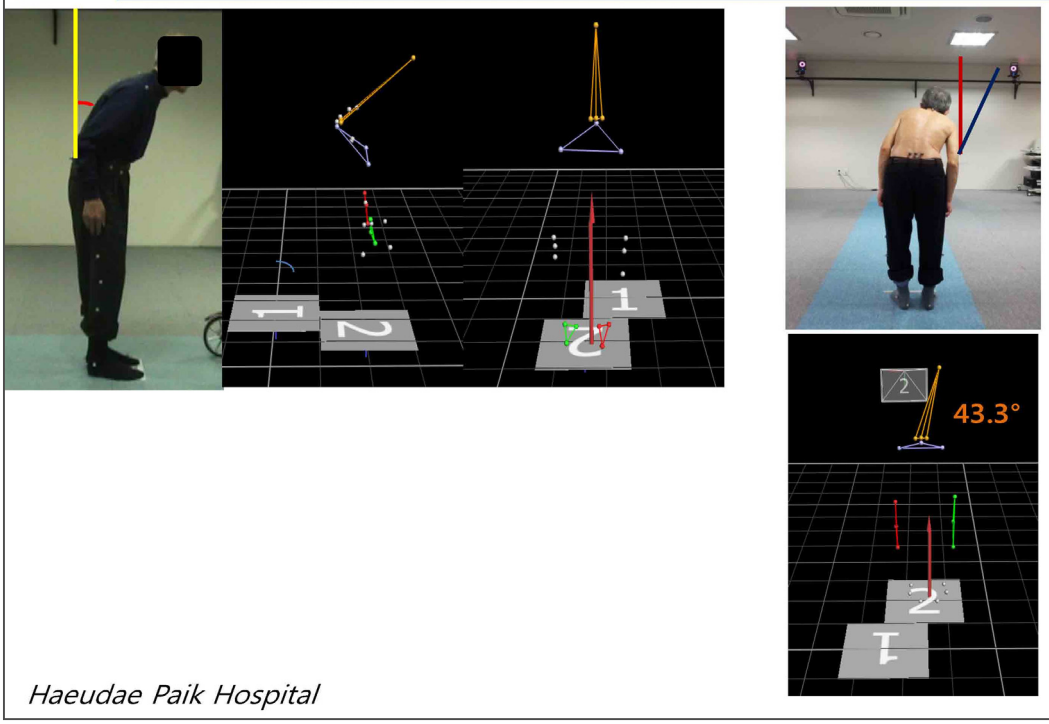
- Camptocormia
  At least 45 degree thoracolumbar flexion
- Antecollis
  Forward flexion of the head and neck
- Pisa syndrome or scoliosis
  Lateral flexion of the trunk

Stooped posture

Pathophysiology
- Not well understood

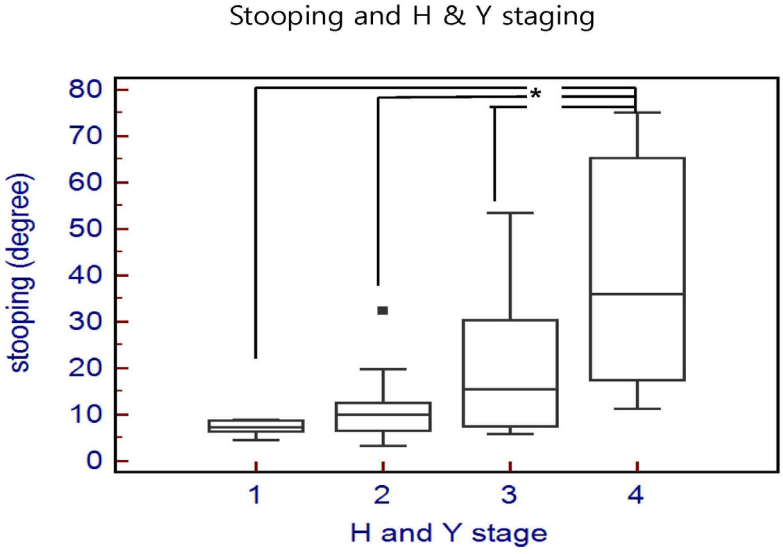


Truncal angle (sagittal and coronal)



Haeudae Paik Hospital

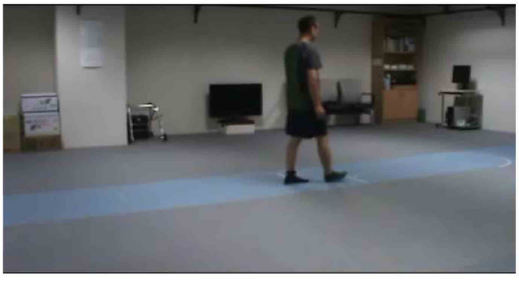
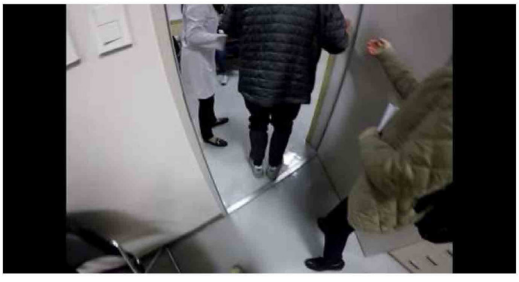
Stooping in PD



Haeundae paik Hospital

Wearable sensor :Freezing of gait

Freezing of gait in PD

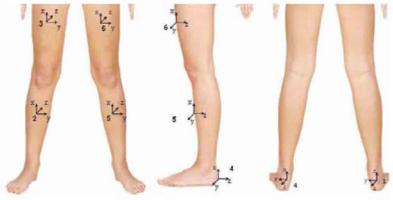
It is difficult to elicit FOG in hospital!!

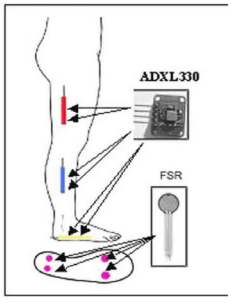
- Unpredictability
- Short time of the FOG test
- Hospital is ideal circumstance (wide corridor, flat floor..)

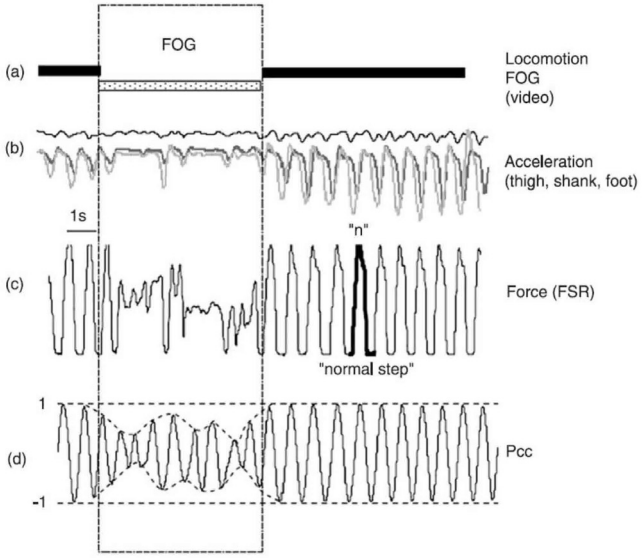
→ Some intervention is needed

Assessment of FOG

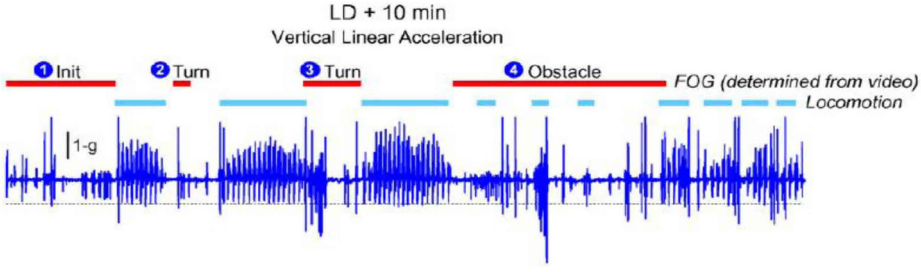
- Ambulatory device (vertical linear acceleration)







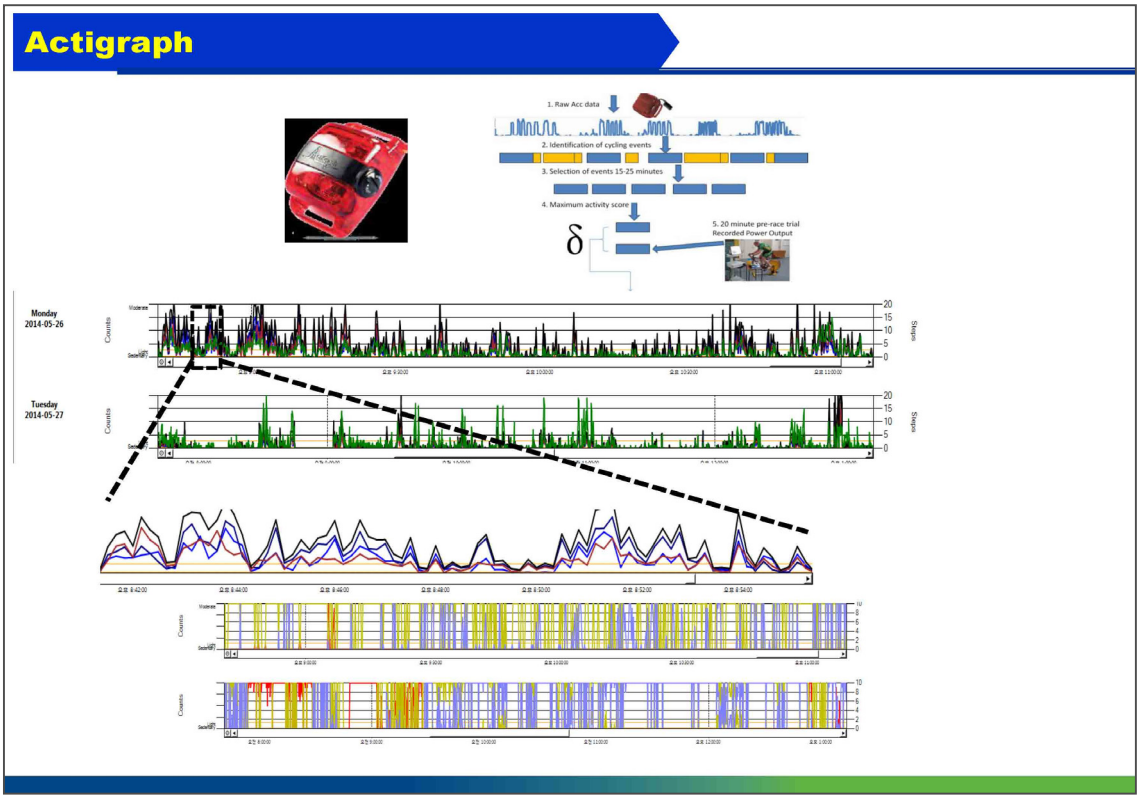
Freezing index



FOG index (FI)

$$\frac{\text{Signal power in freeze band}}{\text{signal power in locomotion band}}$$


엠파워(mPower)
• 파킨슨병 관련 연구 앱
• 로체스터 대학교 & 세이지 바이오 네트웍스
• 파킨슨병 증상 정보 제공
애스머 헬스(Asthma health)
• 천식 관련 연구 앱
• 마운트 시나이, 코넬 의과대학
• 기온이나 유독가스, 오존 수치 등 대기 상태를 토대로 간단한 천식 관리 기능 제공
마이하트 카운츠(MyHeart Counts)
• 심혈관 질환
• 스탠퍼드 대학, 옥스퍼드 대학
• 라이프 스타일이나 활동이 심혈관 질환에 어떤 영향을 미치는지 조사
글루코석세스(GlucoSuccess)
• 당뇨병
• 매사추세츠 종합병원
• 식사나 운동, 약물 등이 혈당에 미치는 영향 조사
셰어 더 저니(Share the Journey)
• 유방암
• 다나-파버 암연구소
• 치료에 사용되는 화학요법의 장기적 효과 추적 연구
팀 쿡의 승부수 '리서치킷'
무병장수 시대 이끈다
헬스케어 시장을 겨냥한 애플의 행보가 본격화됐다. 애플은 지난해 iOS용 헬스케어 데이터를 취합해 보여주는 '헬스킷'과 '헬스' 플랫폼을 선보인 데 이어 최근 앱 개발 도구인 '리서치킷'도 발표했다. 리서치킷은 iOS 단말에 있는 GPS와 내장센서 등을 이용해 환자 상태데이터를 수집해 앱을 개발하도록 지원한다. 이로써 애플은 건강 관련 정보를 취합하고 활용해 다양한 질병을 연구·관리할 수 있는 인프라를 마련했다.
– 김달기자 kt@etnews.com
etview Plus
etview.etnews.com


Actigraph
1. Raw Acc data
2. Identification of cycling events
3. Selection of events 15-25 minutes
4. Maximum activity score
5. 20 minute pre-race trial Recorded Power Output
δ
Monday 2014-05-26
Tuesday 2014-05-27
Counts
Steps

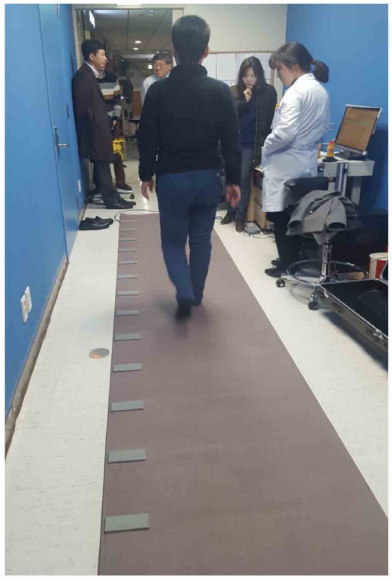
보 험 수 가

인정비급여

1.	에너지 소모분석	5만원
2.	운동역학 : Kinematic parameter	5만원(1개 관절)
3.	역동적 근전도 분석 : Spatiotemporal parameter	5만원
4.	동작분석의 생역학	15만원(3개 관절)
5.	족저압 측정	5만원

수가코드 : 파킨슨병환자의 역동적 보행분석
- Spatiotemporal parameter : 역동적근전도 분석 – 5만원
- Kinematic parameter : 운동역학(2개관절) + 역동적 근전도 – 15만원

보행연구회



Gaitrite

KMDS산하 보행연구회

- **보행분석 연구**
- **보행분석과 관련한 제품 개발**
- **신의료기술개발 및 신청**


Thank you for your attention !!!!
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