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IMU-based Gait analysis for Determining proper assistive device with disabled patients : Case serial

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Gait analysis with IMU technology is effective for people who cannot walk independently in two ways. In previous study, we presented that IMU-based gait analysis allow us to evaluate gait patterns with patients, who needs handling assistive devices. Furthermore, we described its helpfulness for determining best-fitting assistive devices for rehabilitation. Recent days, we focused on utilizing IMU-based gait analysis for making decision of proper assistive device. It can provide quantitative information of gait parameters without consideration of specific environments and surroundings, so, it is useful for determining the most suitable assistive device for disabled patient. Currently, we initially evaluate gait patterns of patients on first day of their transfer, admission(inpatient) or visit(out-patient) to conclude the most affordable device in tailored way. 10 patients with several disease entities were recruited in this study. Table 1 shows baseline characteristic of patients. Testing tool was Humantrack(Figure 1.), which equipped with fusion-sensor system composed with wireless IMU sensor and Stereo camera. First, IMU sensor provided to patients' abdomen, both thigh, shank and foot dorsum(Figure 1.). And next, calibration of axis was done. Then, patients gait 6m with several assistive devices with video monitoring. During the gait, gait parameters(14 items: gait cycle time(sec), stance phase(%), swing phase(%), velocity(m/s), stride length(m), cadence(step/min), preswing(%), initial double support time(%), initial single support time(%), terminal double support time(%), terminal single support time(%), hip joint angle(deg), knee joint angle(deg), ankle joint angle(deg) were detected. Figure 2. shows the result of gait evaluation. The priority factors we gave significance more than others were gait cycle time, stance phase, swing phase, velocity and stride length. All patients were tolerable during 6m gait with IMU-gait evaluation. Patients were evaluated with various assistive devices for finding the fittest one, respectively. If the result showed no significant difference or better performance in superior assistive between two gait analyses, superior level handling devices was adapted. In contrast, if there was difference, inferior level handling devices was adapted. Patient 1-7 shows cases of final choice with superior level handling devices. And Patient 8 presents final choice of inferior level handling device. In addition, Patient 9-10 appears the fittest choice of assistive device among 3 or more options. Compared to previous case study, we think there are variations due to patient characteristics such as age, sex, disease entity and general condition. Therefore, there must be a consideration of these affecting factors. We shows that IMU-based gait analysis may shed light on evaluating disabled patients' gait patterns quantitatively with accuracy, ones again.

Table 1. Baseline characteristics

	Disability	Determined Assistive device
Patient 1 M/65	Right hemiplegia d/t left basal ganglia and left frontal ICH, s/p Left frontotemporal craniotomy, hematoma removal (17/3/12)	Mono-cane vs. Quad-cane ->Mono-cane
Patient 2 M/67	Gait disturbance due to a SAH(18/3/7) b. r/o frontal lobe Syndrome	Independent vs. Mono-cane ->Independent
Patient 3 F/79	Tetraplegia d/t SCI, ASIA D Spine : 1) myelopathy, C4-5 level 2) Disc extrusion, right central zone or OPLL 3) Disc protrusion, left central zone	Quad-cane vs. Walker ->Quad-cane
Patient 4 M/56	Gait disturbance d/t traumatic SDH along the falx and and bilateral tentorium(2018/4/10)	Independent vs. Mono-cane ->Independent
Patient 5 M/60	Right side weakness d/t cervical myelopathy, C4-5, s/p AIF(2017/6/20)	Independent vs. Quad-cane ->Independent
Patient 6 M/49	Right hemiplegia d/t left pons ICH (2017/4/25)	Independent vs. Quad-cane ->Independent
Patient 7 F/76	General deconditioning d/t Gallbladder stone with cholecystitis s/p laparoscopic cholecystectomy(18/2/13)	Mono-cane vs. Walker ->Mono-cane
Patient 8 F/60	Gait disturbance d/t r/o radiculopathy, L3/4	Quad-cane vs. Walker ->Walker
Patient 9 M/11	Gait disturbance d/t cauda equina syndrome(2018/3/5)	Compared Independent, unilateral Mono-cane, bilateral Mono-cane and Forearm crutch ->Independent
Patient 10 M/85	Gait disturbance d/t Chronic SDH at left cerebral convexity(2018/1/28) 2) R/O recent infarction at right side pons	Compared Mono-cane, Quad-cane and walker ->Q-cane

table 3-12. Gait parameters, Patient 1-10

	Moro-care	lono-cane		185. 1		Independe	nt	Mono-can	6		Mono-cane	8	Walker	_
	12	2	11	RL .		11	19	19	21	-	lt.	5	Lt.	2
ait cycle time(sec)	23	23	23	26	gait orde time/sed	12	12	12	12	gait gole time(sed)	17	18	3	12
tace phase[%]	59.8	55.6	572	49.9	stance phase(%)	651	61.1	64.6	60.8	stance phase(%)	581	567	68.4	61.1
wing phase(%)	40.2	444	42.8	50.1	swing phase(%)	339	38.9	354	392	swing phase(%)	419	433	316	389
elocity(n/s)	0.9	66	1	85	velocity(m/s)	0.8	0.8	0.9	1	velocity(m/s)	0.7	0.5	0.4	0.5
itide Length(m)	0.5	05	0.7	03	stride Length (m)	1000				stride Length(m)	0.5	85	0.4	03
cadence (step/min)					cadence (step/min)	967	2.59	963	965	cadence (step/min)	-	-	1	-
zeswing[8]	882	556	572	49.9	pre-swina%)	161	14.0	200	car.	pre-sairo(%)	581	557	68.4	61.1
nital double support time(%)	194	29	29.2	123	initial double support time(%)	122	153	161	115	initial double support time(%)	132	9.8	43.9	17
nitial single support time(%)	363	10	145	242	initial single support time[5]	365	117	313	352	initial single support time(%)	337	31	17	73
eminal double support time(%)	2.9	34	123	24.2	terninal double support time(%)	153	121	11.7	14	ternital double support time(%)	9.8	132	17	439
terrinal single support time(%)	415.	43	4	549	terninal single seport time(%)	144	14-1	11.0	14	terninal single support time[5]	433	45	37.4	318
ip joint angleideg)	324	217	32.6	237	hip joint argle(deg)	305	12	12	8	hip joint angle(deg)	247	142	183	113
nee joint anglejdeg)	47.7	373	40	146	knee joint anglejdeg)	544	50.8	0	59.5	knee joint anglejdeg)	329	181	249	148
nkle joirt angle(deg)	30.4	41	32.8	369	anke joint anglejdeg	525	43.8	57.4	384	ankle joint anglejdeg)	243	203	39.7	165

Table 3. Gait parameters, Petient 1 -> similar, choice : mono-cane

Table 6 Gait parameters, Patient 4 -> similar, choice : no asist

Table 9 Gait parameters, Petient 7 -> better in mono-cane gait, choice : mono-cane

	Independent		Mono-cane			Independer	1	Quad-cane	C		Quad-ci	ane		Walter			1								
	LT.	8	11	RL.	7	()	18	lit.	2	-	lt.	18		lt	1		1								
gait cycle time sec)	1.4	15	1.6	1.6	gait ode timelsed	1.9	12	24	23	gait gole time(sed)	24	2		17	1]	1								
stance phase(%)	546	22.3	573	616	stance phase %	61	222	663	521	stance phase(%)	613	6	3	56.9	5	7.8	1								
swing phase(%)	454	47	27	39.4	saino phase(%)	39	45	317	479	swing phase(%)	387	3	1	431	4	22	1								
velocity(m/s)	1	68	0.8	07	velocitrim/s)	0.5	03	01	03	velocit/(m/s)	0.4	0		0.6	0	6	1								
stride Length(m)	0.6	06	0.6	0.4	stride Length(m)	0.2	02	02	01	stide Length(m)	0.2	0		0.5	0	5	1								
cadence (step/min)				2122.2	cadence (step/min)		-		-	cadence (step/min)	100						1								
pre-sweg(%)	546	553	573	616	presaria	61	222	66.3	521	pre-saing%)	613	6	3	56.9	5	7.8	1								
initial double support time(%)	87	68	84	10.1	initial double secont time%)	138	19.9	243	26	initial double support time(%)	181	3		61	5	2	1								
initial single support time(%)	383	41.4	384	40,4	initial single support time[S]	283	3631	17.9	332	initial single support fime(%)	37.1	3	5	428	4	51	1								
terninal double support time(%)	6.8	87	10.1	84	terrinal double support time(s)	197	142	25	248	terminal double support time(%)	3.9	1	1	52	6	1	1								
terninal single support time(%)	462	42.1	43.1	41	teminal stole spport time[5]	395	413	352	395	terminal single support time(%)	419	3	6	45.9	4	36	1								
hip joint angle(deg)	25	30	22	27.9	hip joint analedes	221	94	164	89	hip joint angle(deg)	259	3	1	37.3	3	1.6	I	1		16	Unilateral	<u> </u>	Bilatera		bilateral fores
knee joint anglejdeg)	326	351	306	327	knee joint angleides)	33	13.6	337	126	knee joint angledeg)	50.1	4	7	563		22	1	Indepe	e dent	17			1355		20212
		Q1	422	41	the second se	165	12.3	112	101	ankle joint angleides)	52.4	4		60.5	4		1 .	-	R	1	nono-ca	ane	mano-	cane	crutch
ankle joint angleideg)	45.6 better in indeper	1		14	⊥ <u> inkle joint anglejdeg </u> Table 7 Gait parameters, Rotient 5 →	1000	COLORIS -	1.11		Table 10 Gait parameters, Patient 8 <	better in w	aker, choi	e : waker				gait cycle time(sec) stance phase(%)	13	13		544	13	15 512	15 546	2 21
anike joint angleidegi fable 4 Gait parametere, Robert 2 ->	better in indeper	1	e : no exist		the second second	better in indepe	ndert gait, dicic	e : no essist		Table 10 Gait parameters, Parlent 8 <		0.516.0			Wala				13		544	13 25 45 11	1.75	15 546 454 11	
anke joint angleidegi		1		R	the second second	better in indepe	ndert gait, dioic t	e : no assist Quad-cane	1	Table 10 Gait parameters, Patient 8 <	better in w	0.516.0	e : waker Qued-ca		Waker	2	stance phase(%) swing phase(%)	929 47.1	13		544 656 1	55	\$3.2		55.5 59. 44.5 40.
anke joint angleidegi	better in indeper	1	e : no exist		Table 7 Gait parameters, Robert 5 ->	better in indepe	ndert gait, dioic t R.	Quad-cane	N.	-	Mono-c	0.516.0	Qued-ca	ne RL	Waker Lt	8	stance phase(%) swing phase(%) velocity(m(%)	52.9 47.1 0.9	13		544 656 1	55 45 11	\$3.2	45.4 1.1	55.5 59. 44.5 40. 0.6 0.7
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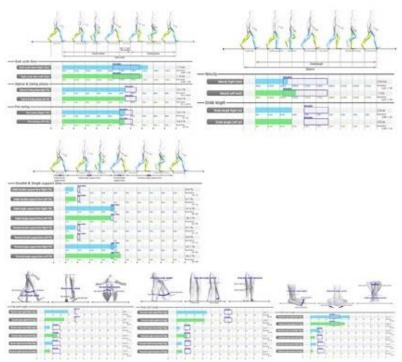


Figure 1. IMU-based gait evaluation(HumanTract) Figure 2. Gait report(HumanTract)