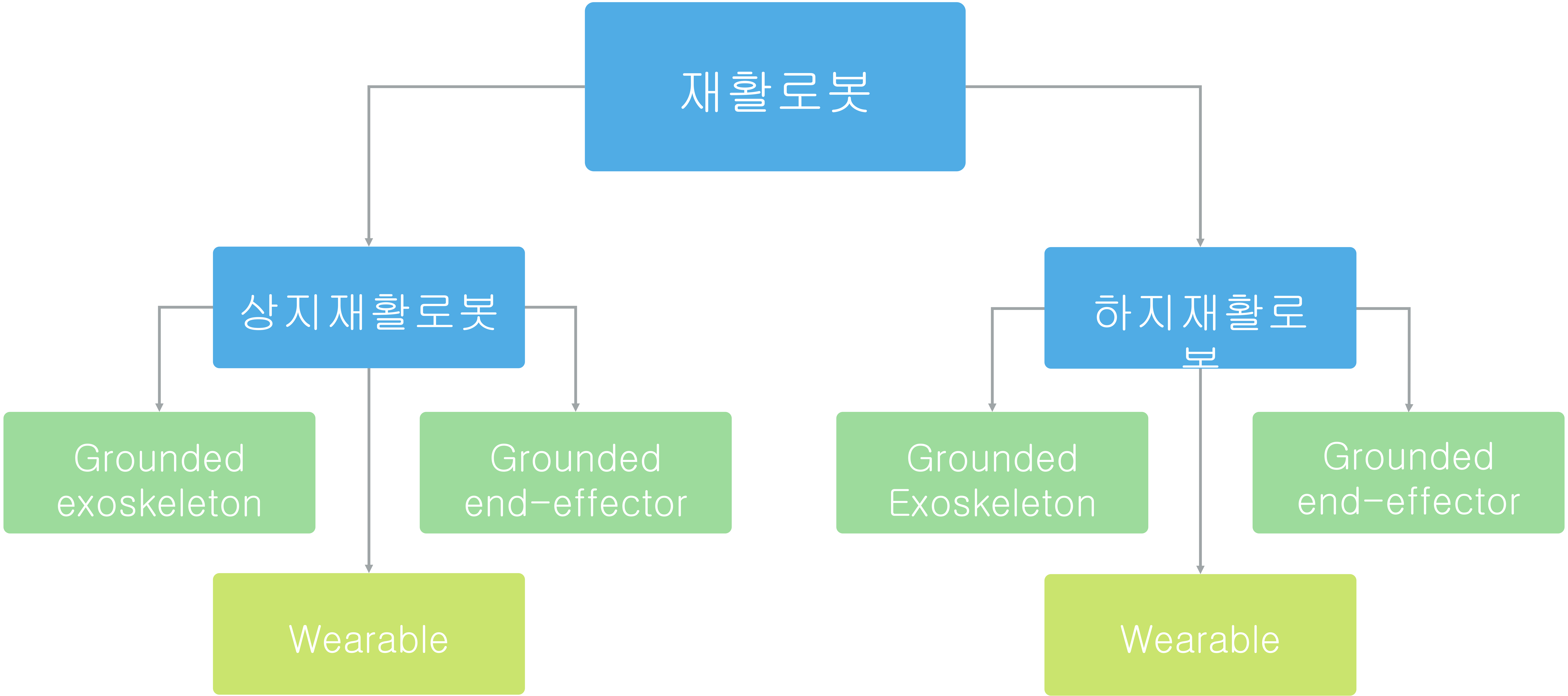
재활로봇의 적용 및 최신 치료경향

인제대학교 일산백병원 재활의학과
유지현


재활로봇
상지재활로봇
하지재활로봇
Grounded exoskeleton
Grounded end-effector
Wearable
Grounded Exoskeleton
Grounded end-effector
Wearable

재활로봇

상지재활로봇

Grounded exoskeleton

Armeo Power®

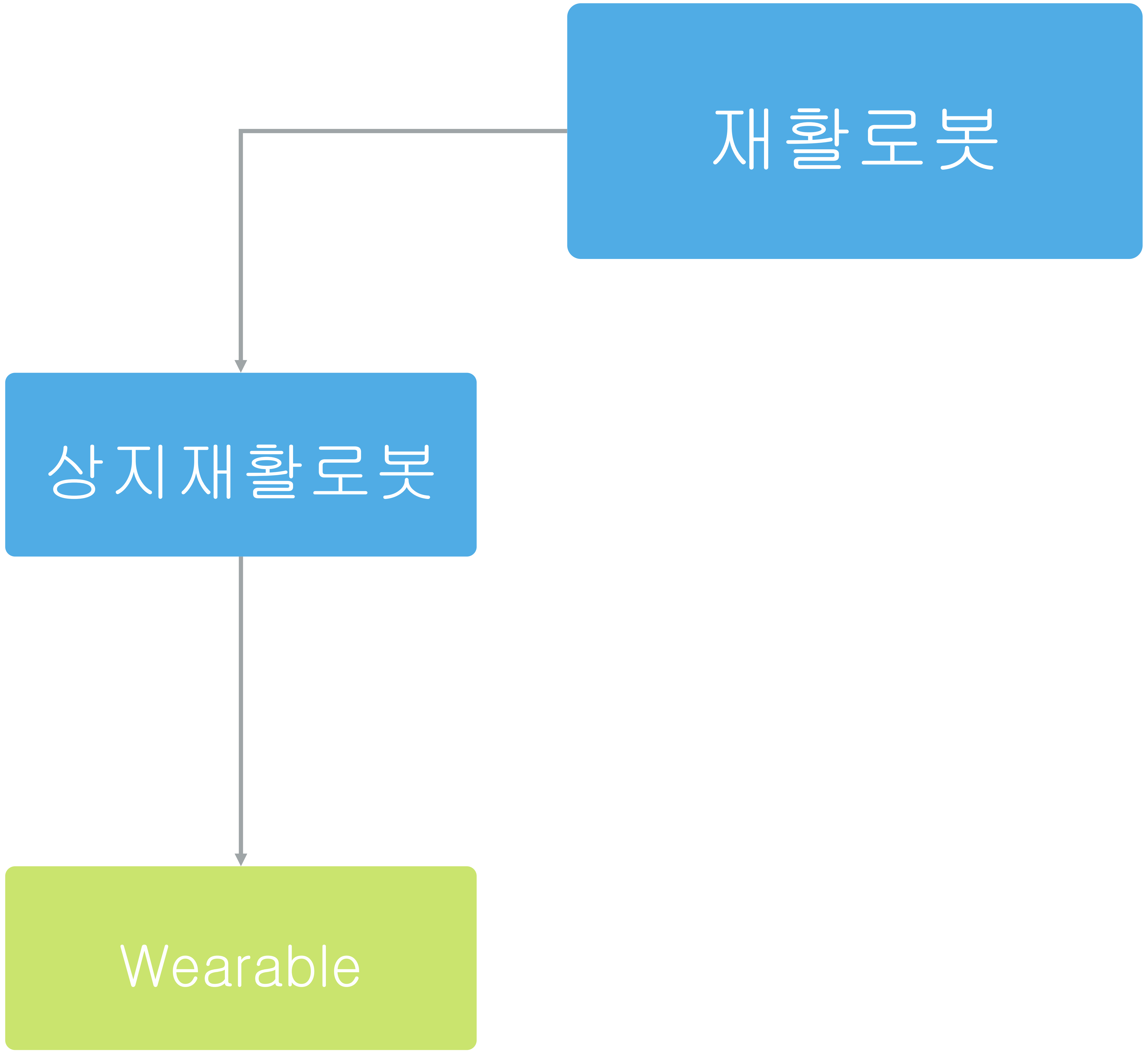
ANYexo®

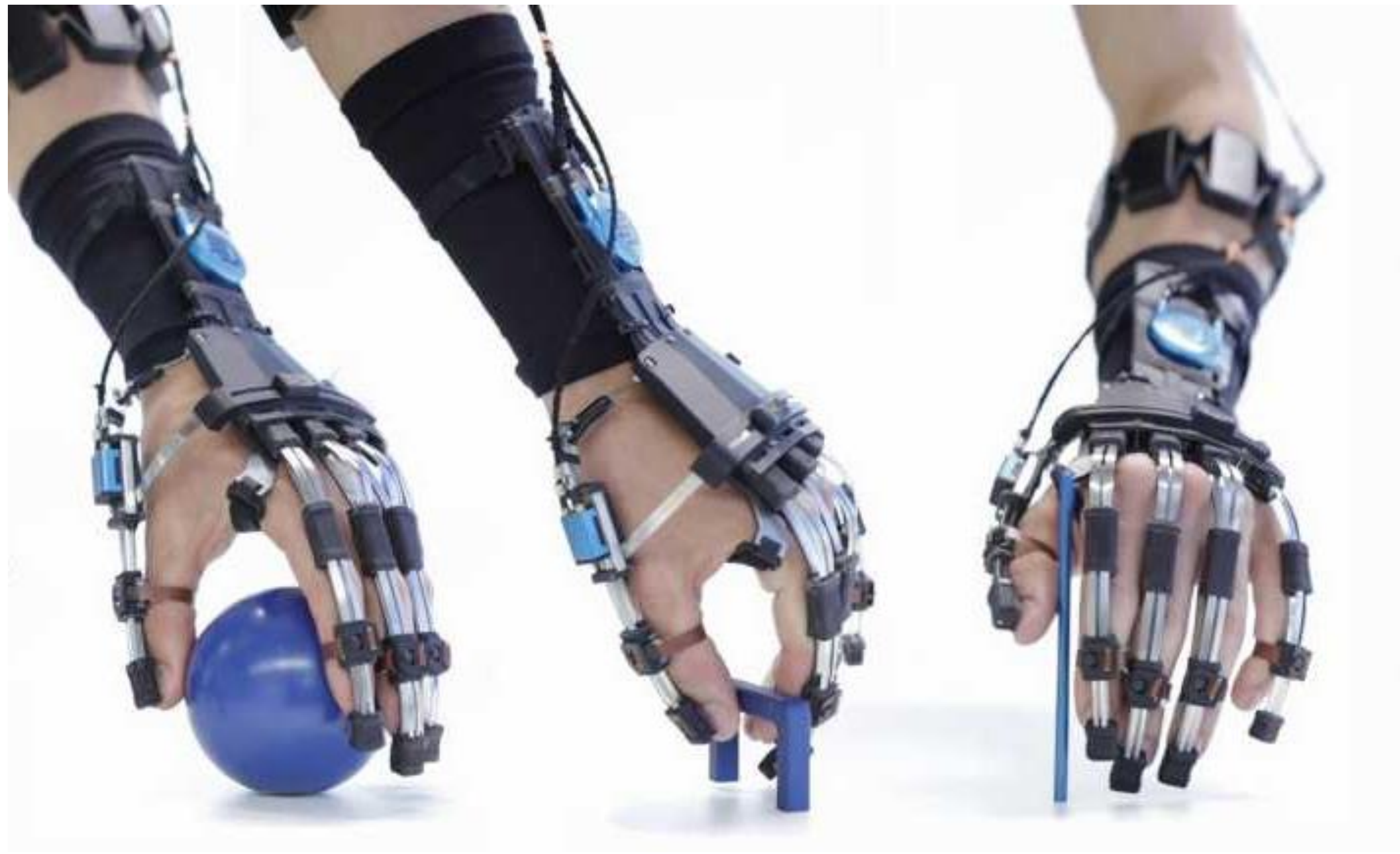
재활로봇

상지재활로봇

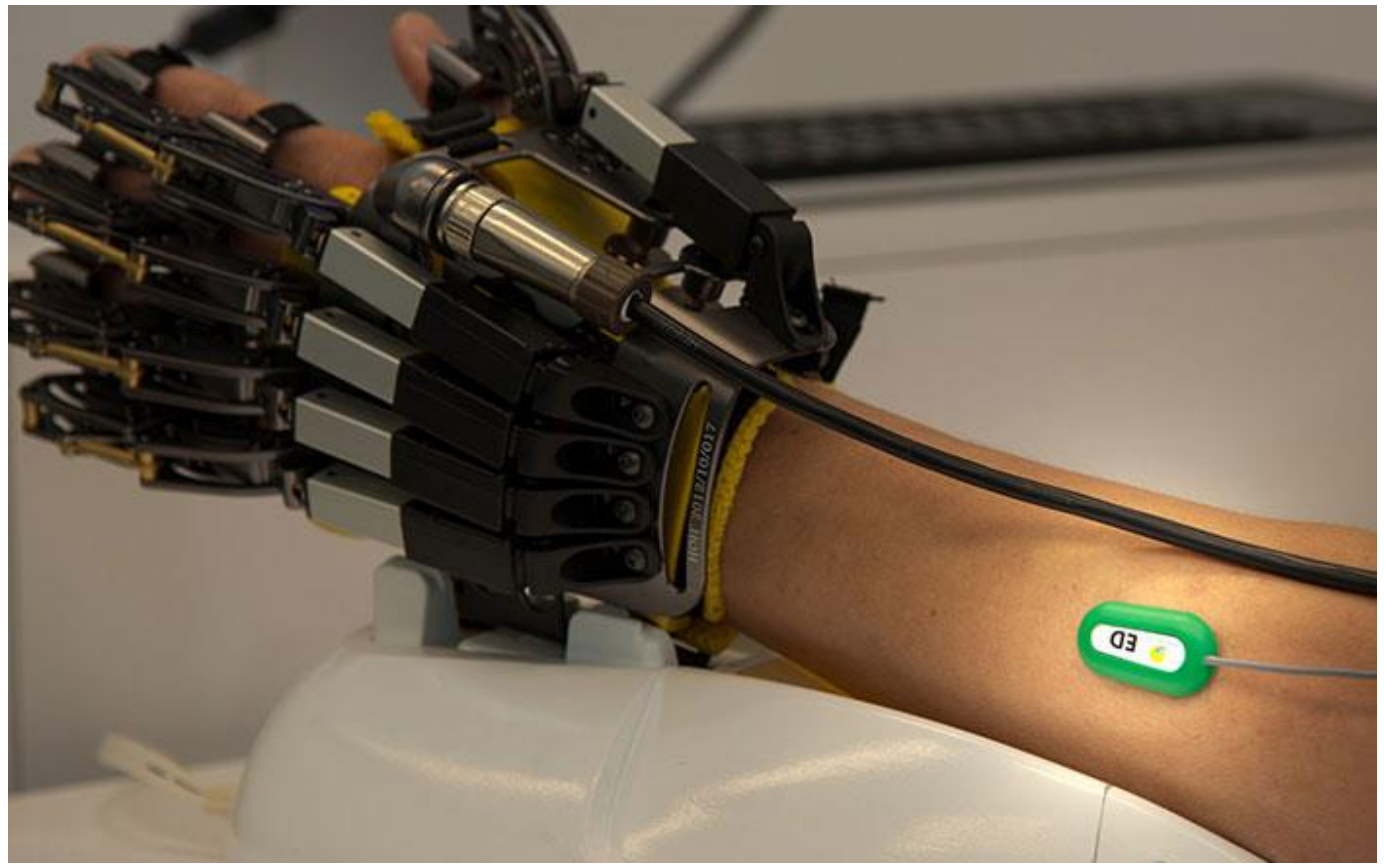
Grounded end-effector

InMotion ARM/HAND®





Tenoexo®



Hand of Hope®

DISABILITY AND REHABILITATION: ASSISTIVE TECHNOLOGY
2018, VOL. 13, NO. 7, 704–715
https://doi.org/10.1080/17483107.2018.1425747

Taylor & Francis
Taylor & Francis Group

REVIEW ARTICLE

Check for updates

Robot-assisted upper extremity rehabilitation for cervical spinal cord injuries: a systematic scoping review

Hardeep Singh[a,b], Janelle Unger[a,b], José Zariffa[a,b,c], Maureen Pakosh[a], Susan Jaglal[a,b,d,e], B. Catharine Craven[a,b,f] and Kristin E. Musselman[a,b,d]

[a]Toronto Rehabilitation Institute-University Health Network, Toronto, ON, Canada; [b]Rehabilitation Sciences Institute, University of Toronto, Toronto, ON, Canada; [c]Institute of Biomaterials and Biomedical Engineering, University of Toronto, Toronto, ON, Canada; [d]Department of Physical Therapy, University of Toronto, Toronto, ON, Canada; [e]Department of Health Policy, Management and Evaluation, University of Toronto, Toronto, ON, Canada; [f]Division of Physical Medicine and Rehabilitation, Faculty of Medicine, University of Toronto, Toronto, ON, Canada

Study design

Table 1. Study design details.

Study	Country	Setting	Design
Kadivar et al. [19]	USA	Outpatient	Case series
Pehlivan et al. [20]	USA	Outpatient	Case study
Vanmulken et al. [22]	Netherlands	Outpatient	Case series
Yozbatiran et al. [42]	USA	Outpatient	Clinical RCT
Zariffa et al. [43]	Canada	Inpatient	Case series
Sledziewski et al. [44]	USA	Inpatient	Case study
Yozbatiran et al. [45]	USA	Outpatient	Case study
Yozbatiran et al. [46]	USA	Outpatient	Case study
Cortes et al. [47]	USA	Outpatient	Case series
Hoei et al. [48]	Japan	Outpatient	Case study
Frullo et al. [49]	USA	Outpatient	Case series
Fitle et al. [50]	USA	Outpatient	Case series

1 RCT (n=9)
6 Case series (n=17, 15, 10, 10, 9, 5, 2)
5 Case studies

RCT

Intervention group	**Control group**
tDCS + robotic therapy	robotic therapy

Table 2. Interventions, participant characteristics, and Down's and Black methodological quality scores.

Study	Sample size	Participant characteristics	Intervention dose	Co- therapy	Down's and Blacks score
Kadivar et al. [19]	2 (M,F)	Chronic C2, C4 AIS C and D Age: 24, 27 yrs TSI: 6.5 months	RiceWrist 1–3 hr ×3 days/week ×7 and 10 sessions	NR	9 (P)
Pehlivan et al. [20]	1 (M)	Chronic C3–C5 AIS C Age: 45 yrs TSI: 83 months	RiceWrist 1 hr ×4 days/wk ×3 wks	No	11 (M)
Vanmulken et al. [22]	5 2 drop outs (3M)	Chronic C5–C7 AIS A(1), B(2) Age: 25–45 yrs TSI: 3.5–15.5 yrs	Haptic Master 1 hr ×3 days/wk ×6 wks	NR	12 (M)
Yozbatiran et al. [42]	9 1 drop out (7M,1F)	Chronic C3–C7 AIS C(3), D(5) Age: 36–62 yrs TSI: 7–244 months	MAHI Exo-II 10 sessions over 2 wks	No	20 (G)
Zariffa et al. [43]	15 3 drop outs (11M,1F)	Subacute C4–C6 AIS A(2), B(4), C(1), D(5) Age: 19–75 yrs TSI: 21–173 days	Armeo Spring 1 hr ×3–5 days/wk ×6 wks	CT	17 (M)
Sledziewski et al. [44]	1 (M)	Subacute C4 AIS D Age: 51 yrs TSI: 26 days	ReoGo 2 hr ×5 days/wk ×4 wks	OT	11 (M)
Yozbatiran et al. [45]	1 (M)	Chronic C4 AIS D Age: 24 yrs TSI: 6.5 months	RiceWrist 3 hr ×10 consecutive days	No	11 (M)
Yozbatiran et al. [46]	1 (F)	Chronic C2 AIS C Age: 28 yrs TSI: 29 months	MAHI Exo-II 3 hr ×3 days/wk ×4 wks	No	10 (P)
Cortes et al. [47]	10 (8M,2F)	Chronic C4–C6 AIS A(3), B(4), C(1), D(2) Age: 17–70 yrs TSI: 2–8 yrs	InMotion 3.0 Wrist robot 1 hr ×3 days/wk ×6 wks	NR	14 (M)
Hoei et al. [48]	1 (M)	Subacute C3–C6 AIS NR Age: 66 yrs TSI: 3 months	Reaching Robot 40 min ×7 days/wk ×2 wks	NR	11 (M)
Frullo et al. [49]	17 3 drop outs (12M, 2F)	Chronic C3–C8 AIS C-D Age: mean 53.5 yrs TSI: mean 16 yrs	MAHI Exo-II 1.5 hr ×10 sessions	NR	14 (M)
Fitle et al. [50]	10 2 drop outs (8M, 2F)*	Chronic C2–C6 AIS C–D Age: NR TSI: NR	MAHI Exo-II 2h × 12 sessions	NR	8 (P)

M: male; F: female; TSI: time since injury; AIS: American spinal injury association impairment scale; MAHI: Mechatronics and Haptic Interfaces Lab; yrs: years; wks: weeks; NR: not reported; CT: conventional therapy; OT: occupational therapy; (P): poor; (M): moderate; (G): good; *Fitle et al. did not report sex of participants that dropped out.

Intervention, participant characteristics

Subacute: 1 case series, 2 case studies
Chronic: 1 RCT, 5 case series, 3 case studies

Armeo spring (1)
RiceWrist (3)
Haptic Master (1)
MAHI Exo-II (4)
ReoGo (1)
InMotion 3.0 Wrist (1)
Reaching robot (1)

Table 4. Results on outcome measures after training.

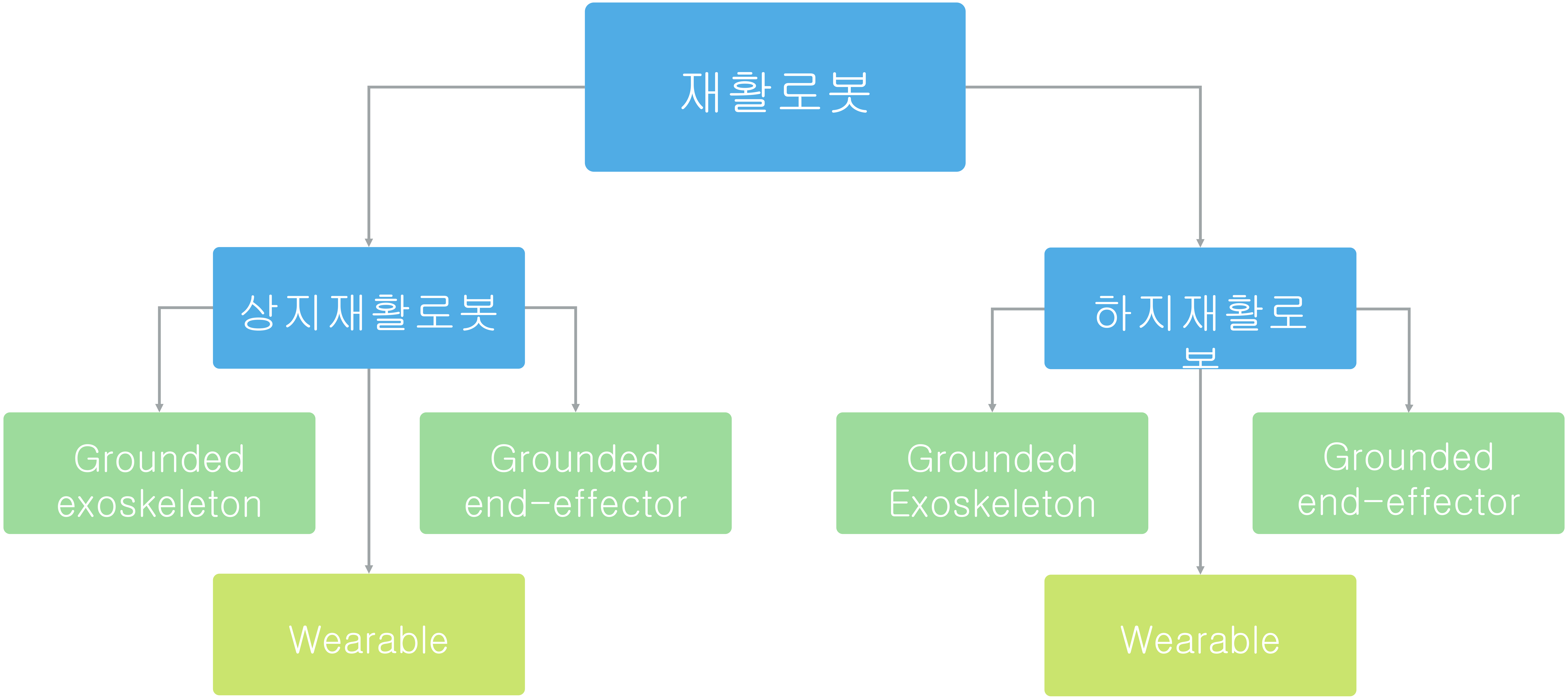
	Body structure and function																			
										Activity level										
																				Participation
	Cortical excitability	Fs	UEMS	Sensory	ROM	Grip	Pinch	MAS	ICSHT	VLT	GRASSP	FIM	JTHFT	SCIM	ARAT	SIAS	STEF	CUE	USE	AOU-MAL
Kadivar et al. [19]		+ (m) nc (s)											+							
Pehlivan et al. [20]		+	nc			+	+						+		nc					
Vanmulken et al. [22]									nc	+				nc						
Yozbatiran et al. [42]			+					nc					+							+*
Zariffa et al. [43]					nc	nc					+ (m) nc (s)				nc					
Sledziewski et al. [44]			+	nc	+							+						+		
Yozbatiran et al. [45]			+ (s) nc (m)			+ (m) nc (s)	+					+	+							
Yozbatiran et al. [46]			+ (m) nc (s)										+ nc (s)		+ (m) nc (s)					
Cortes et al. [47]	nc	+	nc					nc												
Hoei et al. [48]					+			nc								+	+			
Frullo et al. [49]						+	+	nc			+				nc					
Fitle et al. [50]								nc					+		+					

*Improvements did not last at two-month follow-up

(m): mild-moderately impaired side; (s): severely impaired side; nc: no change; +: change; Fs: smoothness of movement; UEMS: upper extremity motor score; ROM: range of motion; MAS: Modified Ashworth Scale; ICSHT: International classification for surgery of the hand in tetraplegia; VLT: Van Lieshout test for UE function in tetraplegia; GRASSP: graded and redefined assessment of strength, sensibility and prehension; FIM: functional independence measure; JTHFT: Jebsen Taylor hand function test; SCIM: spinal cord independence measure; ARAT: action research arm test; SIAS: knee-mouth test and the finger test of the stroke impairment assessment set; STEF: simple test for evaluating hand function; CUE: capabilities of upper extremity instrument; USE: usefulness, satisfaction and ease-of-use questionnaire; AOU-MAL: action research arm test

Robot-assisted upper extremity rehabilitation for tetraplegia

- Safe and feasible
- To reduce assistance provided by therapists
- Lack of RCT study
- Lack of study in acute to subacute stage


재활로봇
상지재활로봇
하지재활로
봇
Grounded
exoskeleton
Grounded
end-effector
Wearable
Grounded
Exoskeleton
Grounded
end-effector
Wearable

Lokomat®

Walkbot®

재활로봇

하지재활로봇

Grounded Exoskeleton

The Journal of Spinal Cord Medicine 2019:42;142-154

Review

Walking speed is not the best outcome to evaluate the effect of robotic assisted gait training in people with motor incomplete Spinal Cord Injury: A Systematic Review with meta-analysis

Ana Valeria Aguirre-Güemez[1], Aberto Isaac Pérez-Sanpablo [2], Jimena Quinzaños-Fresnedo[1], Ramiro Pérez-Zavala[1], Aída Barrera-Ortiz[1]

[1]División de Rehabilitación Neurológica, Instituto Nacional de Rehabilitación, Ciudad de México, México,
[2]Laboratorio de análisis de movimiento, Instituto Nacional de Rehabilitación, Ciudad de México, México

Nam et al. Journal of NeuroEngineering and Rehabilitation (2017) 14:24
DOI 10.1186/s12984-017-0232-3

Journal of NeuroEngineering and Rehabilitation

REVIEW **Open Access**

CrossMark

Robot-assisted gait training (Lokomat) improves walking function and activity in people with spinal cord injury: a systematic review

Ki Yeun Nam[1†], Hyun Jung Kim[2†], Bum Sun Kwon[1], Jin-Woo Park[1], Ho Jun Lee[1] and Aeri Yoo[3*]

Journal of Clinical Neuroscience 91 (2021) 260–269

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Review article

Robot-assisted gait training in individuals with spinal cord injury: A systematic review for the clinical effectiveness of Lokomat

Anas R. Alashram[a,*], Giuseppe Annino[b], Elvira Padua[c]

[a] Department of Physiotherapy, Isra University, Amman, Jordan
[b] Department of Medicine Systems, University of Rome "Tor Vergata", Rome, Italy
[c] Department of Human Sciences and Promotion of the Quality of Life, San Raffaele Roma Open University, Rome, Italy

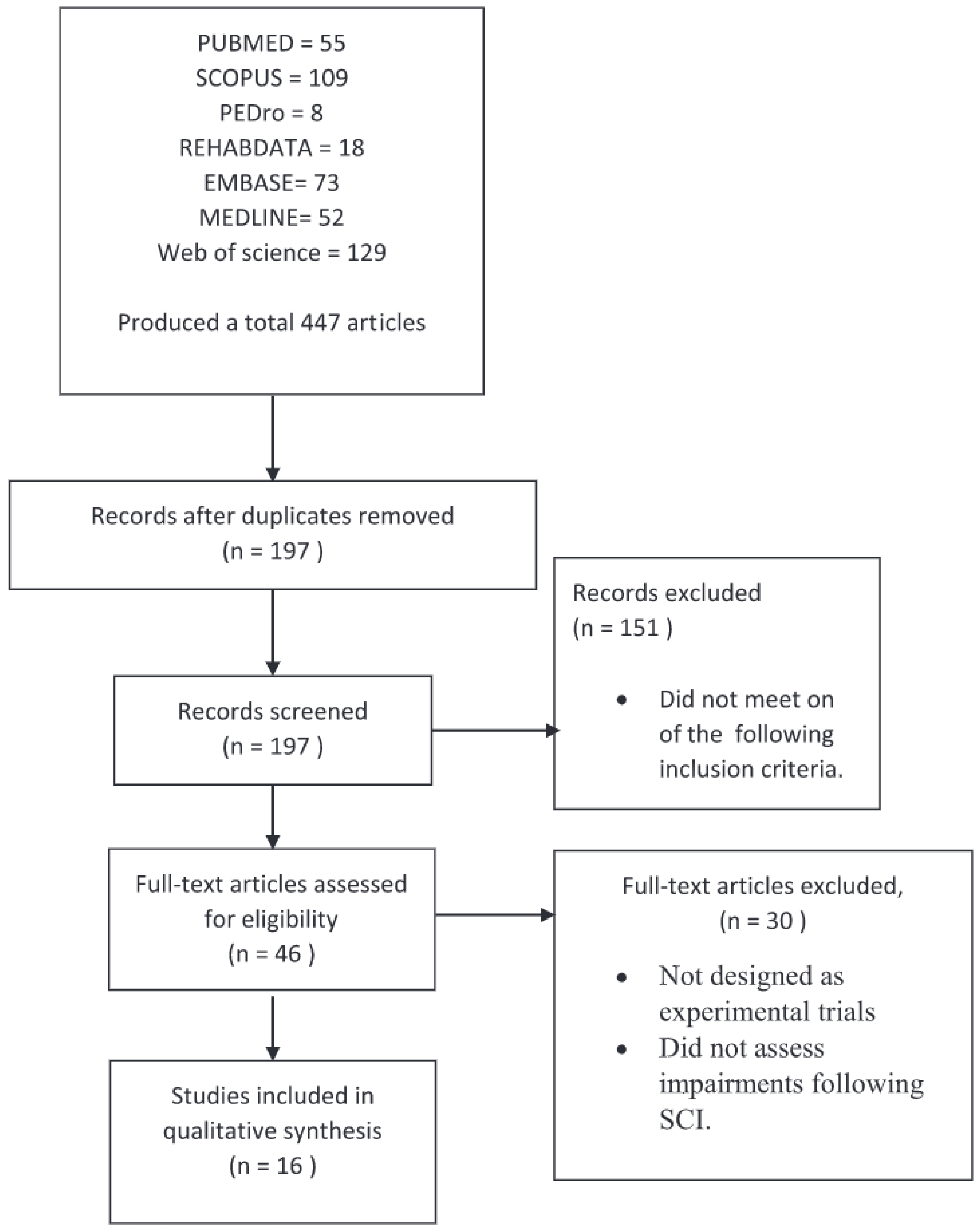


Fig. 1. Summary of literature review process.

- **AIS**
  - AIS C or D (11)
  - AIS D (2)
  - AIS B or C (1)
  - AIS A~D (1)
- **Onset**
  - acute (<6 months): 6
  - chronic (>12 months): 8
  - acute~chronic: 2
- **Study design**: experimental studies

Compared with

Conventional therapy (Overground gait training, body-weight support gait training, Bobath principles..)

Transcranial direct current stimulation (tDCS)

Repetitive transcranial magnetic stimulation (rTMS)

Intervention: Lokomat®

Intervention: Lokomat®

Treatment frequency

One study involved only one treatment session.

2	**7**	**1**	**5**
2~3 sessions/week	3 sessions/week	4 sessions/week	5 sessions/week

Treatment duration

7	**2**	**4**	**1**	**1**
4 weeks	8 weeks	12 weeks	10~16 weeks	20 weeks

Effects of the Lokomat®

- 10 meters walk test (10MWT, walking speed)
- 6 minutes walk test (6mWT, walking endurance)
- Lower extremity motor score of ISNCSCI (LEMS)
- Walking index for spinal cord injury-II (WISCI-II)
- Functional Independence Measure-Locomotor (FIM-L)

Alcobendas-Maestro et al. 2012 [32]	Study design: RCT Participants, *n*: 80 Gender M/F, *n*: 50/30 Mean age: 47.5 Level of injury:C2-T12 (UMN) (C = 49, T [T1-T6] = 12, [T7-T12] = 19 ASIA: C,D Time since injury (months):3–6	Exp = RAGT 30 min × 5/wk × 6 wk Con = OGT 60 min × 5/wk × 6 wk Both = CPT	A. Speed = 10-m walk test B. Distance = 6-min walk test C. Functional level = WISCI II, FIM-L D. Leg strength = LEMS E. Spasticity = Ashworth scale F. Pain = VAS • Timing: 0, 8 wk	A. No significant differences ($p > .05$) B. Experimental group improved significantly in distance compared to control group ($p < .05$) C. Experimental group improved significantly in WISCI II and FIM-L scores compared to control group ($p < .05$) D. Experimental group improved significantly in leg strength compared to control group ($p < .05$) E. No significant differences ($p > .05$) F. No significant differences ($p > .05$)
Esclarin-Ruz et al. 2014 [31]	Study design: RCT Participants, *n*: 88 Gender M/F, *n*: 64/24 Mean age: 39.58 Level of injury: C2 to L3 (UMN; C = 24, T [T7-T11] = 18) (LMN; T [T12-L1] = 30, L [L2-L3] = 11) ASIA: C, D Time since injury (months): < 6	Exp = RAGT 30 min × 5/wk × 8 wk Con = OGT 30 min × 5/wk × 8 wk Both = CPT 60 min × 5/wk × 8 wk	A. Speed = 10-m walk test B. Distance = 6-min walk test C. Functional level = WISCI II, FIM-L D. Leg strength = LEMS • Timing: 0, 8 wk	A. LMN patients improved in speed compared to UMN patients in OGT group but without significant differences ($p > .05$). No significant differences between LMN patients in both groups ($p > .05$). B. UMN and LMN patients improve significantly in distance after RAGT compared to OGT ($p < .05$) C. No significant differences in WISCI II ($p > .05$). UMN patients improved significantly in FIM-L after RAGT compared to OGT ($p < .05$), no significant difference were reported between LMN patients in both groups ($p > .05$) D. UMN and LMN patients improve significantly in strength after RAGT compared to OGT ($p < .05$)
Field-Fote et al. 2011 [26]	Study design: RCT Participants, *n*: 74 Gender M/F, *n*: 51/23 Mean age: 35.46 Level of injury: At or above T10 (UMN) ASIA: C, D Time since injury (months): > 12	Exp = RAGT 60 min × 5/wk × 12 wk Con1 = BWS treadmill-based training with manual assistance 60 min × 5/wk x 12 wk Con2 = BWS treadmill-based training with stimulation 60 min × 5/wk × 12 wk Con3 = OGT with stimulation with BWS 60 min × 5/wk × 12 wk	A. Speed = 10-m walk test B. Distance = 2-min walk test C. Leg strength = LEMS • Timing: 0, 12 wk	A. Speed increased significantly after overground ($p < .05$) B. Experimental group improved significantly in distance compared to control group ($p < .05$) C. No significant differences ($p > .05$)

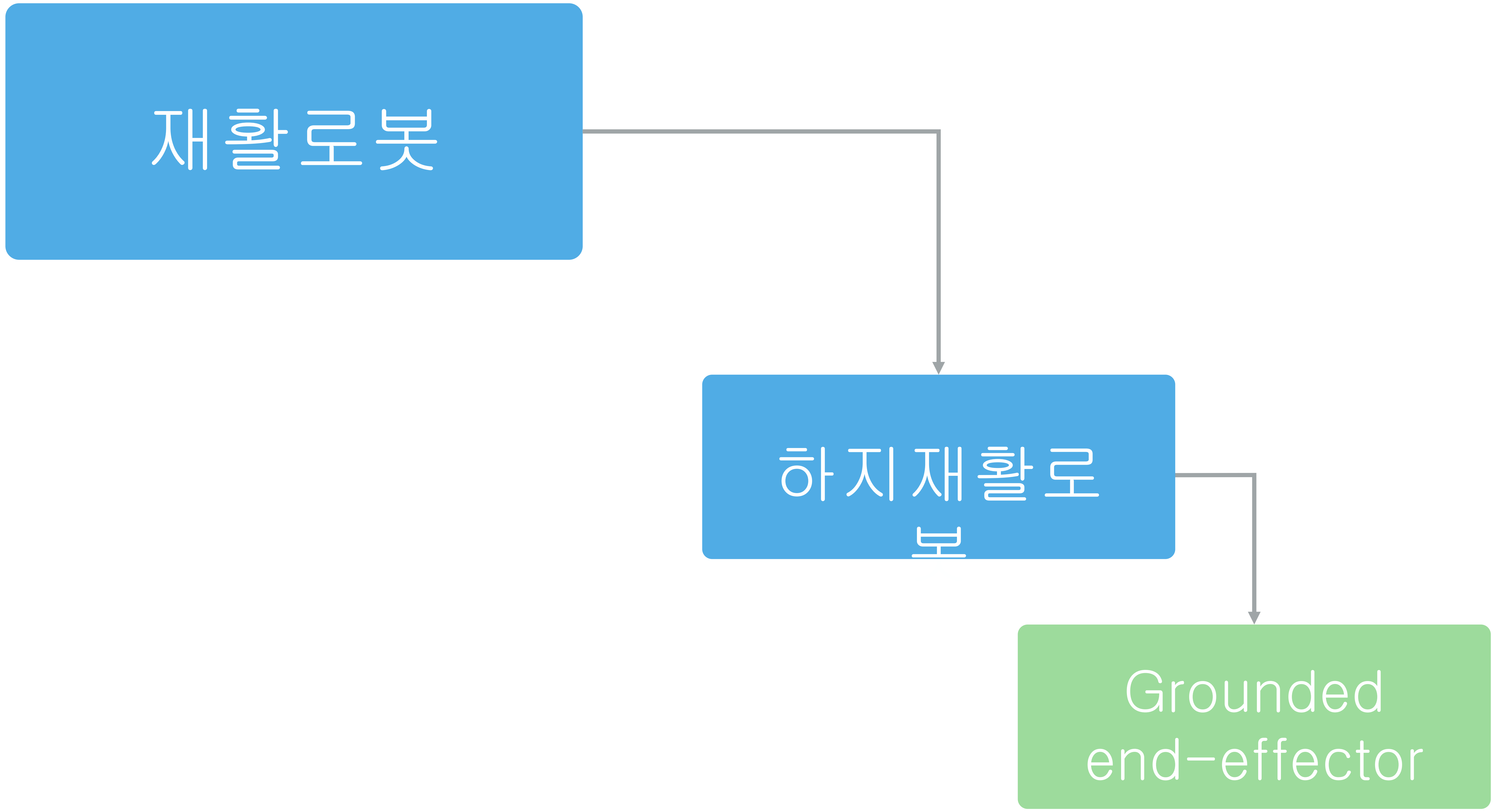
Niu et al. 2014 [27]	Study design: RCT Participants, *n*: 40 Gender M/F, *n*: 27/13 Mean age: 45.95 Level of injury: above T10 (UMN) (paraplegia = 12, tetraplegia = 28) ASIA: B, C, D Time since injury (months): Exp 8.9 ± 9.9, Con 7.5 ± 5.5	Exp = RAGT 60 min × 3/wk × 4 wk Con = no intervention	A. Speed = 10-m walk test B. Distance = 6-min walk test C. Functional ambulation = TUG • Timing: 0, 1, 2, 4 wk	A. Experimental group improved significantly in speed compared to control group B. No significant differences ($p > .05$) C. Experimental group improved significantly in balance compared to control group ($p < .05$)
Varoqui at al. 2014 [30]	Study design: RCT Participants, *n*: 30 Gender M/F, *n*: 22/8 Mean age: 47.37 Level of injury: above T10 (UMN) (C [C2-C7] = 20), (T [T1-T7] = 10) ASIA: C,D Time since injury (months): Exp 11.80 ± 2.54, Con 8.09 ± 1.89	Exp = RAGT 60 min × 3/wk × 4 wk Con = no intervention	A. Speed = 10-m walk test B. Distance = 6-min walk test C. Functional ambulation = TUG D. ROM = PROM, E. Spasticity = MAS F. Strength = MVC • Timing: 0, 4 wk	A. Experimental group improved significantly in speed compared to control group B. No significant differences ($p > .05$) C. Experimental group improved significantly in balance compared to control group ($p < .05$) D. Experimental group improved significantly in ankle PROM compared to control group ($p < .05$) E. No significant differences between groups in change of planter-flexor tone ($p > .05$) F. Experimental group improved significantly in MVC_{DF} and MVC_{PF} compared tocontrol group ($p < .05$)

Robot-assisted gait training (Lokomat®) for spinal cord injury patients

- May improve gait speed, endurance, strength, ROM, and mobility
- Insufficient evidence for the effect on balance, depression, cardiorespiratory fitness and QOL
- Further RCT with long-term follow-ups are needed.

Morning Walk®

LEXO®



End-effector type robot-assisted gait training for spinal cord injury patients

- Total 3 published studies (1 feasibility study, 1 case study, 1 observational study)
- No published RCT studies

Annals of Biomedical Engineering (© 2020)
https://doi.org/10.1007/s10439-020-02611-z

BMES BIOMEDICAL ENGINEERING SOCIETY

Check for updates

Original Article

Robotic Rehabilitation in Spinal Cord Injury: A Pilot Study on End-Effectors and Neurophysiological Outcomes

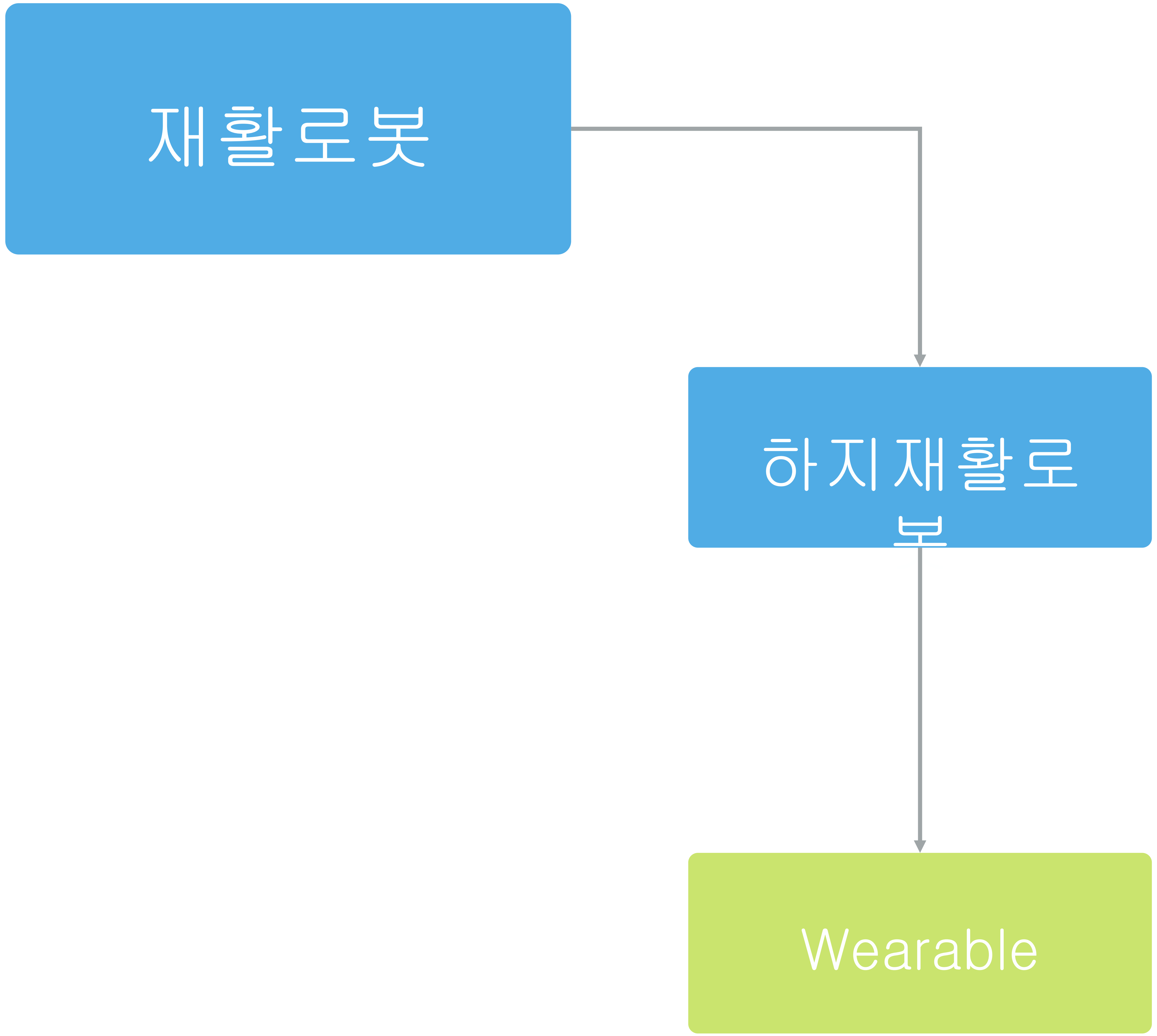
Rocco Salvatore Calabrò,[1] Serena Filoni,[2] Luana Billeri,[1]
Tina Balletta,[1] Antonino Cannavò,[1] Angela Militi,[3]
Demetrio Milardi,[4] Loris Pignolo,[5] and Antonino Naro[1]

[1]IRCCS Centro Neurolesi Bonino Pulejo, via Palermo, Ctr. Casazza SS113, 98124 Messina, Italy; [2]Padre Pio Foundation and Rehabilitation Centers, San Giovanni Rotondo, Italy; [3]Stomatodental Centre, Messina, Italy; [4]Department of Biomedical Dental Morphological and Functional Imaging Sciences, University of Messina, Messina, Italy; and [5]Istituto S. Anna, Crotone, Italy

- subacute~chronic (<18 months), AIS C or D patients (16 participants)
- robot-assisted gait training (RAGT) with GT® (end-effector)
- significant improvements in10MWT, WISCI-II, and SCIM-III
- observational study

HAL®

Angelegs®



Front Neurorobot 2021:15;723206

Improved Physiological Gait in Acute and Chronic SCI Patients After Training With Wearable Cyborg Hybrid Assistive Limb

Alexis Brinkemper[1], Mirko Aach[2], Dennis Grasmücke[2], Birger Jettkant[1], Thomas Rosteius[1], Marcel Dudda[3], Emre Yilmaz[1] and Thomas Armin Schildhauer[1]*

[1] Department of General and Trauma Surgery, BG University Hospital Bergmannsheil, Bochum, Germany, [2] Department of Spinal Cord Injuries, BG University Hospital Bergmannsheil, Bochum, Germany, [3] Department of Trauma, Hand and Reconstructive Surgery, University Hospital Essen, Essen, Germany

- HAL®Robot Suit
- 15 participants
  - acute~subacute AIS D (5)
  - chronic AIS A (5), AIC C (2), AIS D (3)
- Intervention
  - 5 times/wk over 12 weeks training with HAL®
- Outcome measures
  - 10MWT, 6mWT, timed-up-and-go test, WISCI-II
  - gait parameters

European Journal of Physical and Rehabilitation Medicine 2019 April;55(2):209-16
DOI: 10.23736/S1973-9087.18.05308-X

ORIGINAL ARTICLE

Assistive powered exoskeleton for complete spinal cord injury: correlations between walking ability and exoskeleton control

Eleonora GUANZIROLI [1, 2] *, Maurizio CAZZANIGA [1], Laura COLOMBO [1], Sabrina BASILICO [1], Giovanni LEGNANI [2], Franco MOLTENI [1]

[1]Villa Beretta Rehabilitation Center, Valduce Hospital, Costa Masnaga, Lecco, Italy; [2]Department of Mechanical and Industrial Engineering, University of Brescia, Brescia, Italy

*Corresponding author: Eleonora Guanziroli, Biomedical Engineer, Villa Beretta Rehabilitation Center, Valduce Hospital, Via N. Sauro 17, 23845 Costa Masnaga, Lecco, Italy. E-mail: eleonora.guanziroli@gmail.com

- ReWalk®
- 15 chronic AIS A patients
- Intervention
  - three 60-minute sessions/wk over 8 weeks training with HAL®
- Outcome measures
  - 10MWT, 6mWT, time necessary to pass from sitting to standing and start to walk (STS-time)

Powered exoskeleton for spinal cord injury patients

- To allow over-ground walking in chronic complete SCI patients

경청해주셔서 감사합니다