Table SI. Current commercial lower arm rehabilitation devices from the literature search.

Name of device	Developer/creator	Type	Lower arm segment aided	Degrees of freedom (DOF)	Description of function
Amadeo (38)	Tyromotion, Austria	End-effector	Full hand	5 passive	Floor-mounted device allows the patient to grasp an object
Arm-Assist Assistance Robot (39)	Rehub Health Accessible Technology, Spain	End-effector	Wrist	1 active	Desk-mounted hand, wrist and forearm mount used to aid wrist flexion and extension
InMotion HAND (40)	Boinik Labs, USA	End-effector	Full hand	1 active	Desk-mounted hand module that can be used with InMotion ARM Robot for grasp and release training
ExoHand (41)	Festo	Exoskeleton	Full hand	5 active	Glove/exoskeleton for both rehabilitation training and strength enhancement
AMES (42, 43)	AMES Technology Inc.,USA	End-effector	Full hand	5 active	Both an active rehabilitation system as well as being able to provide controlled sensory stimulation
CyberGrasp (44, 45)	CyberGlove Systems Inc., USA	Exoskeleton	Full hand	5 active	Device allows extension and flexion of each finger
Digi-Flex (46)	CanDo, USA	End-effector	Full hand	5 passive	Patients grasp the device to compress springs to build strength
Hand Mentor (47)	Kinetic Muscles Inc., USA	Exoskeleton	Full hand	1 active	Mounted orthotic device that moves the fingers as one in a grasping motion
Kinetec Maestra (37)	Kinetec, France	Exoskeleton	Full Hand	4 active	Helps by providing continuous motion of the fingers
Power-Web (36)	Power Web International, USA	End-effector	Full Hand	1 passive	Circular rubber sheet with holes to allow stretching
TheraBand Hand Exerciser (48)	Hygenic Corporation/Performance Health, USA	Elastic band	Full Hand	1 passive	Hand opening and closing. Fingers move as one
SaeboFlex (49)	Saebo, USA	Exoskeleton	Full Hand	5 passive	Uses springs to replicate each tendon in the hand that the patient can work against to aid rehabilitation
SaeboStretch (50)	Saebo, USA	Exoskeleton	Full Hand	2 passive	Single piece of flexible rubber mounted to a wrist orthotic device for grasping
Hand of Hope (51)	Rehab-Robotics, China	Exoskeleton	Full Hand	1 active	Full-hand exoskeleton with an electromyography (EMG) trigger to extend the fingers

Table SII. Non-commercial hand and wrist end-effectors from the literature search in chronological order of development

Name of device	Developer	Year first published	Hand/wrist segment aided	Degrees of freedom /Active or passive device	Description of function
SPIDAR-8 (52)	Tokyo Institute of Technology, Japan	2001	Both hands	6 active	Dual fixed end-effector where hands interact with to play virtual reality (VR)
Williams (53)	Massachusetts Institute of Technology, USA	2001	Wrist	3 active	Wrist attachment for the MIT-Manus (54) allowing for wrist exercises
Rutgers Masters II (55)	The State University of New Jersey, USA	2002	Three fingers + thumb	4 active	Finger manipulation device primarily designed to sense force and position
GENTLE/s (56)	University of Reading, UK	2003	Upper arm + wrist	1 passive	An upper arm neurorehabilitation system that allows for wrist motion but just records the motion.
HIRO (29)	Gifu University, Japan	2004	Three fingers	11 active	A 3-fingered device for use as a rehabilitation system in which an object is manipulated in VR and the feedback given to the patient.
HIRO II (57)	Gifu University, Japan	2005	Full hand	15 active, 6 passive	A full-hand system designed to be used in a master/slave configuration with the non-paretic arm; however, limited range of motion (cannot register pinch motion)
MR CHIROD (58)	Northeastern University, USA	2005	Full hand	1 active	Gripper that both reads the force applied and implements a variable resistive force
HIFI (59)	University of Ljubljana, Slovenia	2006	One finger	2 active	Device allows the extension/flexion of 1 finger
Masia (60)	Massachusetts Institute of Technology, USA	2006	Full hand	1 active	The final module created for the MIT-Manus to allow complete upper limb rehabilitation by manipulating the hand using a novel expanding cylinder system
HIRO II+ (61)	Gifu University, Japan	2007	Full hand	15 active, 6 passive	Device allows normal movement of the human hand to be mimicked by interacting with a replica robotic counterpart with 3 DOF per finger
HapticKnob (25)	National University of Singapore and Imperial College London	2007	Full hand	2 passive	Used for training the hand to open and close and to manipulate a knob
GENTLE/G: Grasp Assistance Robot (27)	University of Reading, UK	2007	Wrist and full hand	1 active, 2 passive	An addition to the GENTLE/s neuro-rehabilitation system to create a complete exercise routine by including the ability to aid grasping
HandCare (62)	National University of Singapore and Imperial College London	2008	Full hand	5 passive	Using a clutch system each finger is allowed independent movement with only 1 actuator with force feedback
RiceWrist (63)	Rice University, Houston, USA	2008	Wrist	4 active	Wrist-mounted attachment for the MIME Project (64) that provides force feedback and rehabilitation
HEnRiE (65)	University of Ljubljana, Slovenia	2008	Full hand	3 active, 2 passive	Designed to both help with reaching and grasping exercises, created to work with a virtual physiotherapist
Ramos (66)	University of Tubingen, Germany	2009	Four fingers	4 active	A combination of a finger flexion system with a BMI for rehabilitation
Chen (67)	Hong Kong Polytechnic University, China	2009	Wrist and full hand	5 active	Five Firgelli linear actuators are used to provide motion for a patient's rehabilitation, which can be fully active, EMG triggered or continuous EMG motion
Mohamaddan (68)	Universiti Malaysia Sarawak	2010	Full hand	5 active	This wire-driven assistive device uses self-motion control to provide rehabilitation
ReachMAN (69, 70)	Imperial College London, UK	2010	Wrist and full hand	3 active	Designed as a compact portable rehabilitation system to aid pronosupination and grasping using rail-mounted holds with DC motors providing force
Unluhisarcikli (71)	Northeastern University, USA	2010	Wrist and full hand	2 active	Two novel electro-rheological fluid-based hydraulic actuators allows for both grasp/release exercises and pronation and supination of the forearm
Oboe (72)	University of Padua, Italy	2010	Full hand	1 active	A 2-hand orthosis, where the clinician uses an exoskeleton to remotely activate an end-effector shaped as a hand with which the patient interacts
HIRO III (73, 74)	Gifu University, Japan	2011	Full hand	15 active, 6 passive	The latest generation of HIRO systems uses a new mechanism and wire-saving control system to reduce friction and backlash
Master Finger-2 (75)	University of Ljubljana, Slovenia	2011	One finger	2 active, 2 passive	Individual joint manipulation of a single finger for rehabilitation purposes
ReHapticKnob (76)	ETH Zurich, Switzerland	2011	Finger and thumb	2 active	An advancement of the previous HapticKnob (25) system offering a greater complement of sensors and increased torque allowing patients with higher spasticity to train in grasping.
FINGER (77)	University of Idaho, USA	2012	Four fingers	4 passive	Four single DOF mechanisms are stacked to allow for a full range of motion to grasp, this is used with a Guitar Hero© themed game for therapy.
Kazemi (78)	McGill University, Canada	2012	Wrist and full hand	2 active	The manipulation of both the hand (grasping/finger extension) and wrist (supination/pronation) are performed by a jaw mechanism opening and closing
Kim E (79)	Yeungnam University College of Medicine, Korea	2012	Full hand	1 passive	Simple device designed to control and aid in the action of grasping
CAFEx (80)	Universiti Teknologi MARA, Malaysia	2013	Full hand	5 active	Multiple motors are used to provide the extension for a hand once it is mounted to the base unit with each finger fixed separately.
Kim H (81)	Gyeongsang National University, South Korea	2013	Full hand	5 active	Five individual motors connected to separate linkages allow for each finger to be manipulated into a grasping and extension motion
Kang (82)	Universite Teknologi Malaysia, Malaysia	2014	Wrist	1 active	Adjustable device for multiple wrist orientation movement
Marini (83)	Italian Institute of Technology, Genoa, Italy	2014	Wrist	3 active	Full range of wrist motion allowed as well as being back-drivable
Shape-Changing Robot (84)	Hanyang University, South Korea	2014	Hand	1 active	Tactile surface for interactive games and interaction, individual sections move and react to either the users touch or the computer-generated commands
Tsagarakis (85)	Miguel Hernandez University, Spain	2015	Wrist	1 active	Single DOF wrist rehabilitation device with multiple mounting options for simplistic use

Table SIII. Non-commercial hand and wrist exoskeletons obtained from our literature search, listed in chronological order. Each row shows the device's designation, developer, the year it was first published, what part of the hand or wrist it aids, degrees of freedom, if it is passive or active, and a brief description of its function

Name of device	Developer	Year first published	Hand/wrist segment aided	Degrees of freedom	Function of the device
HWARD (86)	University of California, USA	2005	Wrist and full hand	3 active	Hand and wrist assisting robotic device, using a pneumatic system to allow for grasping aid while leaving the palm exposed
Luo (87)	Rehabilitation Institute of Chicago, USA	2005	Full hand	5 active	Use of a palmer based inflatable bladder or tendon driven system to open and close hand with augment reality
Sun (88)	Harbin Institute of Technology, China	2006	Three fingers	5 passive	Through the use of pneumatic muscles, the exoskeleton can provide a range of force feedback to the user for VR usage
Kawasaki I (89)	Gifu University, Japan	2006	Index and thumb	1 active	A wrist support and a pinch grip set-up where a linkage system manipulates thumb and index finger and incorporates a VR environment.
Kawasaki II (90)	Gifu University, Japan	2007	Wrist and full hand	18 active	A full-arm exoskeleton that features control for each joint in the arm in addition to the hand
Cable Orthosis (91)	Rehabilitation Institute of Chicago, USA	2007	Wrist and full hand	2 active	Cable-driven portable rehabilitation device
ADLER FES Grasp Glove (92)	Medical College of Wisconsin, USA	2007	Full hand	2 passive	Passive sensor glove to allow monitoring of pinch and grasp motions
MR Glove (93)	Washington State University Vancouver	2008	Wrist and full hand	10 active	Individual finger joint control for 2 joints per finger used in combination with a Cyberglove
IntelliArm Hand Module (94)	Rehabilitation Institute of Chicago, USA	2008	Wrist	7 active, 2 passive	This system is designed for whole arm rehabilitation, but there is a wrist module for supination/pronation
Ueki (95)	Gifu University, Japan	2008	Wrist and full hand	18 active	Individual joint controlled device with wrist mount
HANDEXOS (96)	ARTS Lab Scuola Superiore Santâ Anna, Pisa, Italy	2009	One finger	3 passive, 1 active	Device uses a wire-guided system to operate the finger in an extension motion
PneuGlove (97)	Rehabilitation Institute of Chicago, USA	2009	Full hand	5 active	Simple set of flexible inflatable cells stitched into various joint positions
J-Glove (98)	University EIA and CES, USA	2009	Full hand	1 active	All fingers linked in a single section to allow for extension
DULEX (99)	University of Dong-eui, Korea	2009	Four fingers and wrist	3 active	Tendon cables driven by air muscles for wrist and fingers used for grasping and wrist motion
Moromugi (100)	Nagasaki University, Japan	2009	Full hand	5 active	Tendon cables allowing for individual motion of each finger and thumb
Wu (101)	Huazhong University, China	2009	Index finger and thumb	2 active	Use of McKibben muscle actuators with wire tendons to allow for a pinch and grasp motion
AFX (102,103)	Rehabilitation Institute of Chicago, USA	2010	Index finger	3 active	The finger can perform both flexion and extension using 3 independent actuators and measure either force or control
HEXORR (82)	Centre for Applied Biomechanics and Rehabilitation Research, USA	2010	Full hand	2 active	The thumb moves individually while the fingers move as one
HEXOSYS (104)	Italian Institute of Technology, Italy	2010	Index finger and thumb	4 passive, 1 active	This device allows for actuation of both the thumb and a finger
Tong (105)	Hong Kong Polytechnic University, China	2010	Full hand	10 active	EMG-controlled device allows for individual muscle motion, using 1 linear actuator per finger to power motion of the device.
FingerBot (106)	Northwestern University, USA	2010	One finger	3 active	Single-finger manipulation requiring external support for balance and a single motor per joint
HIT-Glove (107)	Beihang University, China	2010	Index finger and thumb	2 active	Cable-driven bar linkage system to allow for pinch motion
Iqbal (108)	University of Genoa and Italian Institute of Technology, Italy	2010	One finger	1 active	Single-finger manipulation device with a wrist mount
Orlando (109)	IIT Kanpur, India	2010	One finger	3 passive	This system is used to study the optimal exoskeleton design though the motion tracking of the joints and to match with EMG sensors for finger motion
ATX (110)	Vanderbilt University, USA	2011	Thumb	5 active, 3 passive	Actuated thumb module designed to provide bi-directional motion of the thumb and used in combination with the actuated finger exoskeleton (103)
Bi (111)	University of Sydney, Australia	2011	Two fingers and thumb	5 active, 3 passive	Using 8 DOF this device offers control of the thumb and the middle or index finger, which are moved through a screw nut and multilink transmission
Naidu (112)	University of Kwa-Zula Natal, South Africa	2011	Wrist and full hand	3 active	A module of a full upper body rehabilitation device that allows for wrist motion and grasping motion with finger moving simultaneously.
Li (113)	University of Beihang, China	2011	One finger	3 active	A single-finger active exoskeleton
Tang (114)	Waseda University, Japan	2011	One fingers	2 active	A device that manipulates a finger in 2 DOF and can be used within and MRI scanner
HandSOME (115)	The Catholic University of America, USA	2011	Full hand	1 active	Hand-spring operated movement enhancer. The fingers move as one in motion with the thumb
Burton (116)	University of Bristol, UK	2011	Full hand	2 active	Using a 4-bar linkage system for the thumb motion and an open pulley system for the fingers a cylindrical grasp motion can be achieved

Table SIII. *cont*

Name of device	Developer	Year first published	Hand/wrist segment aided	Degrees of freedom	Function of the device
PRoGS (117)	ITE College West, Singapore	2011	Full hand	5 active	Tendon-driven system using EMG signals as grasping trigger
DULEX-II (118)	University of Dong-eui, Korea	2011	Four fingers and wrist	3 active	Linear actuators pull wire tendons for motion, with a data glove for motion monitoring.
BRAVO Hand Exoskeleton (119)	Scuola Superiore Sant'Anna Pisa, Italy	2011	Index and thumb	3 active	Belt-driven system with motor mounted on the wrist to provide force for pinch motion and is part of a upper arm exoskeleton
Rahman (120)	University of Technology, Australia	2012	Full hand	15 active	Through the use of a lightweight aluminium frame, which mounts linear actuators for the motion, it mimics the motion of the hand the sensor glove is on
Polotto (121)	Simon Fraser University, Canada	2012	Index finger	4 active	Single-finger system, using motors to drive each individual finger joint
IHRG (122)	University Politehnica Bucharest, Romania	2012	Full hand	13 active	Intelligent Haptic Robot-Glove provides both feedback and motion aid with 3 DOF per finger and 1 for the thumb
Surendra (123)	The University of Auckland, New Zealand	2012	Full hand	10 active	Uses 9 air muscles and a signal linear actuator to provide motion though a tendon system to all fingers and thumb
Lambercy (124)	Rehabilitation Engineering Lab ETH Zurich	2013	Thumb	1 active, 3 passive	Cable system for accurate measurement
ULERD hand module (125)	Tianjin University, China	2013	Four fingers	4 active	Hand attachment for upper body exoskeleton using a belt transmission for motion and EMG sensors for monitoring
Delphi II (126)	Worcester Polytechnic Institute, USA	2013	Full hand	5 active	Bowden-cable-driven system for individual finger motion switchable between flexion and extension.
Soft Pneumatic Glove (127)	Harvard University, USA	2013	Four fingers	2 active	Soft robotic cells mounted on each finger, which, when inflated, provide motion for the fingers to grasp an object.
Weiss (128)	University of Lubeck, Germany	2013	Four fingers	4 active	Parametrically designed 3D-printed cable-driven glove designed to be customisable to multiple hand size varieties.
Song (129)	Tianjin University, China	2013	Index finger and thumb	3 active	Three mounted linear actuators provide force to the thumb and finger for a pinch motion to be performed
PAFEx (130)	Shibaura Institute of Technology, Japan	2014	Full hand	1 active	Pneumatic control system for flexion and extension of the fingers
PMHand (26)	Heriot-Watt University, Edinburgh, UK	2014	Four fingers	2 active	Finger manipulation based on tendon design with finger flex recording
SCRIPT Passive Orthosis (30,131)	University of Hertfordshire, UK	2014	Full hand	1 active, 2 passive	Active wrist manipulation with force feedback for wrist and fingers
ReHand-II (132)	Tianjin University, China	2014	One finger	Index active	Index finger exoskeleton with individual joint control as a prototype for future systems
Ushiba (133)	Keio University, Japan	2014	Four fingers	1 active	Splinted wrist with mounted motor linked to the 4 fingers for simultaneous motion using BMI control
SPRM (134)	Harbin Institute of Technology, China	2014	Full hand	2 active	Bowden-cable-driven mounted exoskeleton
Park (135)	Korea Advanced Institute of Science and Technology, Korea	2014	Four fingers	4 active	Tendon-driven module for the J-WREX exoskeleton to allow for 4 finger individual motion
Coffey (136)	National University of Ireland Maynooth, Ireland	2014	Wrist and full hand	5 active	Air bladders between and mounted on to fingers and wrist allow for motion control using a BMI control
Guo (137)	Tianjin University of Technology, China	2014	Index finger	3 active	Individual finger with each joint control by separate belt transmissions and using an EEG as the control method
SCRIPT Active Orthosis Iteration 3 (30)	University of Twente, Netherlands	2015	Wrist and full hand	10 active, 2 passive	SAO-i3 is capable of active 4-finger and wrist actuation and passive thumb actuation in flexion and extension and is fully sensorized.
Agarwal (138)	University of Texas, USA	2015	Index finger	2 active	Each joint of the finger is actuated by a Bowden-cable-based series elastic actuator, the device implements both a force-field and impedance control
Exo-glove (139)	Seoul National University, South Korea	2015	Two fingers	1 active	Bowden-cable-driven device with attachment point on glove allowing for smoother natural motion
Ab (140)	Universiti Teknologi MARA, Malaysia	2015	Full hand	5 active	Lead screw linkage from motors used to manipulate fingers and thumb individually using EMG sensor as trigger
Gasser (141)	Vanderbilt University, USA	2015	Four fingers	1 active	Cable-driven system used to move 4 fingers simultaneously to aid with daily living tasks
Richards (142)	University of the West of England, UK	2015	Full hand	3 active	All fingers move simultaneously while the thumb has 2 DOF to allow for a complete grasp motion
Lee (143)	UNIST, Korea	2015	One finger	1 active	A 4-bar joint linkage system is used to manipulate a single finger, using embedded IMUs is the design to monitor motion
HES (144)	University of Florence, Italy	2015	Four fingers	1 active	Cable-driven device designed around single-phalanx mechanism
SOPHIA (145)	Heriot-Watt University, UK	2016	Four fingers	4 active	Soft robotic system using multi-material soft sections and a sensor array to allow for safe use with BMI control
A Helping Hand (146)	Cornell University, USA	2016	Full hand	5 active	Full-hand soft robotic rehabilitation system using EMG control and novel fibre-optic sensors for bending

3D: 3-dimensional; EMG: electromyography; DOF: degrees of freedom; BMI: brain-machine interface; IMU: inertial motion unit; VR: virtual reality.