Effects of soft robotic gloves on rehabilitation outcomes in individuals with sensorimotor hand impairments: a systematic review

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INTRODUCTION

For individuals with hand hemiparesis following a stroke, rehabilitation strategies are predominantly founded on the principles of neuroplasticity and automaticity [1] to regain optimal hand-related functional abilities and facilitate participation in everyday activities. Such an approach requires to engage these individuals into meaningful activity-specific exercises and to repeat those intensively on a daily basis. Adhering to these principles [2] remains challenging in clinical practice for rehabilitation professionals, especially given various time and productivity constraints. To overcome this challenge, the development of soft robotic gloves to facilitate hand rehabilitation have progressed substantially in the last decade. Moreover, these soft robotic gloves are foreseen as promising rehabilitation intervention to potentiate the effects of conventional rehabilitation interventions and are now about to transition into clinical practice, although their effects remain uncertain given the paucity of evidence. In this context, this review aims to map evidence on the effects of the different rehabilitation interventions using a soft robotic device for sensorimotor hand impairments and, whenever possible, the satisfaction related to their use.

METHODS

Eligibility criteria, information sources, and search

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [3]. A review of the literature published in English and French from 2000 to October 2018 using a combination of search terms was conducted in Medline, EMBASE, and CINAHL. The search strategy included a combination of search terms related to three key domains: technology attributes (robotics, bionics, exoskeleton device, robot*, exoskelet*, motorized, motor-driven, motor assisted), anatomy of the hand (hand, hands, wrist*, finger*, prehension, dexterity), and rehabilitation domains (rehabilitation, exercise*, exercise therapy, physical therapy modalities, physical therapy speciality, physical therapists, occupational therapy, occupational therapist, therap*, physiothrap*). Search terms related to amputation, surgery, computer-assisted device, and teleoperation were excluded. From this initial search, 1870 articles were found and only 1206 articles remained after eliminating all duplicates. To narrow down the number of articles, a new domain was added (i.e., technology= glove, soft, wearable) and the search among the keywords, title, and abstracts was continued in EndNote. Thereafter, 181 articles remained and were imported into the web-based software platform Covidence where 9 additional duplicates were found.

Selection of sources of evidence

The articles title, abstract and full text of 172 articles were screened by two rehabilitation professionals to identify the articles qualifying for a subsequent full review. To be considered for full review the article has to target 1) the effects or effectiveness of rehabilitation interventions using soft robotic gloves to optimize hand-related functional abilities and facilitate participation in everyday activities in people with sensorimotor disorders via randomized controlled trials (RCTs), non-randomized controlled trials (non-RCT), and other types of research designs (cohort studies, pre- and post-case interventions, case series, case-control studies and case reports) and 2) the users satisfaction and stakeholder views on the use of soft robotic gloves. For this review, in order to be considered a soft robotic glove, the technology had to generate assisted pinching or gripping movements soliciting multiple joints involving at least the thumb and the index finger and middle fingers. Interventions using a soft robotic glove could be performed in a hospital, rehabilitation center or at home with the direct or indirect supervision of a rehabilitation professional. The use of the soft robotic glove could also be combined with other technologies (e.g., virtual reality). Research protocols or manuscripts that did not include participants with sensorimotor impairment were excluded. All scientific manuscripts and conference abstracts focusing on upper limb exoskeleton including the elbow or shoulder joint were excluded.

Data extraction and charting process
Studies that met the inclusion and exclusion criteria were read by a single rehabilitation professional and the following information were extracted on project-specific forms data extraction tables organized within an excel file: author-related information’s, journals and publication year, soft robotic glove attributes, study design, population and sample size, intervention, measurement instruments, results and interpretations, and user’s satisfaction. At the end, to establish if the use of a soft robotic glove yield to positive, neutral or negative effect, the p-value and effect size of each outcome measures from each article were determined.

RESULTS

Characteristics of sources of evidence

Ten articles included in this study originated from European or American countries; USA (5/10 [4-8], Italy (2/10 [9,10], United Kingdom (2/10 [11,12], and Netherlands (1/10 [13]. The majority of these studies were published in 2017 (6/10 [6,8-12] or 2018 (3/10 [5,7,13]. Only one study was published in 2011 [4].

Study designs and populations

Both experimental (3/10 [8,10,12] and quasi-experimental studies (7/10 [4-7,9,11,13] were selected with mean sample sizes of 12.4 participants and ranging from 2 to 27. Most studies investigated individuals with hemiparesis following a stroke (9/10 [4-6,8-13] whereas one article investigated individuals with of a traumatic spinal cord injury [7].

Synthesis of findings

Soft robotic gloves

Eight different soft robotic gloves (i.e., HandSOME [4,6], FES Hand Glove [7], Gloreha Light Glove [9], Gloreha Professional [10], VAEDA [8], HandinMind [12,13] and two others without names) with different types of assistance (i.e., motor [7,8,9,10,12,13], elastic [4,6], and pneumatic [5,11]) were identified.

Interventions

Four studies [4,5,11,13] used a transversal design to compare hand function with and without the use of a soft robotic device glove whereas three studies used an experimental design [8,10,12] and three used a quasi-experimental design [6,7,9] to compare hand sensorimotor integrity and functional abilities before and after an intervention with the soft robotic glove. No concomitant therapy was used in all of the studies. The intervention protocols of the experimental and quasi-experimental design studies varied in length from 4 to 8 weeks, in frequency from 3 to 6 times a week and training sessions duration from 40 to 90 minutes.

Outcome measures

The outcome measures included: Ashworth Spasticity Index [9] or Ashworth modified scale [6], edema [9], Hand pain VAS [9], Barthe [9], Motricity index [9,10], Nine hole peg test (NHPT) [9,10], grip strength [4,6,8-10], active range of motion (AROM) [4], Velocity of movements [4], Box and blocks test [4], Fugl-Meyer Assessment of Upper Extremity (FMA-UE) [6,8], Fugl-Meyer Hand (FMH) [8], The Action Research Arm Test (ARAT) [6,8], The Motor Activity Log [6], time to execute tasks [11], Toronto Rehabilitation Institute Hand Function Test (TRI-HFT) [5], pinch strength [8,10,12], JTFHT [12], Activity of Daily Living (ADL) [13], Functional Independence Measure (FIM) [7], Wolf Motor Function Test (WMFT) [8], Chedoke McMaster Stroke Assessment Hand (CMSAH) [8] and the Quick-DASH [10]. Then, each outcomes measure have been classified according to the International Classification of Functioning, Disability and Health (ICF) [14] (Figure 1).

Effects and effectiveness

The results in terms of effects and effectiveness of the interventions are listed in the Figure 1. Mostly, the use of robotic gloves increased joint mobility and functional capacity of the upper limb in terms of performance rapidity. According to muscular strength, functional capacity of the upper limb assessed by questionnaire, and global functional capacity, the results are heterogeneous and do not allow conclusion on the effectiveness of intervention using this technology.

Usability, feasibility and satisfaction
Four studies also assessed the usability, feasibility or satisfaction of the users after trying the soft robotic glove [10-13] using the Usefulness-Satisfaction-and-Ease-of-Use questionnaire [11], observations [4,10], System Usability Scale [12,13], Intrinsic Motivation Inventory [13], cost analysis [10]. Studies concluded that the use of soft robotic gloves is foreseen as being feasible and acceptable by participants and rehabilitation professionals [10-13] and as increasing engagement in rehabilitation program [11,13]. Most of the studies support the fact that the soft robotic gloves are easy to use [10, 1, 13]. However, the robotic glove was found to be more useful when performing gross motor tasks when compared to fine motor tasks [12], the presence of a zipper on the glove made it difficult to put on [13], and the choice of material, especially its thickness, was found to interfere with hand and finger sensations [13]. A preference for the rental of these devices has been demonstrated [11]. The most important features highlighted in the studies included: easy to clean, comfortable, easy to put on and take off. Last, a decreased in rehabilitation cost linked to the use of a soft robotic device at home may be anticipated [10].

**DISCUSSION**

This systematic review of the literature confirms an increased interest over the last decade in the development and use of soft robotic gloves for rehabilitation of individuals with hand hemiparesis following a neurological event. Overall, the use of soft robotics devices in rehabilitation treatment is feasible, safe, and acceptable by patients while its effects and effectiveness appear promising. However, the strength of the currently available evidence remains limited and given the wide variety of soft robotic glove attributes, study designs and interventions, and outcomes measures alongside the small sample sizes tested, it is impossible to highlight which soft robotic glove or intervention protocol would be the most appropriate to obtain the best clinical results. Stronger evidence linked to the effects or effectiveness, in addition to comprehensive stakeholder perspectives (e.g., patients, rehabilitation professionals), especially on the usability, are needed to ensure a successful transition from the laboratory to clinical practice.

**CONCLUSIONS**

This systematic review maps currently available evidence on the use of soft robotic gloves as a rehabilitation intervention while considering effectiveness and usability. This technology is a promising solution to optimize sensorimotor capabilities, hand-related functional abilities and facilitate participation in everyday activities while
overcoming some clinical constraints. Additional research in this area should be encouraged to strengthen current evidence.

ACKNOWLEDGMENTS

Supported by the Initiative for the Development of New Technologies and Innovative Practices in Rehabilitation and by the Université de Montréal (Direction des affaires internationales).

REFERENCES


