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Effects of Passive Exercise Training in Hemiplegic Stroke Patients: A Mini-Review

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Abstract

Stroke-induced hemiplegia is a life-changing event leading to permanent disability and limited movement. The general goals of rehabilitation for the hemiplegic stroke patient are to maintain and improve current function, delay the progression of disease and reduce the risk of another stroke from occurring. Passive exercise has been used for treating stroke patients; however, the efficacy of such interventions is unknown.

Purpose: Thus, the purpose of this literature review was to investigate the efficacy and safety of passive exercise interventions for patients with hemiplegia with a focus on those interventions that could be used in the home setting.

Methods: Medline and CINAHL data bases were searched for articles related to passive exercise training and hemiplegia.

Results: Two types of passive exercise interventions used to treat stroke patients that could be used in the home setting were identified in the literature:

1. Continuous Passive Motion (CPM)

2. Use of motorized-cycle ergometers.

CPM interventions were found to significantly decrease edema and muscle spasticity/stiffness as well as improve motor function. Passive cycle- ergometer exercise training protocols indicated that improvements in motor control and balance can occur following training. There were no reports of any adverse events associated with use of the CPM or passive cycle-ergometry.

Conclusion: Passive exercise is safe to perform by hemiplegic stroke patients and can induce functional improvement. Future research is required to determine best practice guidelines for optimizing exercise prescription for passive exercise using these devices in persons with hemiplegia.

Keywords: Cerebral vascular event; Stroke; Passive exercise; Continuous passive motion; Physical function

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Introduction

Stroke is a leading cause of morbidity and mortality world-wide [1]. It occurs most frequently in patients aged 51-60 years, with approximately 52% of cases attributed to ischemic blockage and 45% of cases caused by brain hemorrhage [2].The main risk factors for developing stroke include hypertension, smoking and diabetes. Men are more likely to experience stroke, compared to women, with a ratio of 1.35:1 for ischemic stroke and 3:1 for hemorrhagic stroke, respectively [2]. Although the clinical presentation of stroke is variable depending upon the site and extent of the lesion in the brain, most patients (80% percent of ischemic stroke patients and 85 % of hemorrhagic stroke patients) experience some form of hemiparesis or hemiplegia during the sub acute and/or chronic stages. This occurs more commonly on the right side of the body. Other physical functions that are affected include speech, swallowing, sensation, balance and co-ordination. Most stroke survivors subsequently need some form of assistance with activities of daily living from a care provider.

Following a severe stroke, hemiplegic patients are commonly bedridden, with whole body movement limited to physical transfers between their bed and wheel-chair (using either a full-body transfer-lift or a weight-bearing transfer aid). Rehabilitation for these patients is directed towards recovering functional ability with the non-paretic side of the body. However, limited mobility due to hemiplegia can lead to a progressive decline in physical function which further exacerbates their condition and contributes to a cyclic spiral of deconditioning. Limitations in physical activity have

Table 1: Studies examining the effects of continuous passive motion (CPM) on stroke patients.

Author/ Year/ (Study Type)	Sample size	Age(yrs)	Acuity	Body Part	Intervention	Objective measures	Results
Bressel& McNair, 2002 (RCT) [25]	n = 10	65 ± 9	N/A	Lower leg (calf)	30 min cycling and static stretching, 5 degrees/ (10 degrees plantar flexion - 80 degrees dorsiflexion)	Joint stiffness	↓ Ankle stiffness (30%)
Dirette& Hinojosa, 1993 (Cases) [18]	n = 2 (1 M, 1 F)	62, 75	1-mo	Hand	2 hrs CPM hand exercise over 5 days	Edema	↓ Edema
Guidice, 1990 (RCT) [22]	n = 11	38 – 78	N/A	Hand	1 bout, 30 min CPM with hand elevation	Edema	↓ Edema & stiffness
Hesse et al. 2008	n = 2 M n = 8 M	55, 67	Chronic subacute	Hand (Fingers)	Standard therapy plus CPM finger trainer. 4 wks, 20 min/d, 5 d/wk	FM scores	↓ Finger/wrist spasticity
Hu et al., 2009 (RCT) [4]	n = 27 (IG= 15, CG= 12)	49 ± 15 53 ± 10	Chronic	Wrist	20 sessions over 7 wks, robot assisted passive motion vs CPM	FMA FIM MAS	↓ Spasticity in wrist flexor
Kim et al., 2001 (pilot study) [23]	n = 20 (10 IG, 10 CG)	61 ± 8	Chronic (> 6 mo)	Legs	6 wks - Isokinetic strength training 3 ×/wk; 45 min/d; 3 sets of 10 reps	Gait Strength HRQoL	↑ Strength (IG > CG) Gait speed
Lynch et al. 2005 (Pilot Study) [21]	(17 per group)	NA	(Subacute) 13 ± 6 d	Shoulder	CPM vs standard care 4 wks,5 × /wk;25 min/session	FMA Motor Power MSS	↑ shoulder-joint stability
Selles et al. 2005 (non-controlled trial) [24]	n = 10	NA	NA	Ankle	4 wks, 3 ×/ wk, 45 min Repeated feedback-controlled stretching of spastic joints	ROM, MVC Ankle stiffness, Walking speed	ROM ↑ MVC ↓ Stiffness

Legend: Case = case study; CG = comparison group; d = days; FIM = Functional Independence Measure; FMA = Fugl-Meyer assessment; HRQoL = Health-related quality of life; IG = intervention group; MAS = modified Ashworth Scale; MSS = motor status scale; MVC = maximal voluntary contraction; ROM = range of motion; RCT = Randomized controlled study; Not available = NA; wk = weeks.

been associated with a variety of health-related-conditions including cardiovascular disease, obesity, diabetes and muscle wasting.

In order to facilitate recovery and at least maintain functional status during and following the acute phase of stroke, these patients need opportunities for some form of movement. Intensive rehabilitation can be labour-intensive upon the care-provider and costly. Thus, alternative methods such as passive exercise training through use of a machine has been one method used in the clinical and home setting to promote physical activity and movement during the acute and chronic phases following a stroke, however, further research is required in order to determine its safety and efficacy. Thus, the purpose of this literature review is to evaluate the efficacy of passive exercise training for the hemiplegic stroke patient.

Materials and Methods

This literature review focused on rehabilitation of the hemiplegic stroke patient using passive exercise training with the intent of being able to apply this to the home setting. Due to limited access to all data bases, two data bases were selected to review due to their wide scope of research findings: Medline Ovid and the Cumulative Index of Nursing and Allied Health Literature (CINAHL). These data basis were searched from 1948 until present day. Medline contains articles on biomedical literature from around the world and CINAHL is the largest and most in-depth Nursing research data base. The following search terms were included: Continuous Passive Motion (CPM), passive exercise training, passive cycle ergometer, stroke, Cerebral Vascular Accident (CVA), hemiparesis and hemiplegia. Inclusion criteria for the articles reviewed included experimental studies using a variety of experimental designs (randomized controlled studies, studies of quasi-experimental design and case studies) and literature reviews published in English. Studies included in this review had to use some form of passive exercise training (with the understanding that training could be performed in the home setting), as therapy for the hemiparetic or hemiplegic patient.

Results and Discussion

A total of 12 research articles on passive exercise for stroke patients are included in this review. This included studies on Continuous Passive Motion (CPM) and passive cycle-ergometry. Although, robotics can be used for stroke rehabilitation [3] and have been used as a comparison group in one of the studies discussed [4], it would not be feasible to use robotics in the home setting, thus, these studies are not included in this review. Data extracted included age, acuity, body part affected by stroke, information on application of the intervention (CPM and passive exercise training) and objective measures.

Hemiplegia

The terms hemiparesis and hemiplegia are often used interchangeably within the rehabilitation literature. This is not always correct when considering motor function and rehabilitation protocols. Hemiparesis refers to muscular weakness or partial paralysis restricted to one side of the body, whereas hemiplegia is a more severe form which occurs much less frequently. One study has reported the frequency of occurrence of hemiplegia in the general population, due to any cause (including stroke), as less than 1 percent (0.0569 percent) [5]. In the hemiplegic state, the patient does not have control of movement of the affected limbs on one side of the body. Understanding the difference between hemiparesis and hemiplegia is important as some forms of rehabilitation (e.g., weight-supported treadmill exercise) [6] are oriented towards the restoration of walking as the main goal of lower limb rehabilitation following a stroke [7]. The ability to ambulate is not present in the hemiplegic stroke patient; however one of the goals of rehabilitation exercise for the hemiplegic stroke patient is promoting movement.

In a seminal study, Newman [8] followed the disease trajectory in 39 hemiplegic stroke patients for 12-weeks post-stroke in order to understand the natural disease trajectory. The majority (87%) of patients demonstrated some form of neurological recovery predominantly in the lower limb. Neurological recovery began as early as the first week post-stroke and continued until week 12 at which time the recovery rates plateau. Functional recovery followed that of neurological recovery. The legs tended to recover function more often than that of the arms and the proximal segments

Table 2: Studies on passive cycle-ergometer exercise and stroke patients.

Author/ Year/ (Study Type)	Sample size	Age(yrs)	Acuity	Body Part	Intervention	Objective measures	Results
Brenner (2017) (Case) [30]	n = 1	93 y	Chronic (2-yrs)	Leg	Passive cycle ergometer exercise-5 wks 5 min - 45 min/d, 3 mi/hr, 5 d/wk	BI	↑ BI 15 points ↑ cognition continence
Fujiwara et al. (2003) (Before & after- trail) [33]	n = 17 12 m, 5 w	51 ± 10	Chronic 159 ± 58 days	Leg	One time 5 min pedaling, 16.2 rpm ± 5.9, 5 N-m (dynamically-controlled dynamometer)	Knee extension test pre- during and post	Muscle activities increased in Quads and Tibialis anterior
Katz-Leurer et al. (2006) (RCT)	n = 24; (10 IG, 14 CG)		Subacute stage	Leg	3 wks - Usual program plus cycling 7 d/wk; intensity 40% HRR; Intermittent-2 min plus 1 min rest for 10 min; then add 1 min for two days, then 3 min to 30 min at end of 1stwk, 3 wks	PASS Standing-balance test FMA	↑PASS scores & subscores ↑ FMA scores (improved balance and motor performance) Better chance of standing independently
Soon et al., 2012 (quasi-experimental) [32]	25 IG 25 CG	NA	NA	Upper arm	Passive upper arm exercise, twice daily, 30 min per session	ROM Manual Muscle Test MAS	↑ ROM shoulder/wrist

Legend: BI = Barthel Index; case = case study; d = day; FMA = = Fugl-Meyer Assessment; HRR = heart rate reserve; MAS = modified Ashworth Scale; NA = not available; PASS = postural assessment scale for stroke patients; ROM = Range of motion; wk = week

recovered function more frequently than the distal segments [9]. The trunk muscles are affected the least in hemiplegia and, in some cases, full recovery of trunk function can occur following a stroke. It was thought that early return of function (in particular of the upper limb) was due to reperfusion of the ischemic area and resolution of cerebral edema (which had contributed to decreased levels of consciousness), whereby, late recovery was due to transfer of function to undamaged neurons. Interestingly, Franz, Scheetz and Wilson (1915), have presented results in which the return of function in a paralyzed limb returned well after the time limit set for improvement by neurologists [9]. More recently, researchers are also proposing that intensive rehabilitation for stroke patients (even during the chronic stage) can further enhance functional ability due to this transfer of cortical function [10, 11].

Stroke rehabilitation

Once the patient is medically stable following their stroke, a variety of rehabilitation techniques are available to help the stroke survivor attain their optimal physical, emotional and social well-being [12]. The general goals of rehabilitation for the hemiplegic stroke patient are to maintain and improve current function, delay the progression of disease and reduce the risk of another stroke occurring [13]. Commonly, treatment is directed towards adapting function of the non-paretic side to compensate for the loss of function on the paretic side [14], however, little emphasis is placed upon simply promoting movement.

For persons with limited mobility induced by a stroke, depending upon the severity and extent of lesion, movement on the affected side of the body may be induced through a variety of different approaches. Constraint-Induced Movement Therapy (CIMT) [15] therapy is an approach to improve upper extremity function in patients with hemiparesis. It involves restraint of the unaffected arm for 90% of the patients' waking hours (through application of a sling or hand splint) which forces the patient to use his/her affected arm. In addition, exercise of the effected arm is also done in small steps of increasing difficulty. Functional electrical stimulation of selected muscle or muscle groups is commonly used in conjunction with passive exercise to facilitate movement [7]. Functional Electrical Stimulation (FES) of muscles of the lower limb that induces cyclic movement has been shown to improve motor function in hemiparetic stroke patients. When applied over 4 weeks, in doses of 5 sessions per week, each lasting 25 minutes, significant increases in motor function (trunk control, gait speed and work output) occurred. Additional techniques used in rehabilitation for hemparesis/hemiplegia involve cortical stimulation, imagery, mirror therapy [10, 16]or use of assistive devices such as an interactive rehabilitation robots [4].

Many of the rehabilitation techniques identified above require a therapist or robot for its application. This becomes time consuming for the therapist as well as problematic from a logistic perspective when a patient returns home following the acute in-hospital treatment of their stroke. Another feature required for some of these techniques to work is that the stroke patient should be able to move his/her body or affected limb to some extent. Passive exercise using assistive devices such as a continuous motion machine or a cycle ergometer can be applied safely at home to help promote movement and to improve function in the recovering stroke patient whether or not they have regained control of their paretic limb.

Passive exercise

Passive exercise is defined as movement of the body without the effort of the patient. It does not require the expenditure of energy in order to induce movement and as a result has not been encouraged as a training method to improve aerobic capacity in the hemiplegic stroke patient. Passive exercise occurs with physical assistance through either health care provider (i.e., a nurse, a kinesiologists or a physical therapist) or through use of a machine. More frequently, the term "passive" has been applied to stretching techniques whereby a partner or machine applies external force to induce or enhance a stretch [17]. For continuous movement of a specific joint through a prescribed range of motion this can be accomplished through use of a machine which provides Continuous Passive Motion (CPM). Alternatively, passive arm or leg cycle-ergometry can be used to engage more muscle groups and joints specifically applied to either the upper or lower body respectively.

Continuous passive motion (CPM) exercise

CPM interventions were initially used for knee rehabilitation following total knee arthroplasty to prevent the development of arthrofibrosis (O'Driscoll, 2000). Since then, there were numerous studies that have measured patient function following CPM interventions in a variety of orthopaedic patient populations. The benefits of this type of intervention have been to increase ROM, preserve hyaline cartilage integrity and the prevent the development of Deep-Vein Thrombosis (DVT). Based upon the types of instruments available, the various joints in which CPM can be applied to include the hip, knee, ankle, foot, shoulder, elbow, wrist and hand.

New approaches to stroke rehabilitation have indicated that intensive repetition of movement (more than 100 repetitions per day, 5 days per week, performed over two weeks) can improve voluntary movement [11]. In support of this, other researchers have indicated that that the dose of therapy has to be sufficiently intense enough in order to bring spontaneous use of the affected limb above threshold. Once reached, spontaneous movement will be continuously repeated on its own.

Several studies have examined the effect of use of CPM devices in the sub acute (1-month post-stroke [18]) and chronic stages(> 1 month post-stroke) [19,20] (Table 1). The majority of research on use of CPM for stroke patients has been applied to the upper body (shoulder [21], wrist [20] and hand/fingers [18,19,22]). These few studies have demonstrated that CPM exercise can significantly reduce physiological symptoms such as edema, muscle stiffness and/or spasticity. As little as one bout of hand CPM exercise, performed for 30 min with the hand elevated, was sufficient to induce a significant reduction in edema and stiffness in the affected hand. Chronic use of the device also has a positive effect. Shoulder joint stability can be increased following 4 weeks of training, 5 × /week/ 25 min per session (plus warm-up and cool-down) [21]. In a pilot study, Kim et al. [23] applied CPM to the legs of chronic (> 6-months post stroke), hemiparetic stroke patients. This treatment was applied to 10 participants for 6 weeks (3 times per day, at a velocity of 30 m/second to 60 m/second, for 45 min each session) in addition to their regular rehabilitation of muscle strength training exercises (which a comparison group also received). Participants in the intervention group demonstrated an increase in lower-leg muscle strength and gait speed. Selles et al. [24] used CPM to apply stretching to the plantar and dorsi-flexors in the lower leg of 10 stroke patients. After 4 weeks of training (3 days per week, 45 min per session), significant improvements were observed in ROM, Maximal Voluntary Contraction (MVC) and walking speed accompanied with a reduction in ankle stiffness.

Several mechanisms may explain the benefits reported to occur with CPM training. CPM induces an involuntary pumping action by the muscles (which normally would be inactive) that increases lymphatic and venous drainage or flow [18, 22]. In addition, Bressel and McNair [25] propose that the thixotropic property of the muscle (i.e., the physical change of the muscle after being mechanically agitated) may improve soft-tissue compliance and decrease muscle stiffness and any associated pain. Any stretching that occurs through CPM could reduce spasticity by a combination of a reduction in reflexive activity and stimulation of mechanoreceptors (vibration within the muscle would activate Pacinian corpuscles) [19]. Lastly, passive movements can induce brain activation patterns on the affected side that are similar to that which occur on the contralateral side. For example, Vér et al. [26] demonstrated that passive movements for the paretic ankle-foot joint increased both ipsi- and contralateral cortical activation simultaneously, improved ankle range of motion and decreased the severity of spasticity.

This review of the literature has demonstrated that CPM exercise is safe for stroke patients to do (no adverse effects were reported in the literature). It can enable patients to perform this type of exercise in their own home with supervision. It also is relatively inexpensive (aside from the one-time cost of purchasing or renting the exercise equipment) it is also cost-effective, induced physiological benefits and saving in cost of a therapist's time. Having said this, there are gaps in the literature which need further investigation. Thus far, there does not appear to be any standard protocols or best practice guidelines for using CPM with stroke patients. More information is required on the type of device, the frequency and duration of each exercise session as well as the intensity (ROM covered per second) and how long the therapy should be continued (i.e., length of treatment). Use of a variety of assessment measures, also makes comparison between outcomes of various studies difficult. More research is also required on which stage of recovery (acute, sub acute or chronic) following a stroke and type of stroke that CPM training may be most beneficial for.

Passive cycling exercise

Historically, exercise physiologists did not believe that passive exercise training on an ergometer was useful. Their reasoning was based upon the principle of overload, which implied that a physiological system (i.e., cardiovascular, musculoskeletal, neuroendocrine system) needs to be repeatedly stressed in order for significant physiological adaptations to occur. There now are a variety of active-passive cycle ergometer exercise machines on the market which are used for rehabilitation purposes (for example, the "Ex N' Flex machine and the "Theracycle", both of which this author has used for exercise therapy for patients). However, studies examining their use in the stroke population and the therapeutic benefits of their use are limited.

Due to the limited research that has been conducted on passive exercise training in stroke patients it is useful to first examine the physiological responses that occur in normal individuals and possibly extrapolate these findings to stroke patients. However, the response of normal, healthy individuals to both acute and chronic passive cycle exercise using motor-driven cycle ergometers has also been minimally investigated. Nurhayati and Boutcher [27]examined the acute cardiovascular response to passive exercise in both trained and untrained male participants and demonstrated that the acute response to passive cycle exercise is fairly similar to that of active exercise (although in smaller magnitude). During passive exercise, heart rate increases, cardiac output increases, but stroke volume remains the same. During passive exercise, a decrease in vagal output occurs as reflected by a reduction in HR variability. The rise in HR and cardiac output that was observed was attributed to the stimulation of muscle mechanoreceptors and withdrawal of vagal tone. Whereas, little change in SV occurred due to the fact that the muscle pump is not as effective in venous return with passive cycle ergometer exercise. The muscle pump mechanism appears to be more applicable with CPM.

Brenner [28] and Nafziger et al. [29] have studied the effects of chronic use of the passive cycle ergometer training in individuals who have not experienced a stroke. Nafziger et al. [29] examined the effects of six weeks of passive exercise training on lean body mass, muscle strength and muscle activity in 28 healthy volunteers (aged 20-44 years). Participants performed passive exercise training 3 times per week, for 45 min per session. No significant changes in body mass, or muscle strength and activity occurred following the 6 weeks of passive exercise training. Perhaps due to the short period of time for conditioning (i.e., 6 weeks). In contrast, Brenner [28] reported on the beneficial effects of passive exercise training in an elderly population living in long-term care. Changes that occurred following training included an increase in resting core body temperature as well as improvements in mobility and strength measures (as reflected by the Timed Up and Go Test (TUG) and the 6-min walk test). Reports of illnesses (such as the flu) also declined in the active group. The differences in findings between these two studies may be the duration each intervention was implemented.

Very few studies have examined the safety and efficacy of passive cycle ergometer exercise in stroke patients (Table 2). This is interesting since personal observation of a rehabilitation unit in a local, community hospital has indicated use of the motorized cycle ergometer regularly as part of rehabilitation therapy in stroke patients. In this review, it was found that two studies were designed to examine the effect of passive leg-cycle ergometer exercise on functional measures [30, 31]. Perhaps, since this type of intervention aims to prevent leg muscle hypotrophy from occurring. One other study examined the effects of passive exercise using the arms [32]. For the chronic exercise training protocols, the duration of training programs ranged from 3 to 5 weeks. Improvements in motor control, trunk stability and cognition were reported following this type of passive exercise training [30]. Regular passive arm exercise led to an increase in the range of motion in the affected arm [32]. Further research on passive ergometer exercise is required to determine the effects of a longer intervention (i.e., > 5 weeks).

Thus far, it appears that neural activation may account for some of the adaptations reported (e.g., improvements in motor control). Fujiwara et al. [33] looked at the acute effects of 5 minutes of passive exercise training on leg muscle activity. Muscle activity in the quadriceps and the tibialis anterior increased with passive exertion. This type of activity promoted facilitation of agonists and inhibition of antagonists.

Use of passive cycle ergometers as an exercise intervention to promote movement in other clinical populations indicates the potential which this type of intervention can have on stroke patients. In a study involving 19 ICU patients, de Franca et al. [34] demonstrated that passive cycle exercise can be safely done as well as reduce levels of nitric oxide and have beneficial effects on oxidative stress. Passive exercise also has been shown to improve cognitive function in patients with Parkinson's disease [35] and can also reduce motor deterioration in patients with Amyotrophic Lateral Sclerosis (ALS) [36]. Although passive exercise training does not appear to induce any central physiological adaptations in patients with spinal cord injuries [37], peripheral physiological benefits (such as increased muscle blood flow) can occur in the trained muscle [38].

Much more research is needed to determine the effects of passive cycle ergometer exercise for the hemiplegic stroke patient. As with CPM interventions, best practice guidelines (related to the FITT principle-frequency, intensity, type and time) need to be made specifically for these patients to use the passive cycle ergometer effectively. Only one study was reported to set a specific intensity for the exercise protocol and suggested that the participants exercise at 40% of their Heart Rate Reserve (HRR) initially [31]. Thus, directions for future research include the design of high quality Randomized Control Trials (RCTs) and use of homogeneous patient samples (i.e., the age and sex of the participant, type of stroke, duration since stroke onset and stage of recovery being the same for all participants). Determination of best practice guidelines for exercise prescription is required (type of device, device settings, frequency, intensity and duration).Overall, this review has indicated that limited research is available on the use of passive exercise therapy for the hemiplegic stroke patient and that research in this area can be further expanded.

Limitations

Limitations of this mini-review relate to the type of search that was done and the of articles that were reviewed. Only two data bases were searched for relevant literature, limiting the scope of this paper. Thus, conclusions cannot be generalized to all types and presentations of stroke conditions. Moreover, the articles that were reviewed included small sample sizes, had various experimental designs, different treatment durations and used numerous tools to assess outcome measures. Lastly, an emphasis was placed on examining passive exercise interventions that could be done in the home settings, limiting a review of studies using robotics to assist with passive exercise training. Overall, more research in this area is required using homogenous patient samples.

Conclusion

Although further research is warranted, CPM and passive exercise are effective interventions to stimulate movement in the hemiplegic stroke patient. CPM exercise is more effective at inducing changes at a single joint, whereas passive cycle-ergometer exercise utilized more joints and muscles and may have a cardiovascular effect if not centrally, then at the local level (increasing blood flow to the skeletal muscle). No reports of adverse events with use of either instrument were reported. CPM devices and motorized cycle ergometers are relatively inexpensive and can be operated with supervision [21]. CPM interventions were found to significantly improve edema, spasticity, stiffness and motor function. Whereas, passive cycle ergometer exercise was found to improve motor control, range of motion and cognition. Further research is warranted in order to determine the effects of passive-exercise training on other systems of the body (e.g., the cardiovascular, respiratory, endocrine and immunological) and to determine proper exercise protocols (device settings, frequency and duration and clinical setting).

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