

Mental Imagery in Spinal Cord Injury: A Systematic Review

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Abstract

Background: The immense potential of structural and functional reorganization of central nervous system i.e., neuro-plasticity following any injury serves the key mechanism behind the recovery of sensory-motor functions. One of the ways of enhancing this reorganization is through the technique of mental imagery. Mental imagery has been studied in various neurological conditions such as stroke and spinal cord injury (SCI) and has been seen to be quite effective in bringing about functional gains. But the research and literature available, particularly in SCI, is quite diverse and inconclusive. This review was, hence, conducted with the aim of understanding the concept of mental imagery and its therapeutic potential in spinal cord injury.

Method: A systematic literature search, using PRISMA 2009 guidelines, was conducted according to the set inclusion and exclusion criteria. After the initial screening, 25 articles were finally selected for the review. These were independently reviewed by two reviewers. The articles selected included mixed designs (reviews, experimental studies and observational studies) and were published between 1990- September 2014.

Results: The review revealed that the common techniques used to study mental imagery were mental chronometry, mental rotation and questionnaires. Apart from these, the vividness of imagery perceived during movement simulation were assessed using Movement Imagery Questionnaire (MIQ), MIQ-R (Revised), Kinesthetic and Visual Imagery Questionnaire (KVIQ), Vividness of Motor Imagery Questionnaire (VMIQ), Time Dependent Motor Imagery (TDMI) screening test etc. Two types of imagery perspectives were discussed about: external (a perspective that involves primarily a visual representation of motor task, i.e., third person); and internal (involves kinesthetic and visual representation from inside, i.e., first person of the simulated movements).

Conclusion: The therapeutic benefits of mental imagery were mixed, with more weightage going towards motor recovery as compared to pain and other sensory areas. However, few questions still remained regarding the best methods of practice of mental imagery and the details of the techniques used with proper protocols.

Keywords: Mental practice; Motor imagery; Mental visualization; Rehabilitation; Reorganization; Paraplegia

Introduction

Spinal cord injury (SCI) is one of the most devastating neurological disorders that have a profound impact not only on the life of the people affected but also on their family, caregivers and society at large. It adds on to the financial burden on the health care system as well. According to WHO fact sheet 2013, every year, around the world, between 2,50,000 and 5,00,000 people sustain SCI [1].

SCI, which involves damage to the central nervous system (CNS), is followed by structural and functional reorganization, which often leads to recovery of sensory- motor functions. This concept of neural plasticity has been studied through various methods by different researchers over the years. The advances in neuro-imaging and brain mapping techniques such as functional magnetic resonance imaging (fMRI), positron emission topography (PET), electroencephalography (EEG), transcranial magnetic stimulation (TMS) and magnetic encephalography (MEG) have allowed the researchers to get an insight into the brain activity while the patient is engaged in some activity. These techniques have allowed us to have a better understanding of the brain behavior.

Though this reorganization is a natural process, but the same can be enhanced through exposing the CNS to different stimulating situations, one of them being the technique of mental practice or mental imagery. Mental Imagery (MI) refers to the cognitive rehearsal of creation (or re-creation) of any experience in the mind- auditory, visual, tactile, olfactory, gustatory, kinesthetic, organic. It is the mental representation of movement without any body movement i.e., no movement is actually produced but is only imagined with a sole purpose of improving its performance. It is self-generated using

sensory and perceptual processes, enabling the reactivation of specific motor actions within working memory [2]. Imagination, as a process, is not dependent on the ability to execute a movement but rather on the central processing mechanisms [3]. It, hence, requires the ability to form internal representations of locomotor activities, which can be made from 2 perspectives: (a) from third person perspective (or external imagery), as spectator when imagining another person walking, or (b) from the first person perspective (or internal imagery), when imagining oneself walking [4].

The use of MI to improve performance in athletes has been there since decades [5]. Various studies have repeatedly shown that mental practice or mental imagery does bring about an improvement in motor performances by strengthening the synaptic connections that underlie the actual motor performances [6]. Mental imagery has been studied in various neurological conditions such as stroke and head injury. Following central nervous system damage, functional recovery is attributed to reorganization processes in the damaged parts of the nervous system. Recent researches suggest that information provided by imagination and observation of movements might play a role in this reorganization or re-learning process. The rationale behind this is that

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the brain areas that are normally involved in movement planning and execution are also active during the imagination of a movement [7]. Studies done by Pascaul et al. [8] and Jackson et al. [9] showed that the neural reorganization following motor imagery training is similar to the changes that take place as a result of actual physical training. Similarly, many other studies have also shown imagery related neural reorganization in stroke and other brain injured conditions.

In contrast to the studies of MI done in stroke and other brain injured subjects, where cognitive functions are likely to be compromised, it would be interesting to know how MI presents in a spinal cord injured person because people with SCI retain many features of normal brain motor function. The diversified nature of the condition i.e., the different pathophysiology including the level of lesion, chronicity of injury, age, completeness of injury may have differential presentations when subjected to tasks of MI. The exact nature of the relationship between the different imagery types and motor learning in people with SCI is yet to be fully understood.

The MI techniques are not only inexpensive and accessible but are also supported by the increasing evidence showing the overlap in autonomic response and temporal reorganization. The above literature discusses the use of MI for bringing about improvements in performances in different populations such as sportsmen, musicians, stroke and other neurological disorders related to brain dysfunction. The therapeutic potential of MI in people with SCI in improving functions, especially motor functions, is increasingly being studied. We wanted to know ‘What work has yet been done in the field of MI for people with SCI?’ Hence, this article aimed to review the available relevant literature about the use or potential use of mental imagery in the field of spinal cord injury.

Methods

Search strategy and study selection

This review was based on a systematic literature search, done during the period February 2014 to September 2014. In order that a study could be selected for the review, the study:

- had to involve human patients with complete or incomplete SCI, both traumatic or non-traumatic, acute or chronic, all ISNCSCI levels.
- had to involve patients of any age and either/ both the genders.
- could have been of any level of evidence including grey literature.
- could have been conducted at any point of time till date.

Only documents in English language were taken into consideration. The exclusion criterion was associated head injury along with SCI. The keywords used were ‘mental imagery’, ‘motor imagery’, ‘spinal cord injury’, ‘mental practice’, ‘quadriplegia’, ‘tetraplegia’, ‘paraplegia’, ‘mental rehearsal’. A mixed search strategy (i.e., both automated and manual search) was adopted. Automated search was done on PubMed, Science Direct, MEDLINE and Embase. The search strategy involved typing in all the above keywords together in each search engine; no limits were used related to year of publication. References of references, online thesis, online books and grey literature were also searched. For a few full texts, email correspondences to the authors were made and obtained. Manual search involved searching thesis, textbooks and print journals. However, no relevant data could be found from manual search, so only online databases were considered for the review.

Selection procedure

A study was selected if it described the role of any or all types of mental imagery in spinal cord injury. Studies describing the neurophysiological basis and rationale of mental imagery in SCI were also included. To enable the most complete review of existing evidence, the search was not limited to only those articles that had exclusively taken SCI as the patient population, but even studies involving a mixed group of patients with one of the patient type being SCI were also included; the aim being to review all available information about the use of MI in people with SCI.

The first phase of selection was performed by two independent reviewers; both were qualified rehabilitation professionals (one physiotherapist and other occupational therapist) with experience in the relevant field. A preliminary screening of the articles, according to the set inclusion and exclusion criteria, was done by reading the title and the abstracts. 47 articles were shortlisted. In the second phase, using PRISMA 2009 Guidelines [10], these 47 articles were then thoroughly reviewed by the two reviewers. The PICO format [11,12] (Table 1) was considered for the intervention studies and no limitation was put on the outcomes of the study. During this review process, 21 articles were excluded from the study. The reasons of exclusion have been given in Table 2.

	Criteria
Population (P)	Human subjects of any age or gender with:
	• complete or incomplete SCI,
	• traumatic or non- traumatic,
	• acute or chronic,
	• all ISNCSCI* levels
Intervention (I)	Any type, mode, duration or frequency of mental imagery protocol
Comparison (C)	All study designs including single group and case studies
Outcomes (O)	No limitation was put on outcomes
*ISNCSCI: International Standards for Neurological Classification of Spinal Cord Injury [12]	

Table 1: Selection criteria (PICO format) for intervention studies.

Number of Studies	Reasons for Exclusion
15	Non fulfillment of inclusion criteria
1	Duplicacy
3	Full text not available
1	Was about brain machine interface only, not on MI
1	Ongoing study

Table 2: Reasons for exclusion.

Level	Type of Study Design
I	Evidence from a systematic review of all relevant randomized controlled trials (RCT's), or evidence-based clinical practice guidelines based on systematic reviews of RCT's
II	Evidence obtained from at least one well-designed RCT
III	Evidence obtained from well-designed controlled trials without randomization, quasi-experimental
IV	Evidence from well-designed case-control and cohort studies
V	Evidence from systematic reviews of descriptive and qualitative studies
VI	Evidence from a single descriptive or qualitative study
VII	Evidence from the opinion of authorities and/or reports of expert committees
Abbreviation: RCT: Randomized controlled trials	

Table 3: Classification of study designs.

Following this, 26 articles entered the third phase of the review. Again one study had to be excluded on ground of duplicacy. So, finally

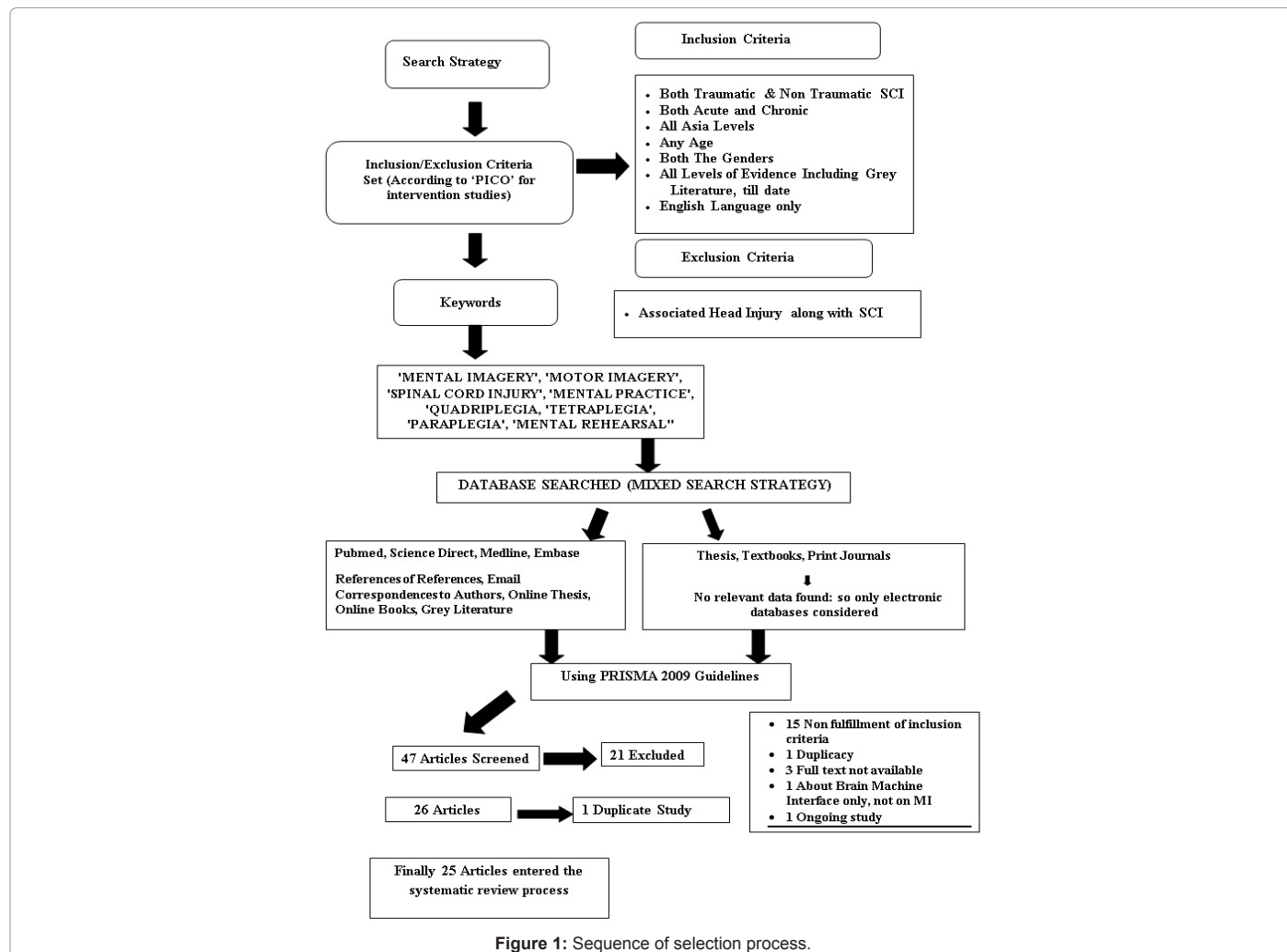


Figure 1: Sequence of selection process.

25 articles were reviewed after mutual consensus of the two reviewers. The articles were found to lie between 1990 -September 2014. Figure 1 depicts the sequence of the selection process.

Methodological quality judgement

To obtain insight into the methodological quality of the included trials, the study designs were classified according to Bernadette M. Melynk and Ellen Fineout-Overholt [13] (Table 3).

Results

Selection of studies

The systematic literature search finally resulted in 25 articles. The level of evidence of these articles has been given in Table 4.

Type Of Study	Number	Level Of Evidence
Intervention Trials	17	
RCT	1	III
Non-Randomised Trials	12	IV
Case Studies	4	VIII
Reviews	7	NA
Online Books	1	NA

NA: Not Applicable

Table 4: Description of studies

Design and subject characteristics of experimental studies

Out of the 25 publications reviewed, there was one RCT, 12 quasi experimental studies, four case studies, two systematic reviews, five literature reviews and one book.

The number of subjects included in the 13 experimental studies (i.e., one RCT and 12 quasi experimental studies) ranged from four to 39, and in different combinations of tetraplegia and paraplegia. The four case studies had taken one subject each.

In the 13 experimental studies, the target population was SCI, between C4 to T12 levels of injury, ISNCSCI A, B, C taken in different combinations. Four studies had taken ISNCSCI A level injuries [14-22] and one study had taken ISNCSCI B level SCI subjects [19]. Two studies had not mentioned the ISNCSCI level of the subjects recruited [3,20-22].

The mean age of the subjects ranged from 30 years - 47 years. One study did not mention the mean age, however had mentioned the age range between 16-64 years [22-25]. Another study by Rohm et al. [26] had also not mentioned the mean age of the subjects.

Most of the experimental studies had taken a mixed group of male and female SCI subjects. Two studies, [18,23], however, had not mentioned the gender of the SCI subjects who had participated in their study. Four studies [3,16,19,20] had taken only male subjects with SCI.

Out of the four case studies, three had been done on ISNCSCI A SCI and one was on ISNCSCI B. The age ranged from 23- 41 years. All four case studies had been done on male SCI subjects.

Outcome measures of MI

The RCT by Soler et al. [14] (Table 5), had used percentage of change in pain intensity on NRS, Neuropathic pain symptom inventory for different symptoms of pain, Brief pain inventory for interference of

pain in tasks of daily routine, anxiety on NRS, Patient global impression of change, as the outcome measures.

In the other experimental studies (Table 6), the outcome measures used were chronometry for movement time, verbal feedbacks about the experience of MI, functional Magnetic Resonance Imaging (fMRI) analysis, Electro Myographic (EMG) activity of muscles imagined during motor imagery, behavioral assessment such as feelings of fatigue in imagined foot movements, McGill Pain Questionnaire,

Design of Study, Authors, Year	Population	Intervention	Outcomes	Result
RCT (Double blind placebo -controlled trial) (N= 1) [14,15]	39 SCI with chronic neuropathic pain, 4/10 on Numerical Rating Scale (NRS), minimum six months post injury, mean age 45 years ± 15.5, range 21-66 years.30 males & 9 females	Four groups: i) Direct cranial stimulation (DCS)+ Visual illusion of walking ii) DCS sham + Visual illusion iii) DCS + Control illusion (video of landscapes, no human images) iv) DCS sham + Control illusion Duration and frequency:10 sessions, 20 min each, 5 days a week for two weeks Direct current was delivered from a battery-driven, constant current stimulator. Visual illusion of walking on a treadmill with a vertical mirror on top of video screen so that patients could see themselves as if walking (in the mirror). Control illusion- movie with graphical illustrations but no human movement with gait actions.	Percentage change in average daily intensity pain scores, Neuropathic Pain Symptom Inventory, Brief Pain Inventory, Pain Perception 0-10, Anxiety Numerical Rating Scale (NRS) 0-10 for anxiety, Patient Global Impression of Change. Blinded outcome measurement done at baseline, day 14, day 24, 12 weeks follow up.	Positive Effects <ul style="list-style-type: none"> The NRS of pain perception reduced by 29.7% in DCS + Visual Illusion group at first and third follow ups. DCS + Visual Illusion group had better maintenance of improvement Anxiety scores decreased significantly after last day of treatment in DCS+ Visual illusion group as compared to placebo group Five patients in DCS+ Visual illusion, three in DCS and one in Visual illusion groups rated pain as 'markedly improved.' Two in Placebo group rated pain as 'minimally improved' Other Effects <ul style="list-style-type: none"> The Visual illusion and Placebo group did not reveal significant changes in reduction of frequency of pain Two patients reported worsening of pain during day Three patients reported feelings of tiredness in DCS+ Visual illusion group after being engaged in fictive locomotion for the first time, and one reported a transient increase in neuropathic pain

N: Number of studies

Table 5: Details of RCT study.

Design of Study, Authors, Year	Population	Intervention	Outcomes	Result
Other Intervention Trials (N=12) [3,16-26]	Tetraplegics and paraplegics, ASIA A & B	Hand laterality tasks, hand and foot movements, Virtual walking, guided imagery, watching film, Transcranial direct current stimulation (tDCS), video-aided motivational general mastery (MG-M)	Pain (McGill Pain Questionnaire, VAS) Hand Laterality Task, Mirror Letter Discrimination Task, fMRI, Transcranial Magnetic Stimulation (TMS), Behavioural Assessment, Electrodermal responses (EDR), Chromometer (movement time), Vividness of Motor Imagery Questionnaire (VMIQ) Weekly Imagery Diary	Pre- task pain and area of pain reduced, pain-free period increased, reduced pain at 3 month follow-up. EDR during MI same as actual execution, it is a reliable method for assessing autonomic arousal and focusing attention during mental representation of actions. Chronometry revealed same time taken to perform actual and MI tasks, MI could facilitate recovery and helped to set mental goals. Degree of activation during MI of foot movements was higher in people with SCI than normals, however modulation during change of motor tasks was absent in SCI. MI-BCI training improved performance upto 70% in people with SCI in contrast to previous studies of 80% -83.3% in normals. tDCS lead to higher performance in controls than in people with SCI- it also facilitates use of BCI for motor rehab. MI may increase neuropathic pain and may induce pain in symptom free clients Improved self-efficacy after MI MI training might have value as an adjunct to therapy, some components of motor learning occur in complete absence of voluntary motor control Future Implications: BMI with MI may help operate neuro-prosthesis to restore movements

Table 6: Details of experimental studies other than RCT.

Design of Study, Authors, Year	Population	Intervention	Outcomes	Result
Case Studies (N= 4) [27-30]	C5, C6 level SCI, ASIA A, chronic cases	Upper limb function was studied; combination of conventional and MI sessions were given. One study was on both hand and foot movements using BMI	Kinematic and Functional Assessments -Kinesthetic and Visual Imagery Questionnaire (KVIQ), Electrodermal response, fMRI, Magnetoencephalography (MEG), FIM, Box & Block, mental chronometry	MI improved motor scores by 1, FIM scores (grasping and dressing), smoothness and hand trajectory, and wheelchair locomotion Good long term retention BMI enabled client to use neuroprosthesis and walk using MI in a virtual environment. Overall feasibility and compliance was good There was correlation between actual and imagined movement time In one case, pain increased during MI, hence close clinical supervision was advised

Table 7: Details of case studies.

Visual Analogue Scale (VAS) (100 mm) for pain, VAS for the degree of difficulty with the task, Vividness of Motor Imagery Questionnaire (VMIQ), Electro Encephalography (EEG), Electro-dermal activity (EDR) for recording skin resistances, Hand Laterality Task and Mirror Letter Discrimination Task.

In the four case studies (Table 7), the authors had used Magneto-encephalography (MEG), Kinesthetic and Visual Imagery Questionnaire (KVIQ), mental chronometry, the kinematics of upper limb movements in terms of movement time and variability, and a self-evaluation of ability to create accurate mental images on a four point Likert scale.

Methods of intervention given

Of the intervention studies, three studies had used the method of watching different videos as a part of visual imagery [16,18,19]. Two other studies had used brain computer interface (BCI) training as a part of MI training [25,26]. The rest of the intervention studies had used visualization of different tasks on the part of the SCI subjects, followed by recording of movement time during actual and imagined tasks and verbal feedbacks. These researches had studied mental imagery using hand movements and foot movements.

Out of the four case studies, the study by Enzinger et al. [27] had used imagination of foot movements to elicit electro encephalographic signals to use a neuroprosthesis in a virtual environment via a BCI. In the other study by Grangeon et al., the kinematics of upper limb movements was recorded in terms of movement time and variability. Grangeon et al., [28,29], had used functional upper limb movements to improve hand transport to reach out and grasp with tenodesis along with MI. Rienzo et al., [30] tried to understand, using MEG technique, the motor activation and inhibition of the related areas of the brain during actual and motor imagery tasks.

Results and Conclusion of Intervention

The results of the study done by Soler et al. [14] (Table 5), showed a significant reduction in the NRS of pain perception in the transcranial DCS+ visual illusion group as compared to the visual illusion and placebo groups. Also the improvement was better at 12 weeks of follow up in the same group as compared to the other groups. There was no significant change seen in severity of neuropathic pain symptoms, continuous pain symptoms, mechanical allodynia and dysesthesias. However, the percentage change in paroxysmal pain was significantly greater in the transcranial DCS + visual illusion group as compared to the placebo group. And so was the daily number of pain crisis. In terms of tolerability, three patients complained of mild headache during some of the active transcranial DCS sessions, but none described it as seriously unpleasant. Three other patients reported feeling tired after being engaged in fictive locomotion for the first time. None indicated significant distress of any sort.

Amongst the 12 intervention studies (Table 6), the results showed that a sensation of effort persisted in patients with spinal transaction, indicating that a signal could be generated centrally in the absence of afferent input from paralyzed limb [3]. Patients with chronic SCI, while retaining many features of normal brain motor function, also showed reduced activation volume, brain activation patterns not seen in controls, and abnormal modulation of brain activity with change in movement task or force. These SCI – associated abnormalities have the potential to reduce the effectiveness of treatments aiming at restoring movements [16]. Reports of fatigue in the imagined muscles have been given in a few studies [18,26]. Cramer et al. [18] said that the motor system of the brain could be modulated independently of voluntary motor control and peripheral feedback. He hence concluded that training in motor imagery can be adjunctive to other forms of intervention strategies. Moseley in 2007 [19] found that following virtual walking, pre task pain and intensity of pain had gradually decreased and the duration of pain relief had gradually increased, and area of pain was less. In follow up, patients reported reduction in analgesic medications. However Gustin et al. [20] reported that six out of seven subjects reported an increase in neuropathic pain during imagination of movements, and two patients without a history of pain or non-painful phantom sensations had onset of dysesthesia. Boendermaker [21] found that SCI patients were able to differentiate between attempted execution and motor imagery. Further that SCI patient showed enhanced activation and recruitment of additional regions in the parietal lobe and cerebellum that are important to sensorimotor integration. The retained integrity of movement attempt and motor imagery networks demonstrate that chronic SCI patients could dispose of the full motor programs and that attempted and imagined movements should be integrated in rehabilitative strategies. Grangeon et al. [23] studied the electrodermal responses using MI and found that autonomic nervous system activity is not inhibited during MI and it could be used as an index of cognitive processes underlying MI. He further suggested that there could be a link between the descending motor pathway and sympathetic function in people with SCI. Chavarriaga et al. [25] supported the idea of using tDCS as a facilitator for using brain-computer interfacing. Rohm et al. [26] found a low average performance in tetraplegics during MI-BCI training for controlling a robotic arm. They speculated that the vividness of the imagined movements is probably restricted by the missing sensory loop, and therefore restricts the performance. Pfurtscheller et al. [22] found in the majority of his paraplegic patients, an EEG based BCI training could achieve satisfied results. In tetraplegics, however, they reported the requirement of extensive training sessions for good BCI performance.

The designs of the clinical studies were heterogeneous. Besides, most studies were characterized by very small sample sizes. Therefore it is not possible to draw general conclusions.

Design of study, Authors, Year	Conclusion
Reviews (N= 7) [2,31-36]	Changes in brain activation were found in cortical and subcortical areas, some studies described a shift in region of brain activation and brain networks remain responsive even in chronic paralysis. Influence of MI on neuropathic pain was not clear. However another review (Guillot et al. 2012) highlighted potential differences in MI and actual motor execution. There is evidence of incomplete inhibition of motor commands addressed to different effectors. Positive correlation was reported between cortical activation and vividness of imagined movements (one study reported poor activation in a client with more than 19 years of injury, Lotze et al. 2006). However, vividness of imagined movements, and therefore the performance was found to be less in people with SCI. Mental representations during observations of others actions and during simulation of one's own action share common neural mechanisms with other covert aspects of motor performance such as planning and programming. Representations after SCI in brain remain active although de-afferented. EEG based computer interface produces hand/ neuroprosthetic movements in tetraplegia. BCI controlled mobility devices- client uses MI based BCI to operate wheelchair. Use of MI training for athletes and musicians has been found to be beneficial.
Online Book (n=1) [37]	Excitability of cortical motor system increases during MI both in non-disabled as well as in people with SCI, but there is no change in excitability of spinal motor neurons or spinal reflexes (F wave) and H-reflex. The authors concluded that following MI, there is no change in excitability of spinal motor neurons or spinal reflexes

Table 8: Details of review articles.

Amongst the case studies (Table 7), the results can be summarized as improvement in hand function scores (as assessed by Minnesota and Box and Block tests), decreased movement time, enhanced hand trajectory smoothness even after three months despite a slight decrease in performance. Self-report ratings and interviews further suggested that no difficulty was encountered in imagining the movements [29]. Grangeon et al. [28] found that the strength of the muscle improved by 1 point after MI training and also a month later, the long – term retention test showed that the performance remained at the same level. The FIM scores also improved from 49/126 to 52/126. Enzinger et al. [27] found that BCI training was able to elicit primary sensorimotor cortex activity in the tetraplegic patient upon imagination of movement, while such activation was absent in healthy untrained controls. Hence concluded that BCI training, as a conduit of motor imagery training, may assist in maintaining access to primary sensory motor cortex despite complete de-afferentation. Rienzo et al. [30] concluded that primary sensory area and supplementary motor area may be part of a functional network underlying motor inhibition during MI.

Discussion of Review Studies

Out of the seven review studies (Table 8), one was a systematic review [31] and six were review article [2,32-37].

The systematic review [31] was done on 25 articles to understand the brain activation after SCI in terms of intensity, volume, somatotopic localization and preservation of activation during attempted or imagined movements. It said that structural and functional changes do occur in the brain following SCI. The review also said that the reorganization does not always equate to improved motor recovery, and that this reorganization is different in paraplegia as compared to tetraplegia. Varying results were reported in terms of brain activation in people with SCI and controls; the authors attributed this variance to the different levels of lesion and time after injury of the subjects studied. The review also found a shift in primary motor cortex activation either posteriorly or in direction of deafferented limb representation. The speculated reasons behind the shift may be attributed to the fact that the surviving neurons in secondary motor cortex may contribute to damaged corticospinal tracts. This review hence found that even in individuals with complete, chronic SCI, the brain still has the capacity to appropriately activate and control functional motor programs in primary, as well as secondary motor areas after SCI.

In the other reviews, the authors had stated that the representation of foot movements is retained in people with complete SCI. The scores of vividness of motor imagery are similar to those of control subjects and the extent of brain activation during imagery of foot movements

correlates with the vividness of their imagery [4]. They had also given the various methods of clinical assessment of motor imagery ability which included Time Dependent Motor Imagery (TDMI), Kinesthetic and Visual Imagery Questionnaire (KVIQ), autonomic responses such as heart or respiratory rates and cardio-respiratory responses. Dickstein et al. [2] had also talked about the various scales such as Movement Imagery Questionnaire (MIQ) and Vividness of Motor Imagery Questionnaire (VMIQ). Regarding the validity of the questionnaires, Malouin et al. [4] had suggested that ratings from imagery questionnaires provided a good indication of the ability to generate vivid mental images of movements. Regarding imagery perspective, the authors said that the first person perspective, as compared to the third person perspective, shares more physiological characteristics with those observed during actual execution of movement; hence the instructions of the training should direct the patient to focus on both visual and kinesthetic components seen and felt from the inside. However, a previous review by Dickstein et al. in 2007 [2] reported that perhaps the application of both visual and kinesthetic imagery appear feasible and appropriate for most individuals and that task familiarity is a prerequisite for successful use of motor imagery practice. Fery 2003 [38] had shown in his research that for learning a new motor task, visual imagery was more suitable for tasks that emphasized form, whereas kinesthetic imagery was better for those tasks that emphasized timing or coordination of the two hands. Malouin and colleagues in 2004 [34] said that for mental rehearsal, a subject needs to maintain and manipulate kinesthetic and visual information in their working memory; thus implying that an impairment in working memory may hinder the ability to successfully engage in MI. Prior to Malouin's work, Porretta et al. in 1995 [39] had demonstrated that MI practice in combination with physical practice enhanced the performance of anticipatory motor task more than physical practice alone, in individuals with deficits in working memory such as adolescents with mild mental retardation. Malouin et al., later in 2010 [4], had added that better results are obtained by combining mental and physical practice of a task. Similar reports were given by Dickstein et al. [2]. He also added that people with high motivation and low anxiety scores performed better mentally on tasks of mental practice. Murphy in 1994 [40] had highlighted that relaxation promotes favorable conditions for vividness of MI.

The reviews by Decety [32], Guillot et al. [36] and Lotze et al. [33] discussed about neural networks mediating MI and actual execution of movements, inhibitory mechanisms during MI, and imagery research in clinical contexts such as stroke, SCI, amputees etc. They also highlighted the neurophysiological mechanisms of mental imagery including motor (kinesthetic) and visual imagery.

Summary of the review

Evidence on the use of different techniques of mental imagery in people with SCI exist [3,14,16-30,36]. Researchers, in various studies, have discussed about mental imagery being a dynamic process and that it shares strong correlates and common neuronal networks with actual execution [16-18,29]. Behavioural studies have also validated a correspondence between imagined and executed movements by chronometry, fMRI and other dynamic brain imaging studies and autonomic monitoring including cardiovascular and respiratory responses, electrodermal responses and thermovascular responses [2,17]. Decety [32] found a co-variation of heart rate and pulmonary ventilation with the degree of imagined effort, and that these are centrally controlled during the motor imagery tasks. This high overlap is being used for bringing about improvement in various domains of dysfunction in people with SCI.

Researchers have also highlighted the fact that good and bad imagers coexist [2,36,41]. And hence it is important that the ability to imagine should be evaluated before introducing mental practice [2]. Patients who had initially demonstrated difficulty in generating mental representations of movements, had subsequently been found to have improved in their abilities to engage in mental imagery with repeated exposures [4].

Three main approaches have been used to assess motor imagery: mental chronometry, mental rotation and questionnaires. Apart from these, the vividness of imagery perceived during movement simulation were also assessed using questionnaires like Movement Imagery Questionnaire (MIQ), MIQ-R (Revised), Kinesthetic and Visual Imagery Questionnaire (KVIQ), Vividness of Motor Imagery Questionnaire (VMIQ), Time Dependent Motor Imagery (TDMI) screening test etc. [2,4,23]. Malouin et al. [41], Dickstein et al. [2] and Guillot et al. [36] had also talked about imagery perspectives being of two types: external (a perspective that involves primarily a visual representation of motor task, i.e., third person); and internal (involves kinesthetic and visual representation from inside, i.e., first person of the simulated movements). This had also been discussed by Decety in 1996 [32]. He said that the first person perspective relies on the motor-kinesthetic information processing, and the third person perspective relies on the visuo-spatial processing.

Few questions still remain as to whether active engagement during imagery is more beneficial than passive engagement, what is the optimal proportion of physical and mental practice sessions, what are the best guidelines for training positions and situations, should clients self-monitor their training, and so on [4,41].

Limitations

The literature available in English language only was taken as the part of review and the articles published after September 2014 were not included in the present review. Publication bias could not be totally overcome which could have resulted from selective publication, whereby studies that reported positive/ dramatic effects of MI were more likely to have got published and cited. However, an effort was made to reduce the possibility of publication bias by undergoing a comprehensive search of available literature that included searching conference proceedings, books, abstracts and grey literature. Moreover, since the included studies comprised of mixed study designs, graphic or statistical methods could not be used to confirm that there was little chance that publication bias might have influenced the results. Assessment of risk of bias was not done for this review.

Future Directions

Strategies for different techniques of selective therapies for mental practice need to be developed for people with SCI and the brain mapping technologies need to be made use of to understand how the mental imagery techniques bring about neuroplastic changes cortically and sub-cortically.

Guidelines or directions are required to be developed that would address the issue of a structured procedure to conduct MI sessions with individuals with SCI. Many questions still remain regarding the optimization of training strategies. Mental practice needs to be investigated in patients who show different deficits in motor performance.

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