Immediate Effect of Mental Practice on Performance of a Neurodynamic Skill in Physiotherapy Students: A Randomized Control Trial.

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Research article

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Abstract

Background

Mental Practice (MP), "the cognitive rehearsal of a task in the absence of overt physical movement," has been used successfully in teaching and rehearsing complex psychomotor tasks in several domains, including sports, music, and recently, in surgical skills acquisition. This study investigates the implementation of MP on performance of a neurodynamic skill in third year undergraduate Physiotherapy students.

Method:

It was a randomized control trial (single-blind) conducted in a Physiotherapy institute. A convenient sample of 40 III year undergraduate students who were novice for the topic were recruited. Some important preliminary steps involved development and validation of the tools used in the study viz. an audio script to guide mental imagery practice and an OSPE checklist to assess the outcome. The OSPE checklist was procedural specific for ULNT-1 and included stations for cognitive, psychomotor and affective domains. A neurodynamic skill (ULNT-1 Median nerve) was taught to all the students (n = 38, 2 drop outs) by a teacher as a didactic lecture followed by physical practice which was supervised and guided by the same teacher. After randomization, the intervention group (n = 19) received MP guided by a structured audio script as a single session for 20 minutes delivered to all the participants together in a group. The control group participants (n = 19) intended to serve as a basis of comparison and received no intervention. Pre- and post-intervention assessment was done by a set of examiners who were blinded to the intervention. Comparative analysis was done within the group using Wilcoxon sign rank test and between the groups using unpaired t test.

Results

MP group showed significant improvement in cognitive, psychomotor, affective domain and total score of OSPE post intervention whereas the control group did not show significant difference except for the total score. Between group comparison showed significant differences in all the domains and total score in favor of the MP group. Also, the extent of improvement (effect size calculated using Cohen's d) was more in the mental practice group than in the control group.

Conclusion

MP as an adjunct to physical practice is a time-and cost-effective strategy to augment traditional training and enhance performance of a neurodynamic skill in Physiotherapy students. This preliminary evidence supported by robust scientific base and ease of integration should facilitate adoption of MP in Physiotherapy education. We recommend future studies to further explore the potential of this promising tool.

Background

Mental Practice (MP) is defined as the cognitive rehearsal of a task in the absence of overt physical movement (Driskell et al., 1994)[1]. It was a paradigm shift in psychology when the idea of ‘imagery practice’ was introduced by Richardson in 1969 who defined this technique as the ‘symbolic rehearsal of a motor skill in the absence of any gross muscular movement’. It involves ‘seeing’ and ‘feeling’ a skill in one’s imagination before actually executing it. MP can be considered an umbrella term that includes various mental training interventions whereas the term ‘motor imagery’ is used to specifically address the imagination of moving specific body parts (Schuster C et al.,2011) [2]. Although physical practice is essential for the mastery of complex motor skills, MP has been found to be a promising adjunct to facilitate skill learning and performance (Taktek, 2004) [3]. This technique has been employed successfully in teaching and rehearsing complex psychomotor tasks in several domains, including sports (Feltz DL, 1983; Martin K., 1999) [4],[5], music education [2],[6] and recently, in perceptuo-motor professional skills such as in surgery (Anton NE, et al., 2017) [7] and nursing (Bachman K., 1990) [8]. Recent upsurge in fundamental and behavioural science have established efficacy of MP and has resulted in widespread use of this technique. There is a growing evidence from rehabilitation science, sports science and psychology that motor learning can be promoted with the application of motor learning principles. In contrast, very little consideration is given and there has been little corresponding research in the health profession education as to how procedural skills are best taught and practiced. Wulf et al (2010) [9] proposed that motor learning principles should be applied to the field of health profession education. Emerging interest has recently proposed a shift away from the traditional approaches of procedural skill learning in health profession education (HPE). Mental imagery prior to the procedure is gaining attention as the subject of intense research activity aimed at optimizing procedural performance and reducing error. Thus, it is essential to systematically investigate whether MP enhances learning and performance and exploring its potential application in this field.

Learning of procedural skills is an essential component of many curricula, including Physiotherapy. Procedural skills in the context of HPE are often classified under the umbrella term “clinical skills (Michels ME, 2012) [10]. However, some authors refer to it as “psychomotor tasks” (Raman M, 2008) [11] where others also include tasks such as communication skills and treatment skills under “procedural skills”. Procedural skills in HPE are highly context specific and educators need to know what specific educational interventions could be used to enhance learning of these procedural skills. For this study, we defined procedural skill as “a motor skill involving a series of discrete responses each of which must be performed at the appropriate time in the appropriate sequence”.

Functional Diagnosis & Physiotherapeutic Skills subject is a stepping stone to introduce III year physiotherapy students to actual concepts of physiotherapy assessment and later to treatment concepts. Neurodynamics is the clinical application of mechanics and physiology of the nervous system as they relate to each other and are integrated with the musculoskeletal system (Shacklock, 2005, p. 2) [12]. A neurodynamic assessment systematically evaluates the length
and mobility of various components of the nervous system; and is divided into upper and lower limb tests. These are diagnostic tests performed by a physiotherapist, who places progressively increasing tension on the components of the nervous system that is being tested. Also referred to as 'nerve tension tests', these tests are designed to bias the neural elements to a greater degree than the surrounding interface and attempt to load specific nerve roots, nerve trunks, and localized regions of the central canal or even component of sympathetic nervous system. Technically for this skill a sequential pattern of movements within a specific range needs to be performed, taking into consideration the movement resistance encountered; sensitivity and reasoning at every step to guide the next chain of events with slow and careful handling of the extremity. This is a symptom-provoking test in which many possible types of responses can occur and, thus, Physiotherapists need to know what each indicates to make a distinction between neural and non-neural structures and also, one nerve from another. With the complex interconnectedness of the musculoskeletal and neural systems and many potential sources of symptoms, precision in neurodynamic sequencing and structural differentiation for correct interpretation is essential. Apart from diagnostic purpose, these tests findings help in clinical decision making to apply the information to planning and application of treatment.

Based on the previous literature we hypothesized that Mental practice might be effective for enhancing the skills that contain greater cognitive elements, such as tasks that require remembering a sequence or a pattern and decision making as in the neurodynamic tests, especially the upper limb nerve tension tests (ULNT). Also, mental practice may help in better visualization of structures that are not directly visible to human eyes such as nerve roots. Thus, this study aimed to determine the immediate effect of mental practice on performance of a neurodynamic skill-ULNT 1 (Median nerve) in III year undergraduate Physiotherapy students. The main objectives of this study can be outlined as: a) To determine the immediate effect of physical practice on performance of ULNT-1. b) To determine the immediate effect of physical practice and mental practice on performance of ULNT-1. c) To compare the immediate effect of physical practice only and physical and mental practice on performance of ULNT-1. All the three objectives are with respect to Cognitive, Psychomotor and Affective domains as applicable to ULNT-1.

Methods

It was a randomized control trial (single blind) with a parallel type design and having equal allocation ratio. The study was conducted in a Physiotherapy Institute. A convenient sample of 40 III year undergraduate students who were novice for the topic were recruited. Students having any neuromuscular or orthopaedic condition affecting performance of the skill were excluded from participation. Institutional ethics committee approved the design and the conduct of the study. The procedures followed protocol and accord with the ethical standards of the institutional review board. Informed written consent was obtained from all the participants before participation in the study.

Some important preliminary steps involved in the development of the tools used in the study are:

1. Randomisation (Simple): After pre test using OSPE, the participants were randomly allocated into Mental Practice and Control Group using computer generated tables.
2. Ability to mentally imagine is a skill in itself and requires mental control for its effectiveness (Gelding et al, 2015) [13]. Thus, to ensure effective delivery, an audio script was developed to guide mental practice of ULNT-1 (Median nerve). It was a task-specific, structured framework for content, instructions, procedure and time. Starting with a brief session of relaxation using deep breathing exercise to improve focus and attention on the skill, the audio script was directed towards the subsequent task of ULNT 1 and provided standardized, acoustic, and elaborated mental imagery cues at every step of the procedure.[script is available from the corresponding author upon request].
3. Objective Structured Practical Examination (OSPE): Procedural specific checklist was developed for ULNT-1 (Median nerve) as an outcome measure. It included Station 1 for Cognitive domain; and Station 2 for Psychomotor and Affective domain. Cognitive domain included questions based on knowledge of ULNT-1 critical to its correct interpretation, numerical scores were assigned for the correct responses. Psychomotor and affective domains contained important steps of the procedure and every performance element was marked on a dichotomous scale being either marked as performed ‘satisfactorily’ (score 1) or ‘unsatisfactorily’ (score 0). The total score of the checklist was 20 with a focus on psychomotor domain. [OSPE checklist is available from the corresponding author upon request].

Content validity was established for the audio script and OSPE from a panel of experts prior to its implementation.

The underlying flowchart (Fig. 1) outlines the study procedure.

MENTAL PRACTICE GROUP (MP)- Mental practice intervention was administered as a single session by the primary investigator to the experimental group. Participants received the intervention together as a group; in a quiet, dimly lit room; sitting comfortably with eyes closed. The pre-recorded imagery audio script was played and the participants were instructed to see and feel themselves performing ULNT-1 along with the recording, keeping their hands in their laps and refraining from any physical movement of their hands and fingers. In order to optimize the efficacy of the imagery intervention, participants were further told to imagine from an internal perspective (i.e., first person imagery perspective), to incorporate all the senses in their imagery (i.e., imagery modality-mainly visual and kinaesthetic), and to try and imagine as clear and as vivid as possible (i.e., imagery vividness) [2]. The task was practiced three times with the same audio script played repeatedly. The MP session lasted for a total duration of 20 minutes with a minutes breaks in between to alleviate the effect of mental fatigue.

During both physical practice session and mental practice intervention, participants practiced the task as a ‘whole’ i.e. the entire procedure is practiced in a serial order and as a whole entity (Brydges R, et al., 2007) [14].

CONTROL GROUP- The control group participants intended to serve as a basis of comparison to assess whether mental practice works. While both the groups had received equal physical practice in session 2; the control group neither imagined nor executed the ULNT-1 task during session 3. Instead, participants in the control group were asked to discuss ULNT-1 in general.
Pre-test using OSPE was taken by all the participants and it served to determine their baseline performance level of ULNT 1. Post-test using the same OSPE was administered immediately after the intervention. Written feedback was obtained from the participants and the OSPE assessors at the end of last session.

We employed certain methodological strategies to improve the reliability of outcome:

1. **Outcome assessors**: Two assessors (not only one) having similar skills, experience & training in ULNT & OSPE assessed all the participants in both pre- and post-test and were blinded to group assignment. They simultaneously assessed but independently scored the performance; and their average score was considered for analysis.
2. **Primary investigator** did random allocation of study participants to either group, and administered intervention to the experimental group. She was blinded to assessment of outcome measures & data analysis.
3. **Participants of the study** (students) were blinded to the research hypothesis and received no concurrent or terminal feedback about their performance. To avoid the diffusion of treatment effect participants from both the groups were not allowed to communicate amongst themselves; and the control group was unaware about the intervention intended and received by the mental practice group.
4. **Co-investigator** was blinded to group assignment; and did data entry & statistical analysis.

The study adheres to the CONSORT guidelines.

**Results**

We employed complete analysis, thus the sample for analysis included 38 students with 2 subjects being excluded due to their absence in the physical practice session. Mean age of the participants was 20 years with a predominance of female students (94.73%). In this experimental design, mental practice served as an independent variable and OSPE score as the dependent variable. Psychomotor and affective domain scores of OSPE were originally 'nominal' type of data; by assigning numbers to them (satisfactory = 1, unsatisfactory = 0), were treated as ordinal data. Comparative analysis was done within the group using Wilcoxon sign rank test and between the groups using unpaired t test. P value was set at < 0.05 level of significance (one-tailed) for all the analyses. To further support the statistical analysis, absolute effect size (using Cohen's $d$) was calculated to determine the extent of improvement and was calculated separately for individual domain and total score of OSPE.

Tables 1 and 2 summarize the results obtained. Within the group analysis showed statistically significant difference in 'Mental practice' group in cognitive, psychomotor, affective domain and total score of OSPE post-test. For the 'control' group, changes in post-test score were small, statistically significant only for the total test-score. Between groups analysis showed that no significant difference existed between the groups for the pre-test whereas statistically significant difference was observed in post-test in favour of the 'mental practice' group. The calculated effect size was large in the 'mental practice' group for all the domains viz. cognitive ($d = 0.9645$), psychomotor ($d = 0.6898$), affective domain ($d = 1.3139$), and for the total score ($d = 1.0710$) whereas it was medium ($d = 0.3881$) as calculated for the total test-score in 'control' group.

Table 1

| Group     | Domain  | Pre-test | Post-test | P value | Cohen's $d$ |
|-----------|---------|----------|-----------|---------|-------------|
| Mental Practice | Cognition | 3.421 | 1.610 | 4.974 | 1.034 | 0.0004 | 0.96 |
|           | Psychomotor | 7.684 | 2.518 | 9.421 | 1.774 | 0.002 | 0.68 |
|           | Affective | 0.7895 | 0.4806 | 1.421 | 0.6070 | 0.002 | 1.31 |
|           | Total | 11.895 | 3.661 | 15.816 | 2.567 | 0.0001 | 1.07 |
| Control | Cognition | 3.447 | 1.332 | 3.974 | 1.338 | 0.1219 | - |
|           | Psychomotor | 7.632 | 2.847 | 8.184 | 1.945 | 0.1261 | - |
|           | Affective | 0.8421 | 0.5786 | 1.079 | 0.6511 | 0.0594 | - |
|           | Total | 11.868 | 3.527 | 13.237 | 2.786 | 0.0171 | 0.38 |
Table 2
Comparison between 'Mental Practice' and 'Control Group'

| Group      | Mental Practice | Control | P value |
|------------|-----------------|---------|---------|
|            | Mean            | SD      | Mean    | SD     |
| Pre-test   |                 |         |         |        |
| Cognition  | 3.421           | 1.610   | 3.447   | 1.332  | 0.4407 |
| Psychomotor| 7.684           | 2.518   | 7.632   | 2.847  | 0.4476 |
| Affective  | 0.7895          | 0.4806  | 0.8421  | 0.5786 | 0.3693 |
| Total      | 11.895          | 3.661   | 11.868  | 3.527  | 0.3906 |
| Difference (Pre-test & post-test) |         |         |         |        |
| Cognition  | 1.553           | 1.536   | 0.5263  | 1.594  | 0.0255*|
| Psychomotor| 1.737           | 2.359   | 0.5526  | 1.964  | 0.0509 |
| Affective  | 0.6316          | 0.7966  | 0.2368  | 0.6094 | 0.0478*|
| Total      | 3.921           | 3.106   | 1.368   | 2.326  | 0.0036*|

Qualitative analysis was done for the feedback obtained from student participants and assessors. The statistically significant improvement was perceived as "overall better performance" by the ‘Mental practice’ group participants (P) as reported below:

P2, P4, P8, P19 “… I could identify my mistakes in pre-test & correct them in post-test” ...

P12, P36 “I gained more clarity about the skill with step by step instructions of audio script”

P4, P23 “… With repetitions I could memorize it better”

P26 “I could use Mental Practice in OPD on my patients”...

P4, P7, P8, P17, P36 “Such a practice should be implemented for other topics too”.

Feedback from ‘Control’ group participants:

P10, P32- “I could not make out my mistakes”

P10, P18, P21- “There was no difference in my performance”

Feedback from Assessors (blinded to treatment allocation): In the post-test, some students showed “improvement in communication skills with the model”, “more accuracy with correct positioning of each joint” and “could interpret the test correctly”.

Discussion

In the present study, we investigated the immediate effect of ‘mental practice’ in comparison to control condition on the performance of a neurodynamic skill-ULNT 1 in physiotherapy students with a pre-and post-test design. While both the groups had shown similar baseline performance, statistically significant difference was evident after the acquisition phase in favour of the ‘Mental practice’ group. ‘Mental practice’ group showed statistically significant improvement in cognitive, psychomotor, affective domain and total score of OSPE post-intervention whereas ‘Control’ group did not show statistically significant difference, except for the total score. Also, the extent of improvement (effect size calculated using Cohen’s d) was more in the ‘Mental practice’ group than in the ‘Control’ group. Overall, findings clearly denote benefits of mental practice intervention. Improvement observed in the ‘Control’ group could be instead attributed to practice effect due to repeatedly executing the OSPE ULNT 1 task during pre and post-test. These results reject the null hypothesis in view of significant improvement in the ‘Mental practice’ group moreover the ‘Control’ group.

The present data build on the fundamental premise of improved performance and skill acquisition after mental practice as reported in sports science and other fields; and extend its application in health profession education. Though it can be speculated that mental practice will have similar advantages when applied to health education, results of the previous studies cannot be extrapolated due to heterogeneity in the study population and outcomes. Thus, a need was felt to bridge this existing gap in knowledge and explore its potential application. Furthermore, to the best of our knowledge, present study is the first evidence of application of mental practice in Physiotherapy education. One of the important highlights of the present study is the design itself, being a RCT which is considered as a ‘gold standard’ in experimental research. MPental Practice has received substantial attention as a strategy for improving motor performance and so far in the literature, the practical implications of MP are predominantly discussed in the motor domain. Apart from the psychomotor aspect, we attempted to assess cognitive and affective domains of the skill which are essential prerequisites to execute any psychomotor task effectively in clinical context. An interesting finding of the study is that though the mental practice training focus was motor (motor-focused), improvement was noticed in cognitive and affective domain as well. Thus, the present study results complement the previous assumptions by providing a more comprehensive aspect of procedural skill.
A recent review in surgery (Anton NE, et al., 2017)[7] reported a number of performance enhancement benefits viz. it could help surgeons mentally prepare for a procedure ahead of time; build their confidence and direct their attention on what is required to perform the procedure; identify potential complications and solutions; and help prime their muscles to physically perform as the same pathways are excited through imagery. Stated advantages during the acquisition of surgical skills included reducing the learning curve of a new procedure, transfer skills from an established technique to a novel but related technique; limit the decay of skills; and optimize preparation for a complex procedure. In line with these extensive findings, benefits were observed in our study in learning and performance of a psychomotor skill and could be explained in the subsequent paragraphs.

**Basis of evidence of mental imagery**

Abundant evidence exists on the positive effects of mental imagery practice on various aspects of motor control and learning. Converging findings from neuroscience and motor learning research has identified that mental practice has its unique set of properties and functional mechanisms. However, recent upsurge in fundamental and clinical science regarding mental practice is revealing the central role mental practice plays in motor skill acquisition.

**Mental Imagery and neural representation**

Mental imagery centrally organizes a motor program and activates neurons within various areas of the brain responsible for priming the execution of the motor command in what is thought to lead to increased performance and learning through repeated imagery use. According to Weisinger and Pawliw-Fry [15], 'the same neural pathways are recruited and the same neurochemicals are secreted when we visualize doing something as when we engage in the actual activity.' Brain imaging work with evidence from fMRI and PET studies has demonstrated overlap in the neural representation of mental imagery and actual motor task (Parsons et al., 1995; Jeannerod and Frak, 1999; Roth et al 1996; Nyberg, et al., 2006)[16][17][18][19]. Motor images have shown to retain many of the properties, in terms of temporal regularities, programming rules and biomechanical constraints, which are observed in the corresponding real action when it comes to execution)[20][21][22][23][24][25]. Moreover, the psycho-neuromuscular theory (Carpenter 1894)[26] postulates that an electromyographic activity of the same muscles occurs during MI and actual movement. This is further substantiated by specific selective muscle activation (Bird, 1984; Jowdy and Harris, 1990; Gandevia et al., 1997; Hashimoto and Rothwell, 1999)[27][28][29][30]; magnitude and location of the EMG pattern reflected by content of the mental image (review by Guillot and Collet, 2005a)[31] and higher muscles excitation for internal imagery than external imagery (Harris and Robinson, 1986; Bakker et al., 1996)[32][33] has been reported. This representational overlap or commonalities in the spatial & activity pattern between real & mental practice suggest engagement of functional sensorimotor networks for imagined stimuli in a manner similar to the processing of real sensory & motor tasks. In addition, mental practice, over a period of time, is associated with increased neurological plasticity with demonstrated increases in cerebral and cerebellar activation as well as structural changes. Some evidence suggests that more than just activating neural pathways, mental practice can actually develop functional adaptations in mental representation structure (Frank C, et al 2014)[34] and functional improvements in skills performance as demonstrated by increase in physical strength after mental practice. (Todd et al., 2003; Feltz and Landers, 1983; Rangnathan 2004, Yao, 2013)[35][36][37].

Further investigation has observed that kinaesthetic, but not visual, motor imagery modulates corticomotor excitability, primarily at the supraspinal level (Stinear CM, et al., 2006)[38]. Depending on the chosen imagery perspective (internal or external), different brain areas will be activated (Guillot A, et al, 2009; Lorey B, et al 2009)[39][40]. Overall, greater effects of internal imagery perspective than those of external perspective have been explained in terms of neural adaptions, stronger brain activation, higher muscle excitation, greater somatic and sensorimotor activation, and higher physiological responses such as blood pressure, heart rate, and respiration rate (Silman M., et al., 2016)[41]. Mulder et al, 2007[42] reported that mental imagery from an internal perspective is more important than from an external perspective in learning a motor skill; and also that younger people are more likely to use the internal perspective. Hall C (1992)[43] claimed that instructions using kinaesthetic imagery were more effective for learning closed motor skills; while Kim JG (1998)[44] found kinaesthetic imagery led to better retention for a task involving hand accuracy performance. Considering this compelling evidence, 'internal' imagery perspective was chosen in the present study.

**Mental Imagery is a sensory experience**

The term 'mental imagery' refers to representations and the accompanying experience of sensory information without a direct external stimulus (Joel Pearson, 2015)[45]. Such representations, also called the 'mind's eye', are recalled from memory and lead one to re-experience a version of the original stimulus or some novel combination of stimuli. In this context, mental imagery refers to quasi-sensory experiences which exist in the mind in absence of those stimulus conditions, and can produce genuine sensory and perceptual experiences. Mental imagery can involve all of the senses, but in this study, while creating a mental picture of ULTT 1, the sensory experience was contributed by visual & kinaesthetic modalities.

**Priming effect of mental imagery**

The priming effect in psychology is explained by the 'sequential priming paradigm' and refers to the preparation of a stimulus-reaction scheme whereby the input stimulus has certain associations and reactions (Bargh JA, 1996)[46]. Priming is the implicit memory effect in which exposure to one stimulus influences a response to a subsequent, related stimulus, without conscious guidance or intention. Priming can be perceptual, semantic, or conceptual and is thought to occur when particular mental representations or associations are activated before a person carries out an action or task. Brain imaging work has provided compelling evidence supporting the hypothesis of a shared representational format in imagery and perception and establishing the commonality between these two functions (J Pearson, 2015)[45]. This is a facilitative effect of priming in which the activation of units of information (schemas) stored in long-term memory is increased and it makes processing faster and speeds up memory retrieval. Research has found the effect of priming can last anything from 15–20 minutes to up to two days with a constant impact (i.e. one that does not depreciate over time). Classical conditioning in imagery based learning has been reported with generalization from the imagined to subsequently performed perceptual task (Jennifer Walinga and Charles, 2020; Dadds, Mark, 1997)[47][48]. Based on these impressive findings which the behavioural sciences have uncovered, we can presume that the visual and semantic content of the mental image of ULTT could have primed the subsequent performance of ULTT in post-test in ‘mental practice’ group. Priming is a type of preparation and this
well-established psychological phenomenon can be utilized as a tool to enhance performance in students. Similar principle when applied to the motor domain, a study reported that MP results in movement anticipation (Nicolo F, 2013) [49]. In principle, the anticipatory pattern could be related not only to motor optimization but also to the preliminary learning of the order of the elements in the sequence.

**Mental imagery and memory**

First process involved when learning a new motor skill is one has to memorize the order of the elements in the sequence (M. Felice Ghilardi, 2009) [50]. Studies employing serial reaction time tasks have shown that, through practice, an initially unknown sequence becomes progressively familiar. Accordingly, a reduction of errors in the selection of the correct item of the sequence is observed (Nakamura et al., 2001) [51]. Practicing the sequence through actual movements is regarded as the most effective way to accomplish learning. However, MP could also be effectively used to rehearse the sequence and to strengthen its mental representation (Jeffrey, 1976) [52]. Our MP group participants reported that they utilized mental imagery as a ‘mental tool or strategy’ to aid memory performance. Mental imagery is presumably based on the recall and recombination of memories. On the other hand, mental images, like visual precepts, rely on representations that are collaboratively constructed by visual areas at all stages of the visual processing pathways (Pearson J, et al., 2015) [45]. High level visual areas are anatomically closer to memory-encoding structures in the medial temporal lobe. Brain imaging work has demonstrated overlap in the neural representation of visual working memory and mental imagery. In our study, visualization exercise through mental practice engaging the visual cortex thus can be coupled to enhanced memory function.

**Cognitive changes**

According to skill acquisition theories, skill acquisition is known to be accompanied by both overt changes (i.e., performance improvements) and covert changes (i.e., cognitive improvements) over time (Frank, 2014) [34]. Learning induced by MP may primarily operate through and find expression on the cognitive level, whereas learning via physical practice may primarily operate through and find expression on the motor output level. MP promotes the cognitive adaptation process during motor learning which involves underlying skill representations in long-term memory and plays an important role in the learning and control of actions. Consequently, an individual's mental representation of a motor skill is thought to change on his/her way to expertise, namely in the direction of an elaborate, well-developed representation (Ericsson KA, 2007) [53] than physical practice only (Frank C et al 2013) [54]. Such changes in neurophysiological variables point to the idea that functional changes on a cognitive level (i.e., concept formation in one's mental representation) may take place during motor practice. All these investigators have pointed that mental practice can be used for more than just technical skills; and it can also improve other cognitive skills such as refining how one makes decisions or judgments, as well as solving problems. It is important to emphasize that as mentioned in the assessor's feedback, some student participants could interpret the test more accurately in post-test suggesting that MP could be an essential cognitive tool for learning an analytical psychomotor task.

**Neuropsychological evidence**

Images created through mental practice can strongly impact behaviour and psychology. The main functions of mental imagery include simulating possible future scenarios and thus, play a role in affective forecasting making prior expectation templates based on past experiences (Moulton ST, 2009) [55]. From this perspective, mental practice can facilitate emotion. Emotional and behavioural impact of mental practice as reported by our study participants and also observed by the assessors in post-test was reduced anxiety and improved confidence. The neuropsychological basis of this observed behavioural change can be derived from the improved psychological skills viz. task-specific self-efficacy (Beauchamp et al., 2011; Slimani et al.,2016) [56] [41], intrinsic motivation (Martin and Hall, 1995; Silmani and Cheour, 2016)[57] [41], self-confidence (Weinberg, 2007, 2008; Silmani et al., 2016) [58] [59] [41] and managing competitive anxiety (Vadoa et al., 1997) [60] as reported previously in other studies. Imagining an event that supposedly occurred in the past (even if did not) inflates a person's confidence that the event actually did occur. Richardson (1967) [61] suggested that motivation may be partly responsible for the effectiveness of mental practice. Specifically, mental practice groups may become more ‘ego-involved’ when asked to mentally rehearse a task. A crucial feature of purposive behaviour is internal representation of the goal which guides behaviour (Decety J, 1996) [62]. Conscious imagined rehearsal of an action influences the likelihood that a person will complete that action (Libby L.K., 2007) [63]. This observation is complemented here by the novel finding as reported by ‘mental group’ participants. I felt pressured to complete the task post-test’. This psychological strategy, widely applied clinically for various mental health problems, can well be used to reduce performance anxiety in students.

**Elements of mental imagery**

There is little in the literature to indicate just how much of motor learning is physical and how much is mental. The variable of ‘mental activity’ is difficult to isolate and measure objectively due to its “concealed nature” (Guillot and Collet, 2005; Malouin et al., 2008a) [31] [64] and thus, mental imagery research has previously weathered disbelief of the phenomenon. Adherence and compliance are difficult to assess as mental practice is an intervention that takes place during mental practice. All these investigators have pointed that mental practice can be used for more than just technical skills; and it can also improve other cognitive skills such as refining how one makes decisions or judgments, as well as solving problems. It is important to emphasize that as mentioned in the assessor's feedback, some student participants could interpret the test more accurately in post-test suggesting that MP could be an essential cognitive tool for learning an analytical psychomotor task.

Driskell et al (1994) [1] in a meta-analysis defined five conditions under which mental imagery was most effective: 1) Type of task- examination mainly of the cognitive aspects of the task performance; 2) Retention interval-short; 3) Experience level of trainees- novices to the task; 4) Length of practice- 20 minutes or shorter.
Type of task

With respect to task-type characteristics, efficacy of mental practice is shown to be better with the tasks that can be represented symbolically and practiced in symbolic form. (Morisset, 1956; Richardson, 1967; Ryan & Simons, 1981; Sackett, 1934) [66] [61] [67] [68]. This explanation, termed symbolic learning, posits that mental practice gives the performer the opportunity to rehearse the sequence of movements as symbolic components of the task. Thus, according to this notion, mental practice facilitates motor performance only to the extent that cognitive factors are inherent in the activity. ‘Cognitive-specific imagery’ as originally coined by Paivio (1985) [69], is part of the cognitive component of imagery in which people are able to gather a blueprint for the skill and use imagery to gain experience with the various steps and imagine themselves properly performing a specific skill (Morris et al., 2005) [70]. Cognitive-specific imagery is used when an individual is learning or practicing newly acquired skills. In fact, in novice learners, it has been shown that imagery is more effective for cognitive tasks rather than tasks that are purely physical (Driskell, et al., 1994) [1]. In other words, those learning new tasks that require a combination of cognitive functioning and physical movements have been shown to increase their performance at a higher rate by using imagery than those learning a new skill that is only physical and does not require cognitive skills. In the present study, selection of the skill- a neurodynamic test with its inherent cognitive elements and symbolic control was thus appropriate for mental rehearsal. Designing of the audio script to guide the mental practice was yet another important strength of the study as it increased the extent to which imagined sensorimotor events mimic their overt counterparts, including their ability to elicit sensorimotor interactions and thus, task specificity. Neurodynamic testing requires visualization of anatomic structures not visible directly to the human eye, creation of visual image and recalling anatomy. Considering also the visuospatial components inherent in ULTT 1 task, the effectiveness of mental practice for ULTT 1 can thus be supported by a study that reported mental modelling with imagery of the anatomical figures in mind to be an effective method for learning and recalling anatomy.(Noorafshan A, et al., 2016)[71]

Mental practice and the stage of skill acquisition

Pertaining to temporal parameters of mental practice, Buegel (1940) [72] noted that introduction of ideational elements in the early stages facilitates motor learning. Fitt & Posner's (1967) [73] model (Fig. 2) illustrates skill acquisition as a function of the cognitive demands placed on the learner and his level of experience. We implemented mental practice intervention at the cognitive stage of skill acquisition. In this stage, considerable cognitive activity and fuller understanding of the required action, or conceptualization to form an executive programme is required and it incorporates a clear mental image. Controlled processing at the cognitive stage requires working memory and attention as the central mediating mechanisms. Neural substrates of mental imagery rely on motor learning principles which in turn may include greater cognitive engagement, selective attention, working memory, goal setting, etc. Mental practice techniques allow parallel processing of huge amounts of information not possible with analytical thinking, which relies on serial processing. Also, in this study, the concept and technique of ULTT was already learnt by the students however the skill acquisition was in the refining stage.

Mental practice-an adjunct to physical practice

Richardson (1967) [61] and others (Clark, 1960; Corbin, 1972) [74] [75] concluded that the efficiency of mental practice was related to the degree of familiarity with the physical performance of the task. Perhaps the physical practice experience is needed to form a perceptual trace or template that the learner can use as a reference against which to compare the mental practice. Mental practice is most effective when combined with physical practice of the same skill, likely because it incorporates an already established motor schema from physical practice of the same task. Early research in this field has shown positive effects of mental practice compared with a non-treatment group and with an equivalent control treatment group. However, previous studies have clearly indicated that mental practice alone cannot replace physical practice and that greatest improvements in motor performance occurred with interventions that combined physical and mental practice. Similarly we found an improvement when ‘mental practice’ was added to the physical practice of the previously learnt task suggesting that MP processes complement and augment the more usual forms of practice.

Mental practice- an active learning method: Hall [43] described the cognitive processes and neural basis of MI in a review on educational literature, and proposed a six-stage procedure for explicit learning of surgical skills: task definition, prior learning, mental rehearsal, reflection, problem solving and reality check. An important key for mental practice to be effective is that mental practice must be structured just as actual practice, with self-evaluation, problem solving, and correction of mistakes. In line with this structure, our ‘mental practice’ group participants reported that they gained more clarity in the steps of the procedure; could identify their mistakes and correct them in the subsequent performance in post-test. Mental Practice also referred to as introspective rehearsal, itself functions as feedback. Thus, this educational supplement can serve as a method of constructive evaluation facilitating deliberate practice to overcome weakness in performance. This also suggests that mental practice can be considered as a self-directed and active-learning method.

Amount of mental practice

The linearity or curvilinearity between amount of mental practice and its effectiveness for skill learning has not been extensively studied. A study which included schedules with different proportions of mental and physical practice concluded that up to 50% of the practice time (or trials) in mental practice can be as effective as 100% of the time in physical practice (Oxendine, 1969) [76]. However, when used in excess (up to three-fourths of the practice time), some students became impatient with this technique. A meta-analysis stated that healthy individuals shouldn't use MI for any longer than 20 minutes due to a negative effect with increased practice duration (Driskell JE, 1994) [1]. Also, it is relevant to add that part of the imagery training time may involve relaxation to prepare the person to imagine more effectively (Page SJ, 2005; Dunsky A, 2006) [77] [78]. Based on these findings, a mental practice schedule of 20 minutes was considered appropriate for the physical practice session given for 45 minutes in this study protocol.

Timing of performance

The delay between MP and performance has not been systematically investigated; however, it has been proposed that MP may be most effective when done immediately prior to performance. Psyching-up technique in the form of mental imagery prior to performance has been widely used as a performance
enhancement strategy in sports psychology interventions. (Tod. et al., 2015) [79]

From a practical standpoint, MP constitutes a cost-effective strategy to practice because it requires no equipment or expense, can be practiced by the students independent of direct supervision, and in circumstances with limited resources, especially just prior to appearing for their practical examination.

However, we acknowledge some methodological limitations in the present study; the most important one being: ‘immediacy of testing’. Learning is a permanent change versus improvement in post-acquisition test could reflect a change in performance. Some student participants reported that they used mental practice during their clinical application of the ULTT 1 skill on patients indicating generalizability of learning. However, we exert caution in interpreting this result as no formal retention test was administered and recommend future designs which implement ‘retention test’ and ‘transfer test’ to assess learning indicative of ‘permanent change’ and ‘adaptability’ respectively. Also, the student participants were assumed to be similar at baseline in motor ability, mental imagery ability and other factors, such as motivation and learning style. However, no formal test was administered to know if they were equated on these factors. Imagery rehearsal is a skill; and like all skills it has to be learned regardless of one’s level of motor ability. Thus, MP delivered through a single session may not be ideal and should be implemented over more extensive time.

**Conclusion**

Mental practice as an adjunct to physical practice is a time -and cost-effective strategy to augment traditional training and enhance performance of a neurodynamic skill in Physiotherapy students. This preliminary evidence supported by robust scientific base and ease of integration should facilitate adoption of mental practice in Physiotherapy education. We recommend future studies to further explore the potential of this promising tool.

**Implications:**

Optimizing the performance of procedural skills is a dynamic and rapidly advancing field with emerging interest in health profession education. Recent upsurge in fundamental & behavioural science supports using mental imagery alongside physical practice. Considering the promising results and encouraging feedback from our study participants we recommend integrating this innovative tool in routine teaching-learning in Physiotherapy and to other psychomotor skills with varying cognitive elements.

Mental imagery is a trainable mental ability that underpins successful learning and performance. To use this cognitive tool efficiently, students can be guided to develop a general ‘set of rules’ to practice various psychomotor tasks ‘mentally’ and self-directed practice to facilitate greater transfer of learning. Students can enhance their performance by adopting mental practice as part of their procedural preparation. Future research will enlighten us on the specific mental imagery strategies for a particular procedure or for different levels of expertise and how best to combine physical practice and mental imagery.

**Abbreviations**

1) MP- Mental Practice
2) HPE- Health Profession Education
3) ULNT- Upper Limb Nerve Tension Test
4) OSPE- Objective Structured Practical Exam

**Declarations**

1. Ethics approval and consent to participate-

An ethical approval was granted by the Institutional Ethics Committee of K. J. Somaiya College of Physiotherapy. The procedures followed protocol and accord with the ethical standards of the institutional review board. A written informed consent was taken from all the participants at the beginning of the study.

2. Consent for Publication-

Not Applicable.

3. Availability of Data and Materials-

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

4. Competing interest-

The authors declare that they have no competing interests.

5. Funding-
The authors have not received any kind of financial support in the conduct or publication of this research.

6. Authors’ Contribution-

Both the authors KC and IA have nearly equal contributions to the conception and design of the work; the acquisition, analysis, or interpretation of data for the work; drafting the work, revising it critically for important intellectual content; and final approval of the version to be published. Specific contribution of KC is in the acquisition of data and IA contributed to the data analysis and interpretation. All authors have read and approved the manuscript.

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8. Image attribution:

Figure 2 displayed in the discussion section of the article is taken from the source Furley P, Memmert D. The role of working memory in sport. International Review of Sport and Exercise Psychology, 2010;3: 171-194.DOI 10.1080/1750984X.2010.526238 and is available in the public domain.

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Figures
Figure 1

Flowchart of methodology
Figure 2

Fitts and Posner's model of skill acquisition

Supplementary Files

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