The Influence of Mental Imagery on Myofascial Restriction

Juan P. Rodriguez
University of Central Florida

THE INFLUENCE OF MENTAL IMAGERY ON MYOFASCIAL RESTRICTIONS

by

JUAN PABLO RODRIGUEZ

A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Kinesiology
in the College of Health Professions and Sciences
and in the Burnett Honors College
at the University of Central Florida
Orlando, Florida

Fall Term
2019

Table of Contents

Abstract:

Introduction: Mental imagery (MI) has been shown to influence flexibility when used with treatments such as stretching. Currently, little evidence supports the efficacy of MI as an independent tool to increase flexibility. Therefore, the purpose of this investigation was to test if a guided mental imagery protocol could positively influence subject physical measures, including myofascial length, muscle tone and range of motion measures.

Methods: Individuals with no history of lower limb injuries that would affect hamstring flexibility underwent initial measures, random assignment to a mental imagery or control group, and post-intervention measures. The imagery group followed a guided visualization of a hamstring stretch, and the control group remained still for the same amount of time. Independent T-Test, Dependent T-Test, and one-way ANOVA were used to analyze between-group differences, within-group differences, and group by time interaction, respectively.

Results: 30 individuals enrolled in the study. No significant differences between groups at baseline were found for baseline demographics and ROM measures. No significant group by time differences were found between the two groups for any of the recorded measures. A posthoc power analysis showed a small effect size on the ANOVA test for knee extension.

Discussion: Our evidence shows an acute MI-only protocol may not positively influence ROM measures. Future work should use familiarization periods, assess if imagery increases perceptions of flexibility, and utilize different musculature and stretches to see if visualization has a uniform influence globally.

Keywords: Mental Imagery, Visualization, Flexibility, Hamstrings

List of Figures:

List of Tables:

1. Introduction

Background

The Hamstrings are a group of three muscles (semimembranosus, semitendinosus, and biceps femoris) whose function is to flex the knee. It is understood that muscles have extensible and elastic characteristics that allow for them to lengthen beyond resting position or be stretched, which is related to an individual's flexibility; stretching can elicit greater mobility or postural shape of the body segment being stretched.

Individuals from the general population, athletes, and other professionals require flexibility and fluid range of motion (ROM), and a lack of functional ROM increases these populations likelihood of injury (Doğan et al., 2019; Sexton & Chambers, 2006). Both flexibility and ROM are thought to play an essential role in many types of movement, from daily activities to performance in sports and other activities. In an attempt to find novel and efficient ways to boost flexibility and ROM, two previous studies have examined the combination of mental practice with physical training (Guillot, Tolleron, & Collet, 2010; Williams, Odley, & Callaghan, 2004). Mental practice or mental imagery (MI) is the act of mentally visualizing performance of a specific task without physically participating in that task.

Previous research shows that brain regions activate in the same manner when comparing an individual performing a task to that same individual visualizing or thinking about performing that same task (Ranganathan, Siemionow, Liu, Sahgal, & Yue, 2004). According to researchers when studying the effect of mental imagery's ability to produce increases in strength in a little finger abduction training protocol when compared to three groups, the group that visualized performing finger abduction increased their finger abduction strength by 35% ($P< 0.005$)

(Ranganathan et al., 2004). The physical training group who physically performed finger abduction increased strength by 53% (P< 0.01). The control group showed no significant change in finger abduction strength (Ranganathan et al., 2004). This implies that mental training alone can produce strength increases similarly to strength training at least for the hand musculature. It is understood that the nervous system plays a role in strength production which is a factor that is related to the increases in strength through mental training alone seen in the previously mentioned study.

Additionally, the nervous system also contributes to flexibility through signaling mechanisms such as the apparent increases in flexibility due to muscle relaxation when stretching is occurring in part due to Golgi Tendon Organ function. The fact that the nervous regulation contributes to both these phenomena may suggest that mental training could produce similar responses in both strength and flexibility outcomes. It is important to note that changes found in the previous investigation occurred over 12 weeks, where subjects trained 15 minutes a day for five days each week. Our current awareness is that little to no literature exists showing significant changes acutely in range of motion measures through using a mental imagery protocol (Ranganathan et al., 2004). This trial shows that it is possible to produce a physical and meaningful impact on measures such as strength through mental imagery; other research has shown similar results in other measures, including muscle activation (Lebon, Guillot, & Collet, 2012). Research has also found that significant gains in flexibility can occur, when physical training protocols are combined with mental imagery protocols (Guillot et al., 2010; Williams et al., 2004). It is important to note that these research projects occurred throughout 5 weeks and three weeks respectively and the protocols were administered over a period of 15 sessions.

Exploration into the full extent to which the neuromuscular connection has an impact on the body still needs further development. Currently, it is unclear if imagery directly impacts flexibility or produces a placebo effect that could explain previous studies findings; mental rehearsal may inherently be relaxing or prime the body for change, which may explain increases in flexibility. It is also uncertain if imagery can acutely positively influence flexibility. Positive expectations and the placebo effect may or may not play into physiological and physical changes that have been presented in previous research. However, for therapy purposes positive expectations could be beneficial for patients, helping to ease the therapy process. It is important to consider that since there is a copious amount of variation between the type of imagery used in different experiments it could be possible that different protocols yield different outcomes. Some imagery protocols involve solely visualizing an action(Ranganathan et al., 2004), and others involve the kinesthetic sensation of moving and feeling of the action that is visualized (Guillot et al., 2010; Williams et al., 2004).

Another variable that may impact the effectiveness of a protocol is the frame of visualization. This refers to seeing a specific action performed in a variety of ways. For example, some visualization frame of references include viewing the action performed by others, observing the action performed by one’s self but in a third-person view, and seeing the action performed in a first-person view. Furthermore, factors such as performing MI in unison with movement or the use of kinesthetic MI may further impact a protocol’s effectiveness by simulating the physical sensations that could lead to muscle relaxation or tension, which could be favorable to certain stretches or exercises and thus produce significant outcomes.

The research about imagery being able to produce significant changes in the short term is limited. Previous investigations have explored the effects of imagery on regions such as the quadriceps, hip muscles, hamstrings, shoulders, and ankles but little literature exists on whether these tools work uniformly across all muscle groups (Guillot et al., 2010; Lebon et al., 2012; Williams et al., 2004). Our investigation wanted to see if mental imagery could provide changes in physical measures in the hamstring muscle group acutely and independent of other modalities. It is crucial then to see what changes in different measures research has shown visualization, and mental imagery can produce. Thus far it has been shown that mental imagery can produce viable changes in flexibility, muscle activation and produce a meaningful influence on subject expectations (Guillot et al., 2010; Lebon et al., 2012; Peerdeman et al., 2015; Williams et al., 2004).

MI has shown to be able to influence strength, increase muscle activation, increase flexibility, and induce positive subject expectations. However, there is lack of recent investigation that exists on MI regarding physical measures in generic muscle flexibility acutely and independent of other modalities and what the exact mechanism is that allows MI to influence muscle flexibility. Since different muscle groups vary in their structure, function, and neural networking, it is possible that imagery and visualization can affect musculature in variable ways and thus produce different outcomes for a given procedure since the structure and function vary for any given muscle groups.

Therefore, the purpose of this study was to find the effects of using a guided mental imagery protocol on myofascial restrictions, essentially seeing if mental imagery can influence hamstring physical measures including myofascial length and muscle tone as well as hip range of motion measures acutely and independently of other modalities such as stretching. This study aimed to develop on previously conducted research and further improve flexibility and ROM gains by adding an extra component to the average stretching regiment

2. Methods

Participants

This study was IRB approved through the University of Central Florida IRB (IRB Study 00000107). 30 individuals were allocated to a two-armed trial (15 individuals per group). The test groups consisted of an imagery group and a control group.

Participants were selected from the population of the University of Central Florida, including students and staff.

The Inclusion criteria for this study was that individuals had to be between the ages of 18 and 65 years, fully recovered from or have no history of lower limb injury that would influence hamstring flexibility, and mixed-gender groups would be used.

The Exclusion criteria for this study was that participants could not have a current development of pathology in the hip, knee, thigh, or low back. Participants recovering from an injury in lower limb that would affect hamstring flexibility were also excluded. Individuals with any of the following criteria were also excluded from participating in the study: pain in lower limbs or lumbar spine, individuals currently using relaxant medication, adults unable to consent, individuals who were not yet adults, pregnant women, and prisoners.

Procedure

The trial involved the evaluation of the effects of two different conditions on hamstring flexibility. Individuals were randomly assigned to one of the test groups; all individuals were involved in flexibility and ROM assessment before testing, measures were assessed with goniometers.

Throughout the entire study, from when the subjects completed initial measurements to when the post-intervention measures were taken the subjects remained in a supine position, with their hips and knees bent and their legs resting on a platform. The reasons for maintaining subjects in a constant position were: to allow for more precise visualization of the stretch and to limit subject movement during the entirety of the study and reduce the likelihood of error as well.

The measurements were collected in a manner similar to previous research. Measurements that were collected from test groups included ROM measurements before and after testing, as well as a mental imagery assessment.

The equipment used to perform measurements was the following: long-arm goniometers to take flexibility measures, sleeping masks to limit outside sensory stimulus and distraction, noise-reducing headphones to limit outside sensory stimulus, and to play the guided imagery audio and an adjustable platform that subjects placed their legs on.

Pre-Intervention Measures

The measurements collected were taken from the subject's dominant leg, whichever leg the subject used to kick with was considered the dominant leg (Williams et al., 2004). To standardize hip flexion during measurements, a support system was used to ensure hip flexion was a constant 90 degrees during both measuring sessions.

Hamstring measurement

To assess hamstring flexibility, subjects were asked to move into a supine position on the examination table, then to move into 90-degree hip and knee flexion, marks were then made on the lateral malleolus, lateral femoral epicondyle, and on the line of the greater trochanter of the femur. One researcher maintained the anterior and posterior position of the thigh to maintain the hip angle. Subjects maintained 90 degrees of hip flexion and then were asked to actively extend the knee as far as possible, then when terminal knee extension was reached, or hip flexion integrity was beginning to be loss, another researcher measured the angle of knee extension and it was rounded to the nearest tenth of a degree. Measurements were taken identically before and after the protocol. The methodology for this test was previously found to be reliable (ICC = 0.899). (Decoster, Scanlon, Horn, & Cleland, 2004) (Figure 3).

Hip ROM measures

The hip ROM measures that were assessed included hip flexion, hip internal rotation (IR), and hip external rotation (ER).

Hip Flexion

Hip flexion was measured by having subjects lie supine on the examination table while the examiner stabilized the adjacent areas including the knee. The examiner then passively moved the subject's lower extremity into hip flexion until resistance, tightness, or a firm terminal feeling was reached, and no further motion could be produced. An assistant then held the subject in position and goniometer measures were taken, measurements were taken with a long-arm goniometer and were rounded to the nearest tenth of a degree. If the position was lost at any point, or motion added, the subject was repositioned to the initial position. Measurements were taken identically before and after the protocol. The methodology for this test was previously found to be reliable with combined right and left side measurements from all examiners. (ICC = 0.95). (Prather et al., 2010) (Figure 4).

Hip Internal Rotation

Hip internal rotation was measured by having subjects lie supine on the examination table while the examiner stabilized adjacent areas including the anterior and posterior part of the thigh and the knee. The examiner then positioned the subject into hip flexion of 90° then passively moved the subject's lower extremity into internal rotation until resistance, tightness, or a firm terminal feeling was reached, and no further motion could be produced. An assistant held the subject in position and took long-arm goniometer measurements rounded to the nearest tenth of a degree, if the position was lost or motion was added, subject position was reset. Measurements were taken identically before and after the protocol. The methodology for this test was previously found to be reliable with combined right and left side measurements from all examiners. (ICC = 0.88). (Prather et al., 2010) (Figure 5).

Hip External rotation

Hip external rotation was measured by having subjects lie supine on the examination table while the examiner stabilized adjacent areas including the anterior and posterior part of the thigh and the knee. The subject's lower extremity was then placed into external rotation until resistance, tightness or a firm terminal feeling was reached, and no further motion could be produced. An assistant held the subject in position and took long-arm goniometer measurements rounded to the nearest tenth of a degree, if the position was lost or motion was added, subject position was reset. Measurements were taken identically before and after the protocol. The methodology for this test was previously found to be reliable with combined right and left side measurements from all examiners. (ICC = 0.95). (Prather et al., 2010) (Figure 5).

Vividness of Imagery

A protocol derived from previous research was used to gauge how readily participants could perform visualizations (Williams et al., 2004). Subjects were shown a demonstration of the hamstring stretch they would visualize, after the demonstration, they were asked to close their eyes and visualize the stretch. Subjects then rated their ability to perform the visualization based off if they were able to see and feel themselves performing the stretch. Subjects rated their visualization on a scale of 0 to 9 where 0 means they could not visualize the stretch, and 9 means they could clearly see and feel the hamstring stretch. The subjects circled a number 0-9 based off their rating (Williams et al., 2004).

Randomization

Individuals enrolled in the study were randomly assigned to groups using an envelope system where 30 envelopes containing the numbers one or two were mixed up, and subjects could choose an envelope. If a subject chose the envelope with the number one in it they were placed in the control group and if they choose an envelope with the number two they were placed in the intervention group. The subject then gave the envelope to the investigator conducting the intervention and then was either taken through the intervention or control protocol. After the respective intervention was provided, the subject was told to refrain from telling the investigators conducting the measurements what group they were placed in.

Interventions

Intervention group

Subjects were demonstrated the hamstring stretch before visualization. The stretch consisted of subjects lying down in supine with ninety degrees of hip flexion (Figure 1). Subjects imagined maintaining 90 degrees of hip flexion and then imagined actively extending the knee as far as possible (Figure 2) (Decoster et al., 2004). Subjects were instructed to visualize the stretch on the earlier identified dominant leg and listened to and visualized based of the instructions of a pre-recorded guided visualization audio script.

The pre-recorded script was used to standardize the procedure and provided subjects with cues to move through an exact visualized stretch. Participants were made aware to not undergo the actual stretch but merely visualize doing so. The imagery group underwent ROM measures before and after the intervention.

Control

Control group individuals solely underwent ROM measures before and after their waiting period in the testing room, which was equivalent to the time it took the intervention subjects to complete visualization (three minutes and fifteen seconds). Participants were also placed in the supine position with ninety degrees of hip flexion. The measures collected from the control group were compared to the other test group.

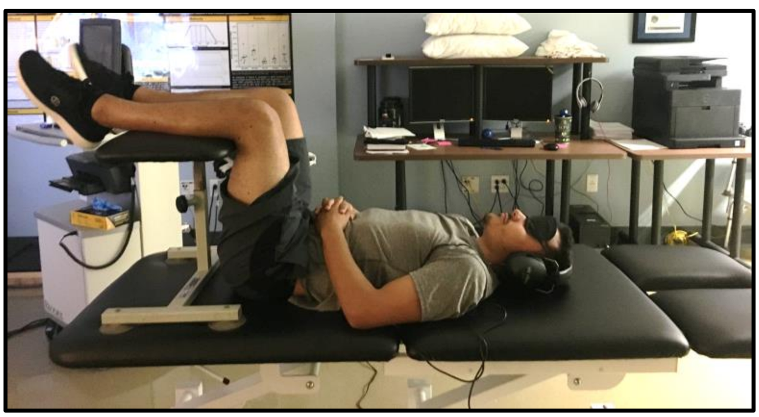

Figure 1: Intervention Group Setup

Figure 2: Visualized Hamstring Stretch

Figure 3: Hamstring measurement

Figure 4: Hip flexion measurement

Figure 5: Hip internal and external rotation with flexion measurements

Statistical Analysis

The statistical analysis plan included the evaluation of descriptive statistics and frequency counts. Inferential statistics were used as well; these included: independent and dependent student T-tests and a repeated measure analysis of variance (ANOVA). A posthoc statistical power analysis was also conducted for the ANOVA to verify power and effect size for the primary variable of knee extension.

3. Results

The present investigation enrolled a total of 30 subjects (43.3% female) with a mean age of 21.7 years. The subjects were randomly placed into either the guided visualization group(imagery) or the control group. The analysis of baseline demographics showed no significant differences between groups for sex, age, height, weight, and leg dominance (Table 1). There were also no significant differences between groups at baseline for knee extension and all hip ROM measures (Table 2).

Table 1: Demographic Data of Participants

	Control Group	**Imagery Group**	**Overall**	**P-value**
Sex (% female)	15 (40%)	15 (46.7%)	30 (43.3%)	0.713
Age Mean (SD)	20.67 (3.04)	22.73 (5.47)	21.70 (4.49)	0.216
Height Mean (SD)	66.00 (3.4)	66.33 (3.94)	66.17 (3.63)	0.806
Weight Mean (SD)	152. 23 (29.90)	146.40 (25.60)	149.31 (27.51)	0.571
Leg Dominance (% left)	3(20%)	3(20%)	6(20%)	1.0

There were no significant differences between initial measurements to post-intervention measurements for either the control or imagery group for the hip ROM measures (Table 2). Knee extension measures proved to be significant in the control group between pre-intervention and post-intervention measures (p=0.007) and non-significant in the imagery group (p=0.106) (Table 2). A repeated-measures ANOVA demonstrated that there were no significant group by time differences found between the imagery and control group for any of the recorded measures (Table 2). Finally, a post-hoc power analysis demonstrated a small effect size and power (3% and 5%, respectively). (Faul, 2007)

Table 2: Pre and Post Intervention outcome measures based on group

	Control Group (N=15)			Imagery Group (N=15)				
	Pre-intervention (SD)	**Post-intervention (SD)**	**P-value (within-group)**	**Pre-intervention (SD)**	**Post-intervention (SD)**	**P-value (within-group)**	**P-value (Between groups at baseline)**	**P-value (group-by time interaction)**
Knee Extension	154.3° (7.3)	156.8° (6.8)	.007*	153.3° (10.4)	156.4° (5.0)	.106	0.748	0.738
Hip Flexion	148.5° (11.3)	149.0° (9.1)	.662	151.3° (4.96)	151.6° (5.3)	.792	0.399	0.935
Hip Internal Rotation	39.2° (11.5)	39.6° (11.8)	.754	43.9° (10.3)	43.6° (10.7)	.876	0.246	0.767
Hip External Rotation	54.8° (17.8)	54.2° (17.1)	.497	50.5° (10.9)	50.6° (11.4)	.955	0.434	0.650

SD: Standard Deviation

° - degrees

4. Discussion

The foundation for the present investigation came from previous literature showing that stretching combined with mental imagery produced greater increases in outcomes compared to control groups and that chronic mental training could enhance output signaling allowing for increased muscle activation and strength (Guillot et al., 2010; Ranganathan et al., 2004; Williams et al., 2004).

An important consideration about this current investigation's outcomes are that this study evaluated the effects of mental imagery as an independent modality, while the majority of other studies utilize some form of stretching or intervention in unison with mental imagery in order to see the combined impact of those interventions, our goal was to see if mental imagery could work as a stand-alone intervention.

Another factor to consider is that the previously mentioned projects occurred over a significantly longer period, while our goal was to see if mental imagery could increase range of motion acutely. Our intervention and preparation for the intervention took only about 30 minutes, excluding time for questions and consent. There is currently no research that we are aware of describing the length of time it takes for mental imagery to begin producing significant results in increases in flexibility as well as if mental imagery as a standalone intervention can produce increases in range-of-motion. While not empirically proven, we can attempt to extrapolate that there may be a learning effect that is necessary for those attempting to use mental imagery as a modality to produce increases in any measure; Essentially for increases in measures such as strength and flexibility to occur an individual must learn to become familiar with their own respective imaging style and visualization style which could possibly describe the positive findings by other significantly longer studies which allow subjects to become familiar with imagery other procedures. This somewhat coincides with previous findings (Guillot et al., 2010). The "best imagers" in that investigation were placed into the imagery group after their initial assessment of imagery abilities and thus these subjects would have an existing knowledge and understanding of how to visualize, however, it is important to note that the investigators in that study found no relationship between participants imagery ability and increases in flexibility.

Other literature suggests that the boost provided to those individuals performing stretching and imagery may be a result of investigators spending more time reinforcing procedures and objectives with the respective imagery group, which could lead to a motivation effect on the subjects and thus increase measures (Williams et al., 2004). Our data contradict this assumption, being that those in our control group and imagery group both received interventions lasting 3 minutes and 15 seconds. Our results showed that the imagery group did not have significant changes in degrees of terminal knee extension($p= 0.106$), while the control group did($p=0.007$).

Our findings coincide with previous investigation (Williams et al., 2004), showing that most subjects consider themselves to have high imagery abilities. In our investigation, individuals were randomly placed into groups showing the unlikelihood of these results to be artifactual. Researchers have postulated that imagery used for increases in range-of-motion acts as a medium which allows users to experiment mentally with the how the act of stretching will occur as well as works as a catalyst only serving to promote or compound increases that are initially as a result of adaptations provided by stretching (Williams et al., 2004). Our investigation included a control and "imagery-only" group, the results of the imagery only group shows that visualization occurring independently of stretching in an acute phase produced no enhancements in ROM, which may suggest that imagery functions primarily as an “attentional-device” to enhance increases of range-of-motion facilitated primarily by stretching.

Research has demonstrated that mental imagery could be used to enhance output by motor neurons and thus lead to increases in finger abduction strength (Ranganathan et al., 2004). From this previous investigations outcomes we extrapolated that since active focus on engaging the central nervous system could produce increases in strength; It could be possible to utilize a mental imagery audio guided visualization to influence myofascial length and muscle tone. We hypothesized that since neuromuscular signaling could increase muscular output, it could be possible that the same mechanisms could produce decreased activity in antagonistic muscle groups (hamstrings during a lying leg extension) through an increased level of reciprocal inhibition.

Our data suggest that a guided audio mental imagery visualization used to enhance hamstring mobility and hip ROM measures produces outcomes that are nonsignificant (knee extension $p=0.106$, hip flexion $p=0.792$, hip internal rotation $p=0.876$, and hip external rotation $p=0.955$). While both groups showed no significant differences in baseline demographics or range of motion measures, the control group showed significant differences in knee extension when compared to baseline ($p=0.007$), and the imagery group did not ($p=0.106$). Research suggests that mental imagery may produce excitatory effects (Ranganathan et al., 2004), which might result in development of muscular tension due to subject unfamiliarity with procedures and thus making it harder to stretch a muscle as a result, which could explain why our control group had significant increases in degrees of terminal knee extension while our imagery group did not. Research has shown that an internal mental imagery protocol for strength produced significant results contrasting to nonsignificant increases in strength as a result of an external mental imagery protocol (Ranganathan et al., 2004). Our project similarily utilized an internal mental imagery protocol where the subjects visualized themselves undergoing a described stretch, and therefore we extrapolate that this protocol would likely have the same utility or better outcomes than an external mental imagery protocol used to facilitate increments in hamstring mobility.

In the previous investigation researchers elected to use the “little finger abductor” and elbow flexors to test the impact of imagery on strength (Ranganathan et al., 2004). Our project chose to see if a larger muscle mass (the hamstrings) could be influenced by mental imagery to increase flexibility measures, this difference in muscle size may contribute to why the present investigation found no significant findings. In the previous investigation the authors questioned the utility of mental imagery for larger muscle masses (Ranganathan et al., 2004). The investigators mentioned that other literature may have found that mental imagery could produce significant findings in smaller muscles such as hand muscles, possibly due to size and neural factors including fact that there are fewer muscle fibers per motor unit in muscles that produce fine movement patterns which allow for complex intricate movements. The fact that our investigation chose to use a larger muscle mass to study mental imagery’s effect on improving flexibility and found no signifiant findings, may help to elucidate the possibility that mental imagery as an independent intervention may be more appropriate for smaller musculature involved in fine movement patterns.

Investigations have used different methods to measure subject imagery abilities (Guillot et al., 2010), these methods include the use of MIQ-R and VVIQ scales (Hall & Martin, 1997),(Marks, 1973). These scales may have allowed investigators to test the imagery abilities of subjects more efficiently and realistically. The present study utilized an imagery procedure where subjects would be shown the hamstring stretch via pictures, auditory description and physical demonstration by an investigator and then subjects would be asked to find a comfortable seated position, close their eyes and visualize the stretch; afterward, the subjects would rate their perceived imagery ability.

Another consideration between the present study and other research is that our investigation randomized which group all subjects would be placed into while the latter placed the best imagers into the imagery group which can help explain the difference between our findings (Guillot et al., 2010). Researchers have theorized the necessity for familiarity with the procedures and effectiveness of mental imagery. That specific investigation showed the imagery group had greater outcomes compared to the control group for the front split (P=0.03), hamstrings (P=0.035), and the ankle stretching exercises (P=0.03) and no significant differences were found for the shoulder and side split stretches (p=0.73 and p=0.08 respectively). The investigators explained these outcomes could be due to the unfamiliarity of the side split and shoulder flexibility and stretches due to the fact that these procedures are not often practiced by the swimmers that were the participants for the study, and therefore the subjects may have had trouble producing mental images (Guillot et al., 2010). The individuals enrolled in our study, as per our knowledge did not regularly practice the hamstring stretch we used in our study, which can be another reason as to why our imagery group did not produce significant results.

In their study (Guillot et al., 2010) inferred that the possible reasons for increases of range-of-motion by mental imagery groups could be psychological and physiological effects which may produce relaxative effects promoting joint flexibility as well as the autonomic nervous system being associated to certain responses that are related to mental imagery such as decreased blood flow to the skin which may play a part into mental imagery's effectiveness (Guillot & Collet, 2005).

5. Limitations

Limitations of our study include the possibility of statistical error due to our project design; these include the briefness of the investigation, lack of physiological measurements, and participant familiarity with procedures and uncertainty of the efficacy of imagery protocol structure and stretch selection we employed to influence flexibility measures. We can also see error through the post hoc power analysis we conducted; a posthoc power analysis demonstrated a small effect size and power (3% and 5% respectively) (Faul, 2007).

Future work should use single variable testing combined with the purpose of imagery to assess changes in subjects perception of flexibility, which could elucidate if positive expectations or a placebo effect can influence flexibility measures. Future investigations should also include orientation periods to promote subject familiarity with imagery and related procedures to account for a possible “learning effect” that may be needed for imagery to be effective. Finally, future work should test different body segments that vary in size and motor function (gross vs. fine) and use different stretches as a means to assess whether or not visualization and mental imagery can influence these measures and if they do so uniformly across the body.

6. Conclusions

The present investigation reports that there is an uncertainty of whether or not mental imagery and visualization can be used as an independent modality to acutely influence ROM measures. The current investigation also reports that the use of mental imagery to primarily influence hamstring flexibility measures produced non-significant results. Future research will be necessary to conclude the efficacy of imagery's ability to influence flexibility measures and if imagery as an independent tool is beneficial for improving flexibility in other body regions and musculature by utilizing different stretching or visual protocols and when assessed in conjunction with instrumentation and specific project design.

Conflict of Interests

No conflicts of interest to report.

References

Decoster, L. C., Scanlon, R. L., Horn, K. D., & Cleland, J. (2004). Standing and Supine Hamstring Stretching Are Equally Effective. *Journal Of Athletic Training, 39*(4), 330-334. Retrieved from https://login.ezproxy.net.ucf.edu/login?auth=shibb&url=https://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=15592605&site=ehost-live&scope=site

Doğan, M., Koçak, M., Onursal Kılınç, Ö., Ayvat, F., Sütçü, G., Ayvat, E., . . . Aksu Yıldırım, S. (2019). Functional range of motion in the upper extremity and trunk joints: Nine functional everyday tasks with inertial sensors. *Gait & Posture, 70*, 141-147. doi:10.1016/j.gaitpost.2019.02.024

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175-191.

Guillot, A., & Collet, C. (2005). Contribution from neurophysiological and psychological methods to the study of motor imagery. *Brain Res Brain Res Rev, 50*(2), 387-397. doi:10.1016/j.brainresrev.2005.09.004

Guillot, A., Tolleron, C., & Collet, C. (2010). Does motor imagery enhance stretching and flexibility? *J Sports Sci, 28*(3), 291-298. doi:10.1080/02640410903473828

Hall, C. R., & Martin, K. A. (1997). Measuring movement imagery abilities: A revision of the Movement Imagery Questionnaire. *Journal of Mental Imagery, 21*(1-2), 143-154.

Lebon, F., Guillot, A., & Collet, C. (2012). Increased muscle activation following motor imagery during the rehabilitation of the anterior cruciate ligament. *Appl Psychophysiol Biofeedback, 37*(1), 45-51. doi:10.1007/s10484-011-9175-9

Marks, D. (1973). *Vividness of Visual Imagery Questionnaire Items Appendix to Marks, 1973*.

Peerdeman, K. J., van Laarhoven, A. I., Donders, A. R., Hopman, M. T., Peters, M. L., & Evers, A. W. (2015). Inducing Expectations for Health: Effects of Verbal Suggestion and Imagery on Pain, Itch, and Fatigue as Indicators of Physical Sensitivity. *PLoS One, 10*(10), e0139563. doi:10.1371/journal.pone.0139563

Prather, H., Harris-Hayes, M., Hunt, D. M., Steger-May, K., Mathew, V., & Clohisy, J. C. (2010). Reliability and agreement of hip range of motion and provocative physical examination tests in asymptomatic volunteers. *PM & R: The Journal Of Injury, Function, And Rehabilitation, 2*(10), 888-895. doi:10.1016/j.pmrj.2010.05.005

Ranganathan, V. K., Siemionow, V., Liu, J. Z., Sahgal, V., & Yue, G. H. (2004). From mental power to muscle power—gaining strength by using the mind. *Neuropsychologia, 42*(7), 944-956. doi:https://doi.org/10.1016/j.neuropsychologia.2003.11.018

Sexton, P., & Chambers, J. (2006). The importance of flexibility for functional range of motion. *Athletic Therapy Today, 11*(3), 13-60. Retrieved from https://login.ezproxy.net.ucf.edu/login?auth=shibb&url=https://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=106313922&site=ehost-live&scope=site

Williams, J. G., Odley, J. L., & Callaghan, M. (2004). Motor Imagery Boosts Proprioceptive Neuromuscular Facilitation in the Attainment and Retention of Range-of -Motion at the Hip Joint. *J Sports Sci Med, 3*(3), 160-166.