MOVEMENT AND STRETCHING IMAGERY DURING FLEXIBILITY TRAINING.

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Abstract

The purpose of this study was to examine the effect of movement and stretching imagery on flexibility increase. Thirty volunteers took part in a four-week flexibility training programme. They were randomly assigned to one of three groups: movement imagery (MI), this group imagined moving the limb they were stretching; stretching imagery (SI), this group imagined the physiological processes involved in stretching the muscle; and control, this group did not engage in mental imagery. Active and passive range of motion around the hip was assessed before and after the programme. Participants provided specific ratings of vividness and comfort throughout the programme.

Results showed significant increases in flexibility over time, but no differences between the three groups. A significant relationship was found, however, between flexibility gain and vividness ratings in the MI group. Furthermore, both imagery groups scored significantly higher than the control group on levels of comfort, with the MI group also scoring significantly higher than the SI group. It was concluded that the imagery had stronger psychological than physiological effects, but that there is potential for enhancing physiological effects by maximising imagery vividness, particularly for movement imagery.

Introduction

Mental imagery has been studied extensively, both inside and outside of the sports domain. A considerable number of studies have shown that mental imagery can produce a wide range of physiological responses (Qualls, 1982-83; Sheikh et al., 1989; Deschaumes-Molinaro et al., 1992; Kunzendorf and Hall, 2001). Within the sport setting the most well-known physiological response to imagery is the electromyographic (EMG) activity produced in muscles as a result of imagining movement (Harris and Robinson, 1986; Bakker et al., 1996).

This response (sometimes referred to as "efferent leakage" or "efferent outflow", Lang, 1979; Boschker, 2001) is generally an unintentional and implicit by-product resulting from the process of imaging movement (although from a theoretical perspective, the activity is often ascribed a role in indicating imagery effectiveness, e.g. in changing behaviour, Lang, 1984, 1985; or enhancing motor performance, Smith et al., 2001). At the same time, a particular physiological response may also be the intended end-product of an imagery exercise. This may be through the use of emotive imagery (e.g. intended to affect respiratory processes involved in asthma attacks, Ritz et al., 2002), imagery of behaviours that affect physical responses (e.g. imaging holding the hands over a fire to raise hand temperature, Blanchard and Andrasik, 1985; imaginary training of specific movements to improve muscle strength, Yue and Cole, 1992), or imagery of specific physiological responses themselves (e.g. imaging tissue healing during rehabilitation from sports injury, Porter and Foster, 1990; Ievleva and Orlick, 1993; Cupal and Brewer, 2001). From research on immune system imagery there is some evidence to suggest that mentally imaging specific changes in a selected physiological process can produce concomitant changes in this process (Rider and Achterberg, 1989; Rider et al., 1990). In the sport and exercise setting, some initial evidence suggests that this type of imagery applied to the healing process of a sports injury is associated with a faster recovery (Ievleva and Orlick, 1991; Cupal and Brewer, 2001). While these studies indicate that it may be possible to effect physiological changes through directed mental activity, it is still far from clear where the boundaries lie in influencing physiological processes via mental imagery.

The present study aimed to explore these boundaries further by focusing on both specific physiological imagery and movement imagery in relation to the physiological process of flexibility. As stretching takes time and offers a possibility for personal thoughts, stretching time may be an occasion when athletes employ mental imagery of their skills (personal observation). Considering the efferent leakage of EMG-activity often found during movement imagery and the associated potential for contracting effects in the muscles, we wondered whether this type of imagery during stretching might be counter-productive to the intended lengthening of the muscle. At the same time, we wanted to investigate if specific physiological imagery of the muscle elongating might have the opposite effect. This type of imagery corresponds with the idea that imagery of specific physiological processes might influence those processes, as suggested by the Rider et al. studies (1989, 1990), and is intuitively more apt for use during stretching than movement imagery.

Hence, the purpose of this study was to explore the effect of using different forms of mental imagery during stretching on subsequent increases in flexibility. Specific questions involved (1) Does movement imagery during stretching interfere with the intended effect of the stretching? It was hypothesized that stretching accompanied by movement imagery would lead to smaller increases in flexibility than stretching without imagery. (2) Does stretching imagery (i.e. mentally imaging the muscles and tendons becoming longer) during stretching augment the effect of the stretching? It was hypothesized that stretching accompanied by stretching imagery would lead to greater increases in flexibility than stretching without imagery. (3) Does imagery vividness influence the effect of the image content on the stretching? Since it is generally assumed that the degree of vividness of the imagery is associated with the magnitude of the physiological response (Qualls, 1982-83; Sheikh et al., 1989), it was hypothesized that the correlation between vividness levels and flexibility increase would be positive for stretching imagery and negative for movement imagery.

In addition to evaluating the effect of the imagery on flexibility gain, we were also interested in exploring a number of aspects of imagery vividness in relation to the requirement of generating images *during* physical exercises. Although several authors have addressed the use of movements during imagery (Gould et al., 2002; Holmes and Collins, 2001) and imagery during movement (Hanrahan et al., 1995; Coote and Tenenbaum, 1998; Van Gyn et al., 1990), the bulk of the literature focuses on imagery conducted in a quiet, non-moving, often relaxed, state, and very little is known about the use of imagery during physical exercise. Specifically, we aimed to explore the following questions: (a) can imagery vividness during stretching be predicted by a general measure of imagery ability, (b) what are participants' experiences with regard to the ease or difficulty of generating images during stretching, and (c) does imagery influence the level of comfort experienced during the stretches? It was hypothesized that movement imagery would have an adverse effect on the comfortableness of the stretch (as it might result in muscles slightly contracting), while stretching imagery would have a favourable effect.

Method

Participants

Volunteers were recruited among employees of a regional university in the north east of England. Forty seven employees, 25 men and 22 women (mean age 40.8 years, S.D. 9.8), volunteered to take part in a four-week flexibility training programme. They were matched for age and gender and were randomly assigned to one of three conditions: (a) movement imagery (MI); this group imagined that they were moving the leg they were stretching, (b) stretching imagery (SI); this group imagined the muscles becoming longer; and (c) control; this group did not engage in imagery during stretching. All participants were Caucasian. Participants were screened for medical problems and provided written consent before taking part in the study.

Tasks

The training programme consisted of 11 half-hour sessions, and was designed to predominantly increase flexibility around the hip joint. Each session involved a 5-7 minute warm-up, followed by a series of seven stretching exercises. The physical components of the training programme were the same for all three groups. The flexibility exercises included: (1) standard sit-and-reach (ex. #46 in Alter, 1988), (2) straddle sit-and-reach (ex. #47 and #75 in Alter, 1988), (3 and 4) straight leg raise assisted by hands pulling leg towards the face; first right, then left (ex. #6 in Alter, 1996), (5) calf stretching (ex. #7 in Alter, 1996); both legs simultaneously, (6 and 7) straddle sit-and-reach with one leg bent; first right, then left (ex. #10 in Alter, 1996). Each stretch was executed three times, with a 20-second rest period in between. The duration of the stretch increased from 20 seconds in the first training session via 25 seconds in the second session to 30 seconds in the third and subsequent sessions.

The content of the imagery to be used by the two imagery groups was explained to the participants individually, on the day of the pre-test. Participants in the MI group were told to imagine continually moving the leg they were stretching by repeatedly flexing the knee, bringing the heel towards the buttocks. The idea of the movement was demonstrated by the experimenter in a standing position using one leg. Suggestions were given about how to imagine the movement in the different stretching positions. It was emphasized that participants needed to try to both see and feel the movements.

Participants in the SI group were instructed to imagine the muscle becoming longer, at cellular level during the first 15-25 seconds of the stretch, then for the muscle as a whole during the last 5 seconds of the stretch. The cellular level imagery involved picturing the sliding movements of the actin and myosin filaments to create a lengthening of the muscle fibres. The content of this image was first explained verbally, accompanied by a manual demonstration of the sliding movements using the hands, as well as by showing figures from Alter (1988, p.14, 18) depicting the actin and myosin filaments in different stages of contraction and elongation. The participants then viewed a 2-minute section on the muscular system from the CD-ROM BodyWorks (1998), which explained muscular contraction and elongation and contained three-dimensional visual images of contracting and elongating muscles in motion. The participants also received drawings of the actin/myosin filaments in different stages of elongation.

Measures

Flexibility

Flexibility measures consisted of active and passive range of motion (ROM) around the hip joint, assessed unilaterally on the dominant leg at baseline and at the end of the training program. All measures, pre- and post, were taken by the same research assistant who was blind to the experimental condition of the participants. Measurement procedures were similar to those described by Roberts and Wilson (1999). Prior to testing each participant, time, date and room temperature were recorded so that conditions could be matched at post-test. Each participant completed a 5 minute aerobic warm-up on an exercise bicycle at 60-80% Heart Rate Maximum, after which the assessment of (first active, then passive) ROM was conducted. All movements took place in the sagittal plane following the assumption of the fundamental anatomical position. Angular displacement was measured using an inclinometer

(Maud and Cortez-Cooper, 1995), and procedural guidelines recommended by MacDougall et al. (1991) were followed to determine start and end positions of ROM. Following identification of anatomical landmarks the inclinometer was positioned, markings were made and the distance of the inclinometer from the joint centre was recorded for future reference. The inclinometer was then removed and the stretching movement performed, either actively or passively. The inclinometer was subsequently replaced in the same ‘marked’ position after which the measurement was recorded. The end of passive ROM was determined once the tester felt resistance or the participant vocalized discomfort. Each movement was repeated three times and recorded in degrees. The average of the three measures served as the final flexibility score.

Imagery vividness

Imagery vividness was assessed both as a general ability measure before the study and as a condition-specific measure during the study. The Vividness of Visual Imagery Questionnaire (VVIQ, Marks, 1973) was used to measure general imagery ability. This is a brief and standardized measure of imagery vividness, of which reliability and validity are well-established (Marks, 1999) and which has been shown to be related to the ability to influence physiological processes (Sheikh et al., 1989). It consists of 16 items, which are rated on a 5-point scale ranging from “perfectly clear and as vivid as normal vision” to “no image at all, you only ‘know’ that you are thinking of an object”. Normally, VVIQ items are scored from 1 highly vivid to 5 not vivid at all (Marks, 1973). However, in order to maintain the same direction across scales within the study, the scores were reversed, with 1 indicating low vividness and 5 indicating high vividness. Participants completed the VVIQ individually, and, in accordance with Marks’ (1973) recommendations, rated the items twice, once with their eyes open and once with their eyes closed. An overall VVIQ score was calculated for each participant as an average of the 32 vividness ratings.

Condition-specific vividness was assessed throughout the study, by participants indicating the vividness of their images after every stretching exercise. Using 9-point scales ranging from 1 "not vivid at all" to 9 "extremely vivid", participants in the MI group provided two ratings, one indicating how vividly they had seen (MI-visual) and the other indicating how vividly they had felt (MI-kinaesthetic) the movement. Participants in the SI group also provided two ratings, indicating the vividness of the actin and myosin filament movement images (SI-cell) and the vividness of the whole-muscle-lengthening images (SI-muscle) respectively. The decision to include separate ratings for visual and kinaesthetic aspects for the MI group was related to the expectation that more vivid kinaesthetic imagery would result in greater contractile activity, hence in a stronger negative effect on flexibility. A similar distinction between visual and kinaesthetic aspects of the images was not made for the SI group, mainly because it was expected that the images of the filament movements would be predominantly visual, and also because we did not want to overload the participants with too many ratings. In order to assess participants' subjective experiences of the imagery conditions, two questionnaires querying them about the content of their imagery, factors affecting vividness and perceived impact of imaging, were distributed half way through and at the end of the training programme.

Comfort level

The subjectively perceived level of comfort during the stretch was also measured on a nine-point rating scale, ranging from 1 "not at all comfortable" to 9 "extremely comfortable".

Procedures

A general introductory meeting was held 10 days prior to the study to inform the participants about the study requirements and to explain the stretches in the flexibility programme. Participants also completed a medical history form. There was no need to exclude participants on medical grounds. All participants agreed to maintain their normal exercise and activity levels for the duration of the study.

Pre-test flexibility measures were taken approximately one week before the start of the training programme. Following the flexibility assessment, all participants completed the VVIQ, and the participants in the imagery groups received instructions on what to imagine during the stretches. All participants also signed an informed consent form on this day. For the flexibility programme, the three groups then met separately for half an hour, three times a week for a total of 11 training sessions. During the programme, participants were instructed to prepare for a stretch by adopting the appropriate stretching position, but to the point where they could not yet feel the stretch. A signal to adopt the stretching position was given five seconds before the start of the stretching time. The command "Start now" was given at the beginning of the stretching time. This was an indication for the participants to increase the stretching position to the point where a stretch was clearly noticeable, and to start their imagery if they were in one of the imagery groups. The last five seconds of stretching time were also announced in all groups. For the participants in the SI group, this was the sign to change their imagery to the image of the whole muscle lengthening. After each stretch (i.e. 7 different exercises x 3 repetitions = 21 times), participants in the MI and SI groups rated the vividness of their images and participants in all three groups rated the comfortableness of the stretch.

Post-testing was undertaken at the end of the training programme, using the same procedures as for the pre-test. All three groups of participants were post-tested under the same environmental conditions and at the same time of day as their respective pre-tests. To match pre-test conditions, participants in the imagery groups were asked to refrain from using imagery during the stretches (post-test1). Following the sets of active and passive ROM measurements matching the pre-test conditions, all participants completed a second series of sets, during which the two imagery groups were required to use their respective imagery strategy (post-test2). Participants in the SI group were told to just use the actin/myosin images, as the time for the stretch was shorter than during the training programme. After each stretch of post-test2, participants again rated the vividness of their imagery.

Analyses

Flexibility scores for both active ROM and passive ROM were calculated for the pre-test, post-test1 and post-test2 respectively. The 21 ratings that the participants provided per session for visual vividness and kinaesthetic vividness (MI group) or actin/myosin vividness and whole muscle vividness (SI group) were averaged to determine a mean vividness rating per session for MI-visual, MI-kinaesthetic, SI-cell and SI-muscle respectively ("session vividness"). A similar procedure was used to calculate mean comfort ratings per session ("session comfort"). Overall mean vividness and comfort ratings throughout the programme were also calculated by averaging the mean ratings per session across the 11 sessions ("overall vividness" and "overall comfort").

Results

Participants

During the course of the study, seven of the 47 volunteers dropped out of the programme for a variety of personal reasons, including lack of time and injuries sustained in other activities. None of the reasons appeared to be directly related to the programme itself. Of the remaining 40 participants, flexibility data on 4 participants had to be discarded because it emerged that they had not followed instructions properly. Questionnaire data revealed that 2 participants had done extra exercises at home, despite being asked not to. One participant in the MI group had become bored and stopped doing the imagery in the last week, and one participant in the control group failed to heed instructions during the post-test, rendering the flexibility measures invalid. As a result, data of 36 participants were used, 12 in the MI group, 14 in SI and 10 in the control group. There were no significant differences between the three groups in age, neither overall (ANOVA, $F_{2, 33} = 0.227$, $P = 0.789$), nor for females (ANOVA, $F_{2, 13} = 0.080$, $P = 0.923$) or males (ANOVA, $F_{2, 17} = 0.478$, $P = 0.628$). Mean age was 40.4 ± 8.3 for MI, 41.1 ± 11.6 for SI, and 38.3 ± 10.6 for the control group.

***** Table 1 near here *******

Flexibility

Means and standard deviations for ROM values are presented in Table 1. In order to compare the three groups on pre-test, post-test1 and post-test2 ROM values, two multi-factorial repeated measures ANOVA's were calculated on active and passive ROM values respectively. Degrees of freedom were adjusted with Greenhouse-Geisser where the sphericity assumption was violated (Atkinson , 2001). Both analyses showed significant main effects for tests ($F_{1.5, 49.2} = 72.4$, $P < 0.001$, $\eta^2 = 0.69$, for active ROM; $F_{1.2, 38.7} = 64.0$, $P < 0.001$, $\eta^2 = 0.66$, for passive ROM), but not for groups ($F_{2,33} = 1.49$, $P = 0.239$, $\eta^2 = 0.08$, for active ROM; $F_{2,33} = 1.54$, $P = 0.230$, $\eta^2 = 0.09$, for passive ROM) and no significant interaction effect ($F_{(3, 49.2)} = 0.796$, $P = 0.501$, $\eta^2 = 0.05$, for active ROM; $F_{2.4, 38.7} = 0.560$, $P = 0.603$, $\eta^2 = 0.03$, for passive ROM).

Using the Least Significant Difference test adjusted with the step-wise Holm-Bonferroni correction (Atkinson, 2002), follow-up pairwise comparisons were calculated on the differences between tests. These analyses indicated that flexibility measures across all three groups differed significantly between pre-test and post-test1 ($P < 0.01$, for both active and passive ROM), between pre-test and post-test2 ($P < 0.01$, for both active and passive

ROM) and between post-test1 and post-test2 ($P < 0.01$, for both active and passive ROM). (Fig. 1).

***** Figure 1 near here *******

Imagery vividness

General imagery ability

There were no significant differences among the three groups in VVIQ scores (ANOVA, $F_{2, 33} = 0.046$, $P = 0.956$). Scores in each group ranged from modestly vivid (2.3) to highly vivid (4.9). Mean scores were: MI 3.69 ± 0.6, SI 3.71 ± 0.7, Control 3.63 ± 0.7.

Vividness ratings during the programme

The overall vividness ratings, taken as an average across all 11 sessions, were: MI-visual 5.99 ± 1.6, MI-kinaesthetic 5.66 ± 1.7, SI-cell 5.30 ± 1.4, and SI-muscle 5.51 ± 1.5. Independent and paired t-tests showed that these differences were not significant (p-values ranged from 0.254 to 0.806 for the independent tests, and were 0.078 and 0.076 for the MI and SI scores respectively).

Vividness ratings in relation to VVIQ scores

Pearson product moment correlations were calculated between pre-test VVIQ scores and overall during-programme vividness ratings. None of the correlations proved significant. Correlation coefficients were r = 0.12 ($P = 0.703$) for MI-visual; r = 0.25 ($P = 0.432$) for MI-kinaesthetic; r = 0.29 ($P = 0.309$) for SI-cell; and r = 0.24 ($P = 0.406$) for SI-muscle.

Flexibility gain and imagery vividness

The relationship between flexibility gain and imagery vividness was examined in several ways. Scores were calculated for the percentage increase in ROM from pre-test to post-test1 (“programme flexibility gain”) and also for the percentage increase in ROM from post-test1 (without imagery) to post-test2 (with imagery) (“post-test flexibility gain”). Programme flexibility gain was correlated with both VVIQ scores and overall vividness scores. Post-test flexibility gain was correlated with the vividness scores provided for post-test2. To limit the number of correlations in this analysis, the two types of imagery ratings within each group were combined. This was deemed reasonable, as the average ratings did not differ significantly and were in fact strongly correlated (ranging between $r = 0.87$ to $r = 0.94$ in both groups for overall and post-test vividness). Because of the directionality of the hypothesis, one-tailed tests were used. Pearson Product-moment correlations and significance values are presented in Table 2.

***** Table 2 near here *******

VVIQ and programme flexibility gain

There was no significant relationship between VVIQ scores and flexibility gain throughout the programme for any of the groups (Table 2a).

Overall vividness ratings and programme flexibility gain

All correlations between overall vividness and programme flexibility gain were positive, and reached or approached significance for passive flexibility but not for active flexibility (Table 2b). This partly contradicts the hypothesis that vividness would be negatively related to flexibility increase for the MI group and positively for the SI group.

Post-test2 vividness ratings and post-test flexibility gain

Correlations between post-test flexibility gain and vividness ratings for the imagery used on post-test 2 revealed significant positive correlations ($P < 0.05$) for the MI group with both active and passive flexibility gain (Table 2c). The correlations for the SI group were very low and negative.

Questionnaire results

The questionnaire results were used both as intervention check, to ensure that participants conformed with the conditions they were assigned to, and as a way to explore the types of images generated by the participants.

Intervention check

With respect to the control group, the questionnaire results indicated that none of the participants engaged in either movement or stretching imagery. In the MI group, all participants reported images of their legs moving. Some commented on physical sensations accompanying the images, e.g. feeling the muscles relax, increased awareness of thigh muscles, feeling the heel hit the buttock. In the SI group, all participants reported images of muscles stretching. The images they described ranged from mostly literal images to more personally enriched images. Both types of images appeared to be based on the pictures and CDROM shown at the beginning of the experiment.

Perceptions of factors affecting imagery vividness

When asked to indicate in which circumstances their images were most vivid, participants in the MI group predominantly emphasized the absence of external (noise, cold, heat) and internal (worries, preoccupation with work) distractions (64.7% of circumstances cited). Although these circumstances were also mentioned by the SI group (21.4%), they were less prominent. The circumstances mentioned most frequently by the SI group were recalling previously shown pictures of the muscle lengthening (28.6%), and times when the stretch was felt very strongly, up to the point of causing pain (28.6%). Other circumstances mentioned once or twice in each group (6-14%) were when the stretch was felt in one isolated area, when the stretch felt natural or synchronous to the image (in the MI group only), after settling into the exercise, and imaging being elsewhere.

Combination stretching and imagery

Participants varied in their impressions of the effect that the stretching had on their image generation and vice versa. A little over a third of the participants (MI 33.3%, SI 42.9%) thought that doing the stretches while imaging did not make a difference to the ease or difficulty of image generation. Comparable percentages (MI 33.3%, SI 35.7%) thought that doing the imagery would have been easier without stretching at the same time, whereas smaller numbers (MI 26.7%, SI 14.3%) believed that doing the stretches helped in generating the images.

Similar variations were found with regard to the perceived effect of imagery on doing the stretches. About a third of the participants (MI 35.7%, SI 28.6%) thought that the imagery had no effect on the ease of conducting the stretches. Smaller percentages (MI 21.4%, SI 14.3%) thought that doing the imagery made the stretching harder. A larger proportion of participants (MI 35.7%, SI 42.9%), on the other hand, thought that doing the imagery facilitated the stretching.

Perceived effectiveness of the imagery on enhancing flexibility

Belief in the effectiveness of the imagery was stronger in the SI than the MI group, as indicated by the fact that 61.5% of SI versus 26.7% of MI participants stated that they thought the imagery helped considerably or greatly in augmenting the effect of the stretches. Conversely, 60.0% of MI versus 23.2% of SI participants believed the imagery either made no difference or even hindered the effect of the stretching.

Comfort ratings

Overall mean comfort ratings were 6.83 ± 1.01 for MI, 5.48 ± 0.93 for SI and 4.16 ± 1.5 for the control group. Univariate ANOVA on these mean comfort ratings revealed significant differences between groups ($F_{2,33} = 15.2$, $P < 0.001$). Follow-up post-hoc tests indicated significant differences between all three groups: $P < 0.001$ for MI-control, and $P < 0.01$ for MI-SI and SI-control. Observation of the mean comfort ratings per session (Fig. 2) shows that the MI group had consistently higher ratings than both the SI and control group, and that the SI group had consistently higher ratings than the control group.

Comfort ratings were not significantly related to percentage flexibility increase (Pearson Product-moment correlation: r = -0.21, $P = 0.230$ for active ROM; r = -0.04, $P = 0.833$ for passive ROM), which suggests that comfort was probably not an indicator of effort put into the stretch, or an indicator of the amount of stretching force applied by the participant during the stretches. Comfort ratings, therefore, appear to be predominantly an indicator of the subjective amount of (dis)comfort experienced during the stretch.

**** *Figure 2 near here* ******

Relationship between comfort and imagery vividness

To examine the relationship between levels of comfort experienced and levels of imagery vividness, a Pearson-Product Moment correlation was calculated between overall comfort ratings and overall combined imagery ratings (i.e. a combined score of both imagery ratings for each participant). This resulted in a significant positive correlation (r = 0.56, $P < 0.01$), suggesting that higher levels of experienced comfort were associated with higher levels of imagery vividness. To further explore this relationship, Pearsons correlations were calculated separately for the two groups and the different types of imagery ratings. Positive correlations were found ranging from r = 0.51 to r = 0.77; however, after applying a stepwise Holm-Bonferroni correction for multiple comparisons (Atkinson, 2002), only the relationship between comfort and MI-combined imagery ratings (r = 0.67, $P < 0.05$) and the relationship between comfort and MI-kinaesthetic (r = 0.77, $P < 0.01$) were found to be significant.

Discussion

The main purpose of this study was to examine the influence of movement and stretching imagery on flexibility gain during a flexibility training programme. A secondary purpose was to explore various aspects of imagery vividness in relation to the requirement of generating images during physical exercise. It was hypothesized that movement imagery would lead to a smaller increase in flexibility than no imagery, while stretching imagery would lead to a greater increase. The results did not support either of these hypotheses. It was clear that the flexibility programme resulted in increased ROM, but that the imagery manipulations had little to no effect on the amount of flexibility gained. If anything, results contradicted expectations.

The hypotheses that more vivid imagers would show the smallest increase in flexibility in the movement imagery group and the strongest increase in the stretching imagery group, were also not supported. Contrary to expectations, imagery vividness in the movement imagery group showed positive correlations with flexibility gain across the programme, in particular for passive flexibility. In addition, post-test vividness ratings for movement imagery showed significant positive correlations with active and passive post-test flexibility gain. In the stretching imagery group, correlations between vividness ratings and flexibility gain across the programme were in the expected direction and were moderately high, also being stronger for passive flexibility. They did not reach significance however. Post-test vividness for this group showed no relationship with post-test flexibility gain.

A final result that was contrary to expectations concerned the levels of comfort experienced by the three groups. It was hypothesized that comfort levels would be lowest in the movement imagery group and highest in the stretching imagery group. The results showed, however, that comfort levels in the movement imagery group were significantly higher than in the stretching imagery group, which, in turn, were significantly higher than in the control group.

There are a number of questions entangled in the area of purposeful use of mental imagery for achieving particular physiological outcomes. One may ask whether the imagery actually has a *direct* physiological effect, as appears to be the case in the Rider et al. studies (1989, 1990), or whether it has an *indirect* physiological effect by influencing other factors (e.g. enhanced motivation, better technical execution, improved information processing), or whether perhaps it has no physiological effect at all but is beneficial in a psychological way. It is worth considering the results of this study in light of these questions.

With respect to stretching imagery, no clear physiological effect was indicated, more or less precluding the need for conjecture regarding the directness or indirectness of such an effect. These results are contrary to some other studies which have shown physiological effects of physiology-specific imagery (Rider and Achterberg, 1989; Rider et al. 1990; Cupal and Brewer, 2001), and this may indicate that the physiological processes involved in increasing flexibility are harder to influence through this type of imagery. On the other hand, some parameters of the present study may have prevented an effect from occurring. It is possible, for example, that the vividness of the imagery that the participants were able to generate was insufficient to produce an effect. One reason for this may be that, although the presentation and explanation of the physiological processes in this study were similar to those used in the Rider et al. (1989, 1990) studies, the execution of the task was very different in that imagery did not take place under conditions of physical relaxation, nor with the help of audio-taped imagery instructions. The requirement to combine two different tasks by doing the imagery while stretching may have affected participants' ability to generate the most vivid images. This is an intriguing issue, as a number of participants claimed that the stretching actually helped them to generate vivid images; for these participants the afferent input provided by the stretch appeared to support the creation of more vivid images. Conversely, there were also participants who reported that the stretching hindered the generation of more vivid images. Hence, the role of afferent input in imagery vividness deserves more exploration in future research.

At the same time, it is worth considering whether the role of specific stretching imagery conducted without simultaneous movement and in the absence of physical training could produce an effect on flexibility gain. Conducting imagery in such conditions has been shown to increase strength (Yue and Cole, 1992; Smith et al., 2003), although in those studies the imagery used consisted of movement images (i.e. exercising the muscle) rather than images of specific physiological processes. The latter also points to another interesting issue. While the concept of imaging specific physiological processes was based on the Rider et al. (1989, 1990) studies and work on healing imagery, another possible avenue of achieving particular physiological imagery outcomes may be to focus on the more indirect route of imaging behaviours that result in the outcome, rather than on the more direct route of imaging the physiological processes involved in the outcome. Hence, it may also be fruitful to investigate the effect of imaging the stretching exercises themselves.

The absence of audio-taped guided imagery instructions is another factor that may have contributed to less than optimal imagery vividness. It would likely have become tedious to repeat the script for each of the 21 stretches per session, but it is plausible that an imagery training period preceding the flexibility programme might have been beneficial. Work by Lang and colleagues (Lang, 1979; Lang et al., 1980) and Smith et al. (2001) has suggested that training people by providing them with personalised imagery scripts, especially ones that emphasise response propositions (i.e. experiencing physiological, emotional or kinaesthetic responses to the image), can enhance imagery's effectiveness. Although the imagery instructions to the participants in this study were personalised to make sure that people understood them, they did not take the form of guided imagery scripts, and this is something to be considered in future studies. In this light it is also worth considering emphasising response propositions in the stretching imagery by encouraging the participants to not only see but also feel the cells and muscles elongating. In keeping with the visual emphasis of the physiology-specific imagery used in other studies, this kinaesthetic element was not emphasised in the stretching imagery group, but it is another avenue worth exploring in future work.

In the movement imagery group, instructions were given to both see and feel the movement, and this was further reinforced by requiring visual as well as kinaesthetic vividness ratings to be provided after each of the stretches. The vividness ratings and answers to the open-ended questions in the questionnaires confirmed that participants in this group included response propositions in their imagery. It is nevertheless possible that an initial training period with guided imagery scripts might have further enhanced levels of vividness.

Despite perhaps less than optimal vividness levels, it was evident that the movement imagery did not have a negative impact on flexibility increase, implying that the often found (e.g. Harris and Robinson, 1986; Jowdy and Harris, 1990; Bakker et al., 1996) direct physiological effect of EMG activity in the muscle during this type of imagery did not interfere with the effect of the stretching exercises. In fact, there were some indications that the movement imagery may have had a positive impact on the stretching. First, more vivid movement imagery was associated with a stronger increase in passive flexibility across the programme. Secondly, the post-tests showed a positive correlation between post-test vividness ratings and percentage increase in active and passive flexibility gain. The latter suggests that vividly imagined sensations of movement may have a beneficial effect on the ROM achieved *during* a stretch. It appears that if participants can create vivid movement imagery, this may help them to push the stretch further. A possible mechanism underlying this effect may be found in the subjective reports of some participants in the movement imagery group who claimed that the imagery helped the muscles relax. The idea that movement imagery might produce relaxation in the muscle is also supported by some anecdotal suggestions in the dance literature. For example, Hanrahan et al. (1995), in discussing Schweigard's (1975) work, noted that "appropriate visualized movement in a muscle produces relaxation of this muscle" (p.423). The finding that passive, more so than active, flexibility gain across the programme was related to imagery vividness may be an indication that those participants who were able to create vivid movement images throughout the programme also had a better ability to relax during the passive post-test without imagery, allowing the ROM to be extended further.

In light of the correlational nature of the data, some attention also needs to be given to the possibility that the direction of the relationship could be reversed, i.e. stronger kinaesthetic feedback from the physical exercise may enhance the vividness of the imagery. This is an option worth exploring further, in particular in conjunction with the finding that some participants reported that the vividness of their images increased when they felt the stretch very strongly.

An interesting result of this study concerns imagery's effect on comfort levels. The finding that both imagery groups differed significantly from the control group in comfort suggests that engaging in imagery may reduce some of the discomfort of the stretching. The fact that, in addition, the two imagery groups also differed significantly from each other suggests that there may be an effect of image content over and above an effect of the imagery itself. This was further reinforced by the significant correlation between comfort and imagery vividness, in particular for the movement imagery group and for kinaesthetic movement imagery. That mental imagery can be used as a strategy to reduce discomfort or pain is commonly recognised in the literature on cognitive pain management (e.g. Alden et al., 2001), where it is often thought that imagery reduces pain perception by acting as a distraction from the pain. Indeed, in our study several participants in both groups mentioned that the imagery helped because it took the focus away from the discomfort or pain of the stretch. At the same time, some other participants indicated that the imagery helped them to concentrate on the stretch. These claims are not necessarily contradictory, as a focus on the stretch might mean a focus on the technique of the stretch or the sense of elongation, while simultaneously directing attention away from the pain. Coote and Tenenbaum (1998), who conducted a study on imagery use during an exertion tolerance test, found that imagery did increase exertion tolerance but did not reduce exertion perception, leading them to conclude that imagery somehow enabled the participants to better cope with the exertion.

Whether the imagery in this study served to reduce pain perception or merely enabled participants to cope with it better is hard to say, but it was clear that it made the experience more comfortable. The additional effect of imagery *content* found for movement imagery may be comparable to some findings from the pain management literature that suggest that mere imagery is not sufficient to produce an analgesic effect, but that a particular feeling or meaning needs to be present in the imagery to achieve this (Alden et al., 2001). In the case of movement imagery, considering the fact that kinaesthetic vividness was associated with comfort levels, the critical additional component affecting levels of comfort may have been the quasi-sensory kinaesthetic input that the imagined movement provided. It is plausible that the information processing circuits and/or brain structures involved in movement imagery may override, interfere or interact with the circuitry involved in processing sensory feedback from the physical exertion of stretching. Future research may address the precise role of this interaction. All in all, despite the more intuitive appeal of stretching imagery (as confirmed by the fact that more participants in the stretching imagery group thought their imagery would be effective), it appears that the movement imagery may in fact have had more advantages.

A note must be made with regard to general and specific measures of imagery vividness. Whereas general indicators of imagery ability like the VVIQ have often been found to be related to the effectiveness of physiologically orientated imagery (Sheikh et al., 1989), this was not the case in this study. The VVIQ was not significantly associated with flexibility increase, neither was it predictive of during-programme vividness levels. Use of the VVIQ was partly based on the assumption that both movement and stretching imagery would be at least visual in nature. Since the movement imagery also included a kinaesthetic component, however, it seems reasonable to speculate that a more movement-specific inventory like the MIQ (Hall and Pongrac, 1983; Hall and Martin, 1997) or VMIQ (Isaac et al., 1986) might have allowed better predictions, at least for the MI group. On the other hand, the fact that the VVIQ scores showed little relationship to even the visual vividness scores reported during the programme may also suggest that the stretching added a qualitatively different dimension to the imagery that affected vividness levels and perhaps tapped into different aspects of imagery ability

This study was the first to examine the effect of imagery *during* stretching. As such, it was difficult to predict effect sizes. Although some experiments with imagery and physiological outcome measures have found fairly large effect sizes that produced significant outcomes with sample sizes of 18 (Yue and Cole,1992) or 30 (Smith et al., 2003), the effect sizes for the physiological effects in this study were very small (η^2 values varied from 0.03 to 0.05; adequate power to detect such small effect sizes as significant would require sample sizes of around 250 participants, Buchner et al., 1997). At the same time, the effects of the imagery conditions on comfort levels were evident and detectable. This suggests that, while there is insufficient power to conclude that the physiological effects of the imagery interventions were nil, there are clear indications that the psychological effects were considerably stronger than any physiological effects. As discussed above, it may be possible to enhance vividness levels through more extensive and explicit imagery training. The positive correlations between imagery vividness and flexibility gain, especially for movement imagery during the post-test, suggest that enhancing imagery vividness may lead to more pronounced physiological effects, and hence to increased and more easily detectable effect sizes. The effects on comfort levels, however, show that even with limited instructions people may derive benefits from engaging in stretching or movement imagery during flexibility exercises.

Conclusion

The results of this study do not support the hypotheses that movement imagery during stretching would inhibit the intended effect of the stretches and that stretching imagery would augment it. For stretching imagery, the possibility of a direct physiological effect on flexibility may be further explored by investigating the use of stretching imagery without simultaneous movement rather than *during* stretching, by emphasising kinaesthetic sensations during the imagery, or by focusing on imagery of stretching exercises rather than specific physiological processes. For movement imagery, there appears to be no direct negative physiological effect on flexibility, but there are some indications that an indirect positive effect may be possible, in the sense that vivid movement imagery might induce relaxation in the muscle which could help in extending the ROM or increasing the duration of the stretch. In the current study the physiological effects were rather small, but there is potential for enhancing effect sizes by providing more support to produce vivid imagery. The results indicate that the psychological effects of the imagery were stronger than the physiological effects, as both types of imagery, but movement imagery in particular, produced benefits in the form of enhanced perceived comfort.

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Table 1. Means and standard deviations for both active and passive ROM, expressed in degrees, at pre-test, post-test1 and post-test2 (mean ± s)

	PRE-TEST		POST-TEST1		POST-TEST2	
ROM	Active	Passive	Active	Passive	Active	Passive
MI	100.2 ± 5.9	107. 7 ± 4.7	109.0 ± 7.3	116.3 ± 6.7	113.5 ± 8.2	117.8 ± 7.6
SI	93.6 ± 11.0	100.8 ± 11.4	104.1 ± 12.2	110.4 ± 13.1	106.5 ± 13.5	112.2 ± 13.0
Control	93.8 ± 11.1	102.6 ± 8.8	107.6 ± 8.7	114.7 ± 8.2	110.6 ± 7.3	116.5 ± 8.3

Table 2. Pearson Product-moment Correlation Coefficients for flexibility gain and imagery vividness indicators, based on combined imagery ratings.

	Active ROM		**Passive ROM**	
(a) Correlation between programme flexibility gain and VVIQ scores for:	**r**	**p**	**r**	**p**
MI	0.17	0.302	0.11	0.363
SI	- 0.34	0.116	- 0.29	0.154
Control	- 0.30	0.201	- 0.27	0.225
(b) Correlation between programme flexibility gain and overall mean vividness for:				
MI	0.31	0.161	0.53*	0.039
SI	0.25	0.197	0.42	0.066
(c) Correlation between post-test flexibility gain and post-test vividness for:				
MI	0.64*	0.022	0.59*	0.027
SI	-0.22	0.239	-0.12	0.346

$P < 0.05$

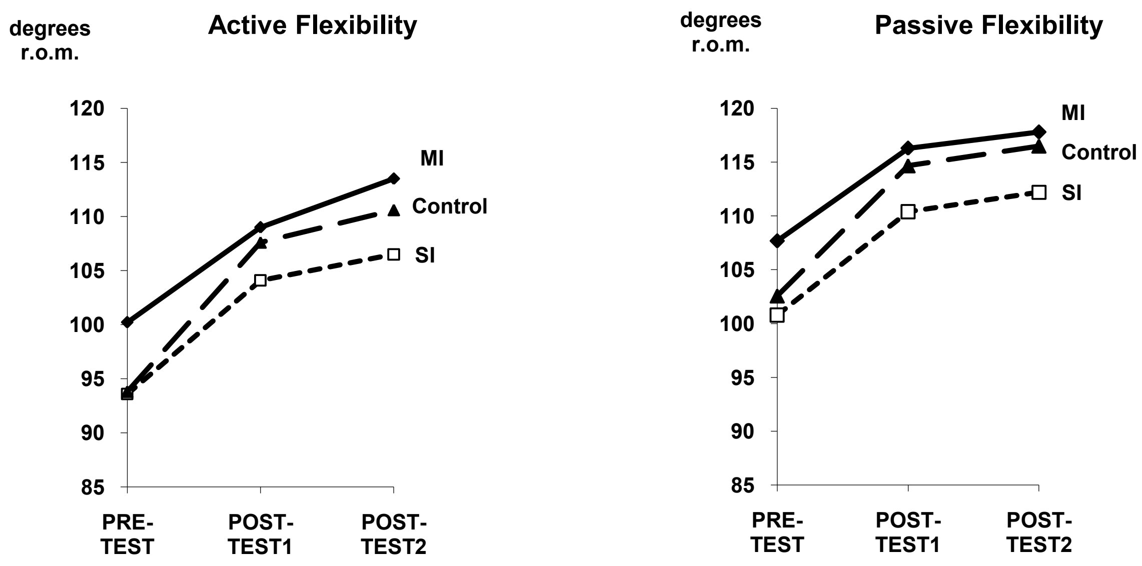

Figure 1. Active and passive flexibility scores, in degrees of range of motion, for the movement imagery (MI), stretching imagery (SI), and control group, prior to the training programme (pre-test) and at the end of the training programme, without (post-test1) and with (post-test2) imagery.

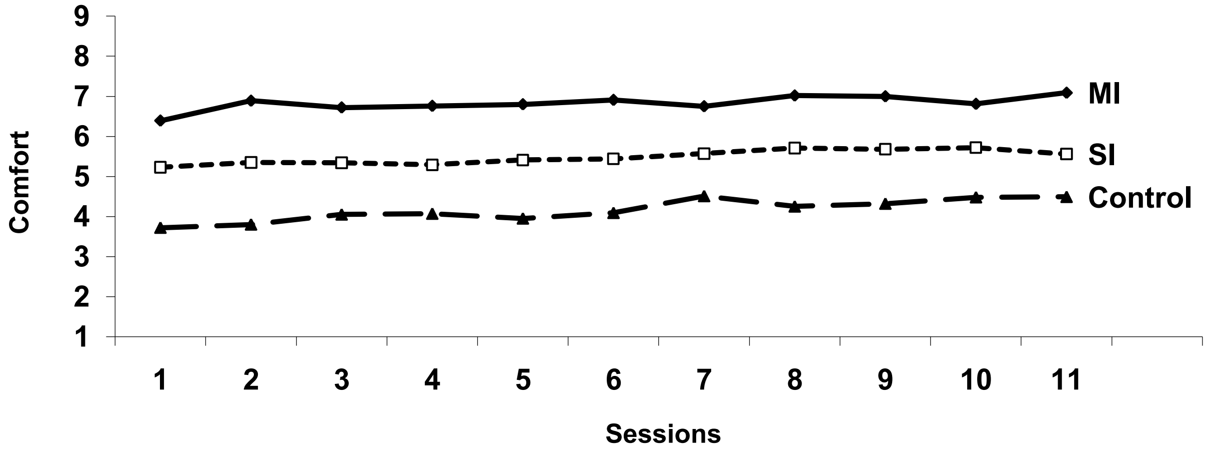

Figure 2. Mean comfort ratings per session, rated on a 9-point scale ranging from 1 “not at all comfortable” to 9 “extremely comfortable”.

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