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Internal imagery training in active high jumpers

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The main purpose of this study was to examine whether the use of internal imagery would affect high jumping performance for active high jumping athletes. Over a period of six weeks, a group of active high jumpers were trained with an internal imagery program for a total of 72 minutes. This group was compared to a control group consisting of active high jumpers that only maintained their regular work-outs during the same time period. Four variables were measured; jumping height, number of failed attempts, take-off angle, and bar clearance. There was a significant improvement on bar clearance for the group that trained imagery ($p < 0.05$) but not for the control group. No other differences were found. The results suggest that internal imagery training may be used to improve a component of a complex motor skill. Possible explanations and future recommendations are discussed.

Key words: Mental practice, internal imagery, training.

INTRODUCTION

Mental training is a broad term used in many situations. It was defined by Richardson (1967) as the mental rehearsal of a task without any muscular movement and is often referred to as imagery. The question of whether a motor skill would benefit from imagery training has been examined in several studies (for overviews see e.g. Driskell, Copper & Moran, 1994; Felz & Landers, 1983). Although the results have varied across studies, the majority show that imagery training results in positive effects on subsequent performance.

In one study, Mendoza and Wichman (1978) examined the effects of imagery training on dart-throwing performance. Participants were scored on their dart-throwing ability and then assigned either to a control group that did nothing, to a group that trained imagery, to a group that trained both imagery and physically or to a group that only trained physically. The training interventions lasted for six weeks with daily training twice for 15 minutes. After the training sessions the participants were again tested on the dart-throwing ability. The conclusions were that physical practice was more effective than no practice. Imagery practice was added on top of that. The results showed that the physical + imagery group improved significantly greater than the group that only trained physically.

Grouios (1992) investigated the effects of imagery on female springboard divers. They were first tested on a selected dive and then the participants were randomly assigned to physical practice, imagery practice or a control group. The imagery practice group imagined themselves performing the task 10 times each day for 21 days. The physical practice group physically performed the springboard dive for the same amount of time. The control group solved crossword puzzles for approximately the same time. The results showed that imagery training had positive effects on springboard performance. In addition to these examples there are several other studies showing positive effects of imagery training on sport performance (e.g., Mamassis & Doganis, 2004; Peynircioglu, Thompson & Tanielian, 2000; Smith & Holmes, 2004; Wisberg & Anshel, 1989).

Although most studies show positive effects of imagery training, there are some that do not demonstrate such effects. In a study by Mumford and Hall (1985), figure skaters’ ability to use imagery training to improve a figure was investigated. Three groups received imagery training and a control group did not receive any imagery training. All three treatment groups received four training sessions for one hour on separate days and were then tested on the figure again. The results

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showed no difference in performance between the four groups after the imagery training (for other studies with null effects from mental training see Corbin, 1967; Gordon, Weinberg & Jackson, 1994; Nordin & Cumming, 2005; Taylor & Shaw, 2002).

A possible explanation for the different outcomes in studies of mental imagery could be the type of sport examined. Poulton (1957) categorized different sports into either closed or open. In a closed sport, the environment never changes, it is predictable, and every move can be planned in advance. Examples of closed sports are golf and springboard diving. In sports such as basketball, except for certain closed elements such as free-throw shooting, the environment changes constantly and little is known about the next move. Therefore these sports are classified as open. Many individual sports are closed and most team sports are open.

Weinberg, Butt, Knight, Burke and Jackson (2003) investigated the relationship between the use and effectiveness of imagery in athletes from both individual and team sports. They concluded that for a closed sport, such as high jump, it is much easier to know what to imagine since there is the possibility to prepare and imagine exactly what will take place. This is in contrast to an open sport in which athletes must be concerned with several factors that may impede the performance. They also found that athletes in closed sports, mostly individual sports, tended to find imagery more effective than athletes in open sports. In a study comparing individual and team sports use of imagery, Hall, Rodgers, and Barr (1990) examined 381 female and male athletes using a 37-item questionnaire. The participants were competitive athletes from recreational/house league up to the international level. The results showed that athletes in closed sports tended to use internal imagery more often than athletes in open sports and also that higher level athletes tended to use imagery to a greater extent than lower level athletes. When examining the use of mental imagery among elite athletes it was found that between 70 and 90% of elite world-class athletes were using imagery training as a way to enhance performance (for review see Jones & Stuth, 1997).

A second possible explanation for different outcomes in studies of mental imagery could be based on the distinction between external and internal imagery. Mahoney and Avener (1977) classified the internal view of imagery as a first person's visual and kinesthetic view, experienced from within and where the agent feels as if she/he is performing the action. This should be distinguished from the external view, where the agent takes the view of a spectator watching the action as on a video. The common view seems to be that internal imagery is more effective as performance enhancement than is external imagery. For example, studies using self-reported questionnaires among Olympic, national, and university level athletes show that elite athletes tend to rely more on internal imagery than non-elite athletes (Mahoney, Gabriel & Perkins, 1987). Other studies support the view of internal imagery being more effective than external imagery (e.g., Fery & Morizot, 2000; Hale, 1982; Mahoney & Avener, 1977; Murphy, 1994; Rotella, Gansneder, Ojala & Billing, 1980). It is also known that internal imagery produces greater physiological responses (Hale, 1982; Perry & Morris, 1995) and this is argued to be more effective on performance outcomes (Holmes & Collins, 2001). In a study by Smith (1987) in which specific conditions that help imagery training in sport are outlined, the use of external imagery is simply seen as a motivational factor that should not be discounted for, although, as a performance enhancer the use of internal imagery is more beneficial. In three experiments, Hardy and Callow (1999) investigated external and internal imagery perspectives on motor performance. They used experienced athletes in karate learning a new kata, students learning a simple gymnastics floor routine, and high-ability rock climbers performing new boulder problems. They found that for the acquisition of a task, external imagery was superior to internal. However, internal imagery was more effective when the athlete already had reached a certain level of expertise. Thus, for active athletes, the internal view should be more effective as a performance enhancer than the external view.

Type of outcome measures is a third, and much overlooked, explanation for variability across studies of the effectiveness of imagery. In studies of imagery training the measures are generally in terms of hit or miss (e.g. when examining basketball shooting) or in total performance (e.g. in gymnastics routines). Having only one type of sub-optimal outcome measure may be a reason why some studies of mental imagery failed to show any effects. Support for this notion comes from studies of physical performance, as in a study of golf (Jagacinski, Greenberg & Liao, 1997). When looking at golf tempo, which is the overall duration of a golf swing, they found no significant difference between older and younger players. However, when looking at another outcome measure, the rhythm, which is the speeding up and slowing down within a shot, a significant difference was found. To have appropriate outcome measures may depend on having appropriate equipment to estimate the outcomes. In studies of children's motor performance, the effects of additional outcome measures and more advanced equipment is seen clearly. Using film cameras, von Hofsten and Lindhagen (1979) showed that children at about 4 months of age were able to make a successful reach for a moving object. When further decomposing children's reaching trajectories into movement elements, von Hofsten (1979) found that children between 4 months and 6 months not only could make a successful reach, but their reaching pattern was organized into acceleration and deceleration phases. Using an optoelectronic device, which is a technology based on monitoring the movements using infrared light attached to the children, von Hofsten (1991) showed that reaching trajectories become straighter over time and, thus, have a structure similar to adult reaching at approximately 6 months of age. One example where type of outcome measure made a difference when studying the effects of mental imagery was a study by Ranganathan, Siemionow, Liu, Salgad, and Yue (2004). In
this study the effects of mental imagery on a strength task were examined. When comparing muscle volume before and after imagery, as a measure of strength gain, they did not find any effects of imagery training. However, when comparing the total force exerted from the muscle, which also would be a measure of strength, before and after imagery training, there was a significant improvement.

The present study examined the effectiveness of internal imagery on high jumping performance after taking into account the above-mentioned factors. The recruited participants, active high jumpers, were chosen because of high jump being a closed sport, appropriate for imagery training. Internal imagery was used because of its apparent advantage over external imagery for athletes that are on a higher level. When constructing the internal imagery program several top-level high jumping coaches were contacted. They stressed two critical technical components that influence jumping height. These were take-off angle, which is the angle of the lean of the athlete away from the bar, and bar clearance, which is the bend over the bar where the athlete arches the back by pulling their feet towards their head in order to more efficiently clear the bar. The internal imagery program included imagining of take-off as well as bar clearance. The importance of appropriate outcome measures was considered by using video analysis to analyze and quantify changes in bar clearance and take-off angle. The main purpose of the study was to investigate the effects of internal imagery training on actual jumping performance and on the motor parameters take-off angle and bar clearance. Of the latter two, the bar clearance component is arguably the more complex process from a cognitive/internal imagery point of view, involving a complex series of movements. Thus, as internal imagery tends to more easily benefit activities of high cognitive complexity (Martin, Moritz & Hall, 1999; White & Hardy, 1995), we hypothesized that the bar clearance will benefit the most from the internal imagery training. A related purpose was to evaluate the relation between take-off angle, bar clearance and jumping height. To the extent that jumping height is related to take-off angle and bar clearance, a positive relation was hypothesized.

METHOD

Participants

Twenty-four participants were recruited for this study. They ranged in age from 16 to 29 years (mean age 19.3 years; SD 3.4 years). There were 13 males and 11 females. Inclusion criteria for this study were that the participants had to be competitive track and field athletes competing at the national elite level. The participants were recruited from a national track and field high school in Umeå, Sweden. Also, active track and field athletes living in Umeå were recruited. All the participants included had been training for a substantial amount of time, thus there were no novel high jumpers included in this study. Four participants dropped out from the study because of injuries and leaving the city. The data was initially screened for outliers and one participant had to be excluded. Therefore, the final sample included ten athletes in the motor group, with a mean age of 20.2 years (SD = 4.1) and nine athletes in the motor + imagery group, with a mean age of 18.1 years (SD = 2.6). The participation was voluntary and the participants could drop out at any time. The participants received a monetary reward of $125 after completing all stages of the study.

Procedure

The study consisted of three main components: (I) pretest, (II) intervention, and (III) post-test.

I. Pretest. The study started with pretest jumping (i.e. how high the participants jumped before the intervention). For an overview of the set-up for the pretest, see Fig. 1. They were asked to jump as high as possible as if they were in a competition. The participants had a maximum of three attempts on each height. The participants were free to choose a starting height. They started to jump and after each cleared height the bar was raised. To make sure that the participants were going to get a chance to jump as high as possible they freely decided the next jumping height. When the participant made three failed attempts on a height the pretest was completed. The heights for all jumps including the number of failed attempts were written down.

II. Intervention. The second part of the study was the intervention or training phase. When all the participants were done with the pretest, they were randomly assigned to one of two groups; either the motor group or the motor + imagery group. The length of the intervention phase was based on earlier studies on physical training in which six weeks of practice led to positive effects on motor performance (Karni, Meyer, Jeazzard, Adams, Turner & Ungerleider, 1995). Each participant met individually with the experimenter for 12 sessions over a six-week period. Participants in the motor group were asked to do a finger tapping task (not reported in this paper) and a cognitive task (not reported in this paper). None of the tasks had anything to do with high jumping and the session took approximately 15 minutes. When participants in the motor + imagery group met with the experimenter they did the same two tasks as the motor group (tapping and cognitive). These tasks were added to the experiment in order for both groups to spend approximately the same amount of time with the experimenter minimizing the possibility of experimenter effects. In addition, at the beginning of each session they were asked to imagine high jump according to an internal imagery instruction. This instruction was based on information about high jump given by three high jumping coaches who trained athletes on the top international level. Information was also taken from international web-pages describing what is important when performing and training high jump: www.brianmac.demon.co.uk/highjump (16 August 2006); www.todd.acheson.com (16 August 2006). Before each imagery session it was made sure that the athletes understood the concept of internal imagery and that it was important that they tried to feel like they were executing the high jump when imagining it.

The high jumping instruction for the internal imagery stated:

Imagine that you are running towards the bar in a calm pace. At the curve you are slightly leaning inwards from the bar. In the last two steps the legs run past the body and you lean slightly backwards. In the take-off you plant the whole foot, you feel that the knee is straight, and you lean away from the bar. The lead leg bends and is parallel with the bar, the arms help you up. The take-off foot leaves the ground; you rotate so that your back is against the bar. You pull your heels towards your head so your back bends. You push your hip up and lean your head back and pull your legs over the bar. You land on the pit and you made the jump.
At each session, the participants in the motor + imagery group imagined for 6 mins. They imagined repeatedly four times for 1.5 minutes with 30 s of rest in between. They were given the same instruction each session and when there was 5 s left of rest in between the imagery sessions they were told to get ready for imagery. The participants were told to do their best at all times. The total time the participants spent imagining high jump in the study was 12 sessions \( \times \) 6 mins. Some of the participants imagined with their eyes closed and some imagined with their eyes open. When asking the participants how many jumps they did when imagining they reported that it took approximately 10 s to complete one jump; hence the total number of jumps was about 8 for each 1.5 minute period.

### III. Post-test

The third and last part of the study was the post-test. The set-up was the same as during pretest (Fig. 1). The participants started to jump on the same height as they did during the pretest. In addition, when raising the bar it was also made sure that it was raised to the same height as in the pretest. If the participants cleared the height they stopped at during the pretest they kept on jumping on higher heights until they made three false jumps. As in the pretest, each jump was written down as a cleared jump or as a false jump.

### Instruments

Two cameras were used to film the high jumps. One camera was set up in line with the position for bar clearance and the other where the participants made their take-off (see Fig. 1). A Panasonic NV-DS65 digital camera and a Sony DCR-TRV33E PAL digital camera were used for the recordings. The films were analyzed using Adobe Premiere Pro 1.5 and Adobe Illustrator CS2.

### Outcome measures

All the heights that the athletes were jumping on, both cleared and false jumps were marked. The video recordings were first taken over from the video cameras into a data program for video editing, Adobe Premiere Pro. To estimate the take-off angle, the video was stopped at the first frame when the take-off foot was completely planted on the ground. That particular frame was exported into Adobe Illustrator CS2 where a line was drawn from the foot of the participant through the middle of the head (see Fig. 2). The program provided us the coordinates for this line and the angle for the take-off was calculated using basic trigonometry. From the recordings of bar clearance, the frame when the participant’s hip was over the bar was exported to Adobe Illustrator CS2. In this context, the bar clearance is defined as the distance between shoulder and foot. A line was drawn from the foot to the left shoulder (see Fig. 2). The coordinates were given by the program and the distance of the line was calculated using trigonometry. In some jumps the bar clearance measure was not possible to estimate. This was the case when the participants did not follow through with the jump because they interrupted the attempt shortly after take-off, pushing the bar down with their hands. Another exclusion possibility was when the participants jumped much higher than the bar, such that bending of the back was unnecessary for the participants in order to clear the jump. These jumps were excluded from the statistical analysis. Fifteen jumps from the take-off and the bar clearance were randomly selected for an inter-rater reliability test. The inter-class correlation coefficient was 0.962, \( p < 0.01 \).

Improvements in the technique after the training sessions could be shown in the take-off angle and the bar clearance. The imagery program emphasized leaning away from the bar at take-off, and pulling the feet towards the head during bar clearance. Therefore a performance increase should result in a greater take-off angle and a smaller distance between head and foot in bar clearance. A smaller distance would improve the athletes’ jumping height because they would be able to clear the bar more easily. In addition to these two parameters, improvement was qualified as maximum height and number of false jumps.

### Statistical analysis

After excluding the jumps where bar clearance was not measurable at pretest, 19 participants performed a total of 46 jumps showing bar clearance and 68 jumps showing take-off angle from each
height and corresponding take-off angle and bar clearance from the pretest were correlated to validate the take-off angle and the bar clearance measures as variables that are related to high jump performance. If this shows a positive correlation it would strengthen the coaches’ view of these variables being important for jumping height, and, thus, validating these measures. Independent samples t-tests were done on the pretest and post-test performance for the outcome measures height, take-off angle, bar clearance and false jumps to see if the groups differed before and after the training sessions. Within-group changes in performance were assessed using paired samples t-tests. Also, a group by session (pre/post) mixed ANOVA was done to see whether there was an interaction which could be an indication of a selective improvement after imagery training. Non-parametric tests for independent samples, Sign test, were also computed to evaluate any differences between the two groups after the training sessions in terms of the number of participants that showed any improvement. The statistical calculations were done using SPSS 13.0 and the alpha level was set to \( p < 0.05 \).

**RESULTS**

At pretest the correlation between take-off angle and height, across groups, was significant (\( r(67) = 0.478, p < 0.01 \)). There was also a significant positive correlation between bar clearance and height (\( r(45) = 0.574, p < 0.01 \)).

There were no significant differences between the two groups before the intervention, \( p > 0.05 \). Thus, any differences between the groups after the intervention should be attributable to the imagery training.

Table 1 shows the pretest values, the post-test values as well as the change in performance used in this study for the motor group and for the motor + imagery group. Both groups tended to show positive improvements on all the outcome measures.

Similar to the pretest results, there were no differences between the two groups after the intervention phase. However, a comparison of the pretest results with the post-test results revealed a positive trend for both groups for bar clearance. A group by session (pre/post) mixed ANOVA revealed a tendency for an interaction on the bar clearance measure (\( F(2, 17) = 3.22; p = 0.091 \)). As expected the strongest effect was for bar clearance, where an improvement was seen for all participants in the intervention group. We further analyzed...
this interaction by $t$-tests of the pre-post difference for each group. We found that the difference was significant for the mental + imagery group. For the motor group, the corresponding change was not significant. No other outcome measures showed a significant change, either for the motor + imagery or the motor group. Also, there were no between-group differences in the number of participants that improved after the intervention.

**DISCUSSION**

The main purpose of this study was to examine whether internal imagery would enhance high jumping performance after six weeks of intervention. The control group, that maintained their regular physical training program, showed positive trends on all measured variables, although no increase was statistically significant. A similar pattern was seen for the intervention group, but for this group the improvement was significant for one of the measured outcome variables; bar clearance. For this variable, the intervention group showed a 50% greater gain than in the control group, suggesting that the internal imagery training program helped to improve this component of the high jump. The internal imagery program emphasized bar clearance by encouraging the athletes to visualize bending the back and pulling the feet towards the head. The significant result in the bar clearance variable for the intervention group suggests that internal imagery combined with regular physical practice improved bar clearance greater than only maintaining physical practice. Thus, internal imagery may help to improve a critical component of high jumping.

The present study shows a relation between take-off angle, bar clearance and height, thus confirming that bar clearance and take-off angle are significant parameters for active high jumpers to improve in order to jump higher. As a result, these parameters are valid measures when investigating the effects of imagery training. We observed no greater gain in the height outcome measure after the intervention. On average, both groups increased their height by less than 2 cm. Given the limited length of the training program (6 weeks) it is probably unrealistic to expect greater gains. One would expect that enhanced technique improves performance and since these results confirm the relationship among the measured variables, over time, it is predicted that improved bar clearance will lead to higher jumping height. Longer-term studies are needed to address this issue.

It was possible to detect the changes in performance due to the video analysis. The reason why some of the previously done studies failed to show effects from mental imagery may be due to not considering small improvements in technique. If we had relied only on results categorized as hit or miss it would be more difficult to determine whether an individual has improved or not (cf. Schmidt & Lee, 1999). Thus, in order to better understand the effects of mental imagery, future research should emphasize both measuring motor performance and using more appropriate outcome measures to detect small but potentially important changes.

It was hypothesized that the bar clearance would benefit most from the internal imagery program. The bar clearance is the most complex component of the high jump. During the bar clearance the athlete needs to rotate the body in the air in order for the back to turn towards the bar. Also, the athlete needs to push the hip up in order to arch the back and, thus, clear the bar. Therefore it is argued that this component is more complex, and has a lot of degrees of freedom when executing it. As a result, it is in need of more cognitive work than, for example, the take-off, which is more dependent on physical power and thus have less degrees of freedom when performing it. This complexity may be a reason for the benefit of internal imagery on the bar clearance. This is supported from findings that internal imagery is beneficial for skills that require complex movements (White & Hardy, 1995).

An important aspect of human research is individual differences. Developmental theories explain individual differences to be associated with individual development, where genetic activity, neural activity, and behavior together with environmental factors such as physical, social and cultural, all together determine the individual development and cause individual differences (Gottlieb, Wahlsten & Lickliter, 1998). This is also likely to be a factor to take into account when explaining performance effects from imagery training. Everybody has the ability to use imagery; however there are individual differences in how well one can create these images (cf. Martin et al., 1999). It has been shown that imagery is associated with sport performance, and also that high confident athletes, who in addition were associated with being top-level athletes, tend to have a higher ability to perform imagery (Moritz, Hall, Martin & Vadocz, 1996). Even though all the participants were advanced athletes in this study they were on different achievement levels. It is therefore likely that there were differences of the imagery ability. Nonetheless all participants in the intervention group increased their performance on the bar clearance measure. It is suggested that if an athlete has a good imagery ability, the imagery is more likely to have greater performance effects compared to if the athlete has low imagery ability (Hall, 1998; Martin et al., 1999). Further, it seems to be a relationship between the use of imagery and imagery ability, thus there is a possibility to improve your imagery skill (Rogers, Hall & Buckolz, 1991; Vadocz, Hall & Moritz, 1997). Improving your imagery ability will then improve the results of the imagery training. Therefore, taking into account the individual differences, in the present study it is likely that those athletes that had high imagery ability might have been able to use the imagery for the intended performance improvement at the start of the training program. Those athletes that had a low imagery ability first had to increase their imagery ability and then were able to use the imagery to improve the performance.

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There are some limitations with this study. First, there were a limited number of high jumpers available for this study which resulted in small groups. Second, even though the participants were advanced athletes, for internal imagery to be effective, the participants must have a strong motor representation of what they imagine. There is a possibility that the participants in this study were not skilled enough for the internal imagery to be very effective, which may have affected the outcome. However, with these caveats in mind, the conclusion from this study is that mental training can improve a complex motor component in high jumping.

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