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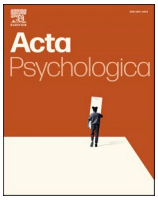

Imagining flying increases jumping performance in volleyball players: A pilot study

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ABSTRACT

Objective: The study aimed to examine the effect of mental imagery on sports performance. Specifically, it was tested whether imagining flying (i.e., air travel) increases jumping performance in a group of female volleyball players.

Methods: The study included 46 female young athletes (mean age = 15.23 years; standard deviation = 2.4) divided into two groups: the experimental group viewed a three-dimensional video that simulated a flying experience, while the control group watched neutral footage. The jump performance of both groups was measured before and after viewing the videos, using the Vertec Like® instrument to assess jump height. Participants were assessed for their flow disposition, mental imagery skills, and image vividness.

Results: Comparing pre-post jump performance scores, the experimental group showed a significant improvement over the control group, with a medium-large effect size (d = 0.634). There was no significant association between flow disposition, mental imagery skills, image vividness, and pre-post jumping performance differences (respectively: $\beta = -0.107$, $p = .484$; $\beta = -0.008$, $p = .957$; $\beta = 0.024$, $p = .913$).

Conclusions: These findings suggest that the experience of imagining flying, enhanced with an immersive video, has a positive effect on jumping performance in a one-session study with young female volleyball players. This effect does not appear to be associated with pre-existing characteristics or the vividness of the image itself.

1. Introduction

In recent years, the study of how mental images and visualization strategies can impact physical performance has received a growing interest in the field of sports psychology (Lindsay et al., 2021). It is now recognized that, in general, imagery is used by most people. Additionally, many athletes and coaches have realized the important role that imagery plays and have incorporated its use into their training regimens (Weinberg et al., 2010). Mental imagery is the internal representation that creates the experience of perception without any actual sensory input (Pearson, 2019). It is an effective tool for enhancing skills (Wraga and Kosslyn, 2002), widely used as a psychological strategy in sports to boost capabilities such as the level of performance, motivation, and emotional competence (Weinberg, 2008). Imagery in sports is defined as the creation and recreation of experiences using memory, involving quasi-sensory, quasi-perceptual, and quasi-affective characteristics, under the control of the imager and can occur without real stimuli (Watt et al., 2008). Imagery allows the brain to effectively rehearse, process, amplify, and retain important athletic skills and sequences such as physical endurance, self-control, balance, and coordination (Englert, 2017; Graham & Bray, 2012). The impact of this strategy is evident from the success stories of athletes from various sports (Cumming & Williams, 2012). A few studies have shown that imagery can effectively improve performance, decrease anxiety, and increase concentration and self-confidence (Mousavi & Meshkini, 2011; Rehbein & Doussoulin, 2011). Combining mental imagery with physical practice was found to be more effective than physical practice alone, highlighting the unique benefits of combining both forms of preparation. Imagery is popular among athletes and sports coaches for enhancing different aspects of performance and the acceptance of such a technique is well-known (Cumming & Williams, 2012).

Examining the relationship between the use and effectiveness of mental imagery among athletes in both individual and team sports, findings suggest that in closed sports, such as the high jump, athletes find it easier to employ mental imagery effectively due to the ability to precisely envision forthcoming actions (Yu et al., 2015). This stands in

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contrast to open sports, where athletes must contend with numerous variables that could potentially hinder performance. Notably, athletes engaged in closed sports, predominantly individual sports, tended to perceive imagery as more impactful compared to those in open sports. In a related context, Taneja et al. (2019) demonstrated that the combination of mental imagery training with plyometrics resulted in superior outcomes in terms of vertical jump and agility when compared to interventions solely focused on either plyometrics or mental imagery training. Transitioning to volleyball, the sport presents distinct movement patterns associated with jumping, including block jumps and attack or spike jumps. Vertical jumping holds significance within various aspects of the game, such as spiking, blocking, and serving. At elite levels of volleyball, jumping also plays a crucial role in setting, facilitating quicker attacks, and complicating defensive strategies for opposing teams. Consequently, vertical jump assessment forms an integral component of volleyball training and evaluation protocols. However, despite the substantial body of research focusing mainly on adult athletes, there is still a paucity of studies investigating mental imagery among young athletes. Young athletes tend to employ mental imagery in diverse manners and for varying objectives depending on their age (Simonsmeier et al., 2021). While children and adolescents naturally gravitate towards imagery as a rehearsal tool for skill acquisition and practice strategies (Weiss, 1991), comprehending the primary factors influencing the development and application of imagery skills remains essential. Of particular note is the underexplored realm of mental imagery among adolescent and youth sports performers, a demographic characterized by significant physical, cognitive, and emotional transformations during their developmental journey. To assess the immediate impact of mental imagery on jumping performance, a study was devised among young volleyball players. The focal point of the imagery intervention was the simulation of the act of flying. To enhance the vividness and realism of the mental images, an immersive video experience was incorporated, providing participants with a virtual encounter of flying, thus enriching the imagery experience.

Hall et al. (1992) claimed that everyone can create images, but the quality and effectiveness of these images may vary. It is crucial to consider certain elements that can optimize the effectiveness of imagery, such as vividness (Hall et al., 1992; Smith, 1987), which is an important factor in the relationship between imagery and performance (Callow et al., 2006). In a recent meta-analysis by Simonsmeier et al. (2021), it was found that imagery interventions significantly improved motor performance, motivation, and emotional regulation in sports such as golf, gymnastics, basketball, cricket, and football. Athletes must focus on their internal emotional reactions to make the images as realistic as possible (Di Corrado et al., 2020). The effectiveness of mental imagery was also associated with higher levels of imagery training (Barrett & Simmons, 2015). Positive correlations have also been found between the use of imagery and sports performance among swimmers (Parnabas et al., 2015), as well as improvements in serve, forehand, and backhand strokes among young tennis players (Dana & Gozalzadeh, 2017). A study (Taylor et al., 2008) aimed at investigating the performance strategies of US Olympic athletes in training and competition found that mental imagery was a commonly used technique. The study analyzed the use of various performance strategies, including imagining or visualizing sports movements and tactics before actual participation. Significant relationships between mental imagery and goal setting were reported, as well as between relaxation and mental imagery (Cumming & Williams, 2012).

Mental imagery has the potential to optimize performance to its limits across multiple dimensions, including goal setting, enhancing flown, and overcoming obstacles. The implications of surpassing these limits in imagined scenarios, however, remain unclear. For instance, imagining flying does not result in an actual flight, but could it potentially affect the duration of time spent airborne during a jump? The impact of mental imagery on jumping performance was already observed in a study using a six-week intervention (Battaglia et al., 2014) consisting of video observation in virtual reality and mental training combined with physical practice with elite rhythmic gymnasts. The study found significant correlations between imagery ability and post-training flight in the experimental group. The results showed that using mental imagery improved jumping performance, allowing the athletes to conserve energy for other tasks (Battaglia et al., 2014). This study required a long training period, and it is not clear whether mental imagery can improve jumping performance in an "immediate" setting (Cumming & Williams, 2012). Furthermore, there is a limited understanding of the development of mental imagery during adolescence (Schwarz et al., 2021), particularly among athletes.

To evaluate the instantaneous impact of mental imagery on jumping performance was designed a study among young volleyball players. The target of the imagery was the act of flying. To further boost the vividness of the images, given the lack of previous training, an immersive video was used in which participants would virtually experience flying.

2. Methods

2.1. Study design

This pilot project was designed to test the hypothesis that imagining flying, aided by an immersive video, would immediately enhance the jumping performance of young volleyball players. The link to the commercially available video is provided in the Supplementary Material file. Participants were randomly assigned to either the experimental group, which imagined flying with the support of an immersive video, or a control condition. Block randomization, according to age, was used. Jumping performance was measured before and after the test. The participants' flow disposition and kinaesthetic imagery were also evaluated at baseline and those in the experimental group rated the vividness of their mental imagery after the exercise. It's noteworthy that the athletes completed all phases of the test in a single execution and overall, the entire jumping performance took 10–15 min to complete.

2.2. Participants

To qualify for inclusion in the research, participants had to be female volleyball players, actively enrolled at a volleyball club in Italy in one of the considered teams (from "Under 13", to "First division"), able to read and understand Italian, and willing to participate in the study. We recruited 46 female volleyball players (mean age = 15.23 years; standard deviation = 2.4), from various age teams: "under 13" (at least 11 years old; $N = 14$), "under 14" ($N = 13$), "under 16" ($N = 9$), and "first division" (older than 16; $N = 12$). Twenty-four participants were assigned to the experimental group (mean age = 15.51 years) and 22 participants to the control group (mean age = 15.52 years).

2.3. Procedure

At baseline, all athletes completed the self-reported measures through the Qualtrics© online suite (Qualtrics, Provo, UT) and performed a jump test in the gym where they regularly trained, during one of the regular weekly training sessions. Afterward, the participants were randomly assigned to either the experimental or the control group. One athlete at a time performed the jump test as the participant would take a run-up, often referred to as an "attack run-up" in volleyball which consists of three steps and was then shown the video according to their assigned group (either experimental or control) in a quiet room within the gym, free from auditory distractions. Each athlete was instructed to wear the visor and adjust it to their needs without being given any information about the video's content. These instructions were provided to all athletes in a similar manner. Before proceeding with the video stimuli, all participants underwent a preliminary jump test. The experimental group received a three-dimensional (3D) virtual reality video presentation through VaR's VR Player Pro app designed with Adobe

Premiere Pro to guide the listener through an immersive experience of flight. The video comprised various commercially available flying videos and included visual stimuli, which were guided by the experimenter's voice. The recorded text is included in the supplementary material. It was accompanied by relaxing piano music and it lasted four minutes. The control group was shown neutral and technical footage extracted from a multimedia content platform that featured the technical description of running and jumping in volleyball without any reference to flight. After viewing the videos, both groups performed a jumping test again to measure their vertical jump height.

In assessing the validity of participants' jump performance, several criteria were considered. Participants were instructed to execute a vertical jump, aiming to touch the colored markers with their dominant hand. By doing so, we could accurately measure the height reached in each jump, providing valuable insights into participants' jumping abilities. To replicate real-game conditions, participants were asked to perform an approach run similar to that of an attacking jump in volleyball. This approach ensured that jumps were executed with the appropriate technique and intensity, reflecting authentic athletic performance. Following each jump, participants were required to land safely and maintain stability without exhibiting any signs of imbalance or uncontrolled movement. This criterion prioritized participant safety while also facilitating consistent and reliable data collection throughout the testing process. A critical aspect of assessing validity was whether participants successfully contacted the colored markers during their jump. This criterion played a crucial role in determining the effectiveness and accuracy of each jump attempt, thereby contributing to the overall reliability of the test results. Lastly, participants were reminded of the importance of avoiding any physical contact with surrounding objects or individuals during their jumps. This precautionary measure aimed to minimize external interference with the test results and maintain the safety and integrity of the testing environment for all participants.

After completing the test, participants in the experimental group were asked to rate on a scale of 1 to 10 (where 1 corresponds to: “I never thought about flying during the sports performance” and 10 to “I imagined flying firmness throughout the performance”) how much they had imagined flying. None of the participants had previous experience with either the jump test or virtual reality immersion experiences.

2.3.1. Instruments

2.3.1.1. Vertec like® instruments (Sports imports, Inc., of Columbus, Ohio). This device, widely used in sports like basketball and volleyball, consists of adjustable vanes or slats that athletes aim to displace during a jump, providing a quantifiable measure of their explosive power and lower body strength. Specifically, it consisted of a metal rod with colored dowels at the end, each one centimeter in length. To measure the jump, the participant would take a run-up as described, and touch the dowels with their dominant hand. The height was determined by adding the measurement taken from the ground to the start of the dowels to the height touched by the athlete's hand. The participants' vertical jump height was measured using a hand-held Vertec Like® instrument.

2.3.1.2. Flow experience. The Flow State Scale (FSS) is a self-report questionnaire composed of nine dimensions and 36 items, based on the dimensions of flow (Beck, 1992). We utilized the Italian version of the FSS to measure the perception of the flow state in sports and physical activity. The Italian validation of the FSS (Diana et al., 2012) was performed on a sample of 136 competitive athletes across various sports. It is important to note that our study used the Italian version of the questionnaire. Certain dimensions, such as the balance between task difficulty and skill (D1), clear goals (D3), and immediate feedback (D4), can be considered predisposing factors for an optimal experience. The other dimensions represent the experiential product, contributing to peak performance through increased motivation and self-efficacy.

2.3.1.3. The vividness of moving images. The Vividness of Movement Imagery Questionnaire (VMIQ) (Isaac et al., 1986) was used in an Italian-adapted version validated by Antonietti and Crespi (1995) to assess the ability to imagine a variety of movements visually and kinaesthetically (e.g., running downhill and jumping off a high wall). The questionnaire consisted of 24 items divided into six groups of four items each: standing, walking, running, and jumping. Once the participants have imagined an item, they are asked to rate the images on clearness and vividness using a five-point Likert scale. The rating process was completed using the same anchors of the Vividness of Visual Imagery Questionnaire, with a higher score indicating greater vividness.

2.3.2. Statistical analysis

A repeated measures ANOVA was conducted, in which the baseline and the post-intervention scores represented the within-subject factor, and the group (intervention and control) was the between-subjects factor. Normality and sphericity were checked with Mauchly's test. Furthermore, regression analyses were also used to examine the relationship between flow disposition, mental imagery skills, and imagery vividness (for the experimental group only) with the jumping performance changes. The software used for statistical analyses is IBM SPSS Statistics 27.0. A significance level of 0.05 was considered. We used Cohen's (1988) effect size index (d) to evaluate the magnitude of the effect. We interpreted the effect size as follows: a d value of 0.20 indicates a small effect, 0.50 indicates a medium effect, and 0.80 indicates a large effect to understand the magnitude of the observed effect and its practical relevance.

3. Results

The repeated measures ANOVA showed a significant interaction between time and group ($F(1, 44) = 4.619$, $p = .037$, $\eta p^2 = 0.095$), favoring the intervention group. The mental imagery group improved their jump performance on average by 1.56 cm (SD = 2.874), while the control group had a decrease of −0.41 cm (SD = 3.018), providing a Cohen's d of 0.634 (95 % CI: 0.038–1.224), which can be considered a medium effect. Flow disposition, mental imagery skills, and image vividness did not predict the pre-post jump performance difference (respectively: $\beta = -0.107$, $p = .484$; $\beta = -0.008$, $p = .957$; $\beta = 0.024$, $p = .913$).

4. Discussion

This pilot study investigated whether imagining flying would impact jumping performance in young female volleyball players. Results suggest that this mental activity, further enhanced by an immersive video, improved performance compared to a control condition. To further elaborate on the mechanisms underlying the outcomes of the study, it's essential to consider the intricate interplay between cognitive processes and physiological responses implicated in mental imagery. This effect can be interpreted with the Bayesian brain hypothesis, which posits that mental imagery modifies pre-existing beliefs (priors) and the body acts to confirm these priors through a mechanism known as active inference (Friston, 2010). Additionally, insights from research on the placebo effect offer further understanding of the potential mechanisms at play. Similar to mental imagery, the placebo effect involves the cognitive modulation of physiological responses. By harnessing the power of belief and expectation, individuals may induce physiological changes that positively impact their performance outcomes (Pagnini et al., 2023). Through a cognitive embodiment of these beliefs (e.g., *I believe I can fly*), the body may tend to overcome its current limits, resulting in improved performance. Our findings did not show any association with flow disposition, mental imagery skills, or image vividness. Moreover, the

utilization of an immersive video in our study represents a crucial factor in shaping the observed outcomes, as it provided a standardized and vivid experience for all participants. This likely minimized individual variations in imagery quality or predisposition, thereby enhancing the overall effectiveness of the intervention. The detected effect was consistent across participants, suggesting that the immersive video may have played a significant role in reducing the importance of individual predisposition or imagery quality by providing a similar experience to all participants. However, it's important to acknowledge the complexity of mental imagery, which operates within a multifaceted framework influenced by various factors such as individual differences in imagery ability, cognitive processes, and prior experiences (Cumming & Williams, 2012). Further exploration into these mechanisms is warranted to gain a comprehensive understanding of how mental imagery impacts physical performance. By unraveling the intricate interplay between cognitive processes and physiological responses, future research can refine mental imagery interventions in sports psychology and optimize athletic performance. Further studies are required to investigate the relationships between individual skills and the effects of these technologies on sports psychology.

The goal of sports psychology researchers for the past three decades has been to identify an optimal psychological state for sports performance and, more importantly, to train the mind to achieve that state (Park & Jeon, 2023). Mental imagery is widely used to improve physical performance, but the inclusion of "out of the limit" images has not been deeply explored. This training may have a place in enhancing performance using a complex mind/body framework. The role of psychological abilities in athletic performance cannot be overstated (Mujika et al., 2018). To our knowledge, this is the first study exploring the hypothesis of a short-term impact of a similar mental imagery activity on physical performance. As such, the present study contributed to increasing research in the specific area of open and closed-ability sports and imaginative ability, to develop a deeper understanding of imaginative ability in sports performance (Di Corrado et al., 2020).

4.1. Limitations

These results should be interpreted with caution as the study had several limitations that must be considered, including its small sample size, which limits generalizability. Among these constraints is the absence of detailed growth-related data. This lack of information may have implications, particularly in understanding potential age-related variations. Furthermore, other intervening variables, such as psychological characteristics like optimism, anxiety, or suggestibility, may moderate the effects. Another limitation of this study is that the speed of the approach before the jump was not controlled. Future research should consider standardizing the approach speed to better understand its impact on the results and to enhance the accuracy of the findings. These preliminary results call for further studies to extend and explore their potential beyond young female volleyball players.

4.1.1. Clinical implications

Based on these preliminary findings, utilizing imagination, potentially with the assistance of technology, can significantly aid in the mental preparation of athletes and help them push beyond perceived limits. Mental preparation is increasingly recognized as a fundamental and essential factor that influences physical performance. Therefore, sports psychologists, coaches, and sports counselors should consider recommending "over-the-limit" imagery strategies to enhance athlete performance. It is important to note that mental imagery techniques may need to be tailored to the specific needs and goals of individual athletes, and further research could help identify the most effective strategies for different sports and populations. These results have important implications for the development of mental skills in athletes, which can help them achieve greater success and reach their full potential. By encouraging athletes to utilize "over-the-limit" imagery strategies, we can help them prepare more effectively and perform at their best.

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Ethics approval and consent to participate

This study was conducted by the guidelines of the Declaration of Helsinki and involved obtaining written informed consent from all participants. For athletes under the age of 18, parental informed consent was also obtained. Although there was no Ethics Commission in place at the author's institution at the time the data was collected, ethical clearance was not deemed necessary as the study posed a minimal risk to participants, following the Ethics Committee of the Italian Association of Psychology guidelines.

Consent for publication

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CRediT authorship contribution statement

Francesca Grosso: Formal analysis, Data curation, Writing – original draft. **Camilla Balzarini:** Methodology, Investigation, Data curation. **Francesco Pagnini:** Supervision, Conceptualization, Writing – review & editing. **Alessandro Antonietti:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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