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Examining the frequency variable in the imagery dose-response relationship

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ABSTRACT

Imagery training is a well-known technique in sport psychology that it is often applied to improving skill performance in a range of sports. In this study, the central aim was to experimentally examine the effect of different imagery frequencies (3, 4, 5 imagery sessions per week) on basketball shooting performance. We applied a new imagery dose-response protocol, in which we varied frequency, but systematically held the other two key imagery dose variables (repetitions and duration of sessions) constant. Participants were 40 male basketball players (Mage = 20.92, *SD* = 3.01) who were allocated into four conditions: 3 imagery sessions per week, 4 imagery sessions per week, 5 imagery sessions per week, and a control condition. All 3 imagery conditions had 4 weeks of imagery training. For all four conditions, we measured free throw shooting (FTS) at pre-test, Week 1, 2, 3, post-test, and retention test (Week 5). Control condition participants performed their usual basketball practice with no imagery training. Results showed that the 4 imagery sessions per week condition had the highest FTS means at post-test and retention test, with FTS means that were significantly higher than the control condition at post-test and retention test. The findings and information form this study could contribute to the design of effective imagery training by supporting athletes and coaches to tailor imagery programs. Moreover, the imagery dose-response protocol utilised in this study has potential application to further examine imagery dose-response relationships.

Introduction

Imagery is a cognitive process that can be applied in a variety of ways to enhance sport performance (Cherappurath et al., 2020; Ely et al., 2020; Farmer & Matlin, 2019; Lindsay et al., 2021; Morris et al., 2005). Imagery in sport refers to the “creation or recreation of an experience generated from memorial information, involving quasi-sensorial, quasi-perceptual, and quasi-affective characteristics, that is under the volitional control of the imager, and which may occur in the absence of the real stimulus antecedents normally associated with the actual experience” (Morris, et al. 2005, p. 19). Imagery training programs can be applied to a range of outcomes to enhance performance in sport (Munroe-Chandler et al., 2007; Nordin & Cumming, 2005), such as psychological states (Anton et al., 2016; Haight et al., 2020; Marshall & Gibson, 2017; Sardon et al., 2015; Strachan & Munroe-Chandler, 2006), and in rehabilitation (Harris & Hebert, 2015; Sordoni et al., 2000). Commonly, though, imagery training is used to enhance motor skill performance or acquisition (Coelho et al., 2007; Dana & Gozalzadeh, 2017; Hashmi et al., 2020; Holmes & Collins, 2001; Shambrook & Bull, 1996; Williams et al., 2013). Classic (Driskell et al., 1994; Feltz & Landers, 1983; Hinshaw, 1991), as well as recent (Ely et al., 2020; Lindsay et al., 2021; Paravlic et al., 2018; Schuster et al., 2011; Simonsmeier et al., 2020; Toth et al., 2020), reviews have highlighted the beneficial effects of imagery on motor skill learning and performance. Despite the evidence for the benefits of imagery training on motor skill learning and performance and existence of practical imagery models that provide principles for applying imagery in sport effectively (Holmes & Collins, 2001; Munroe et al., 2000) , there is limited evidence on the effective dose of imagery in training design to enhance learning and performance. Researchers have rarely directly comparing compared imagery dosages to determine effective levels. In particular, there have been few systematic efforts to determine the dose that produces the most desirable response, what has been called the dose-response relationship between imagery and sport performance (Morris et al., 2012). Dose-response relationships have been challenging to explore as the variable of interest needs to be isolated in a systematic way and the dose-response relationship needs to be the specific focus of investigation.

Thus, in a range of contexts, dose-response relationships examine the associations between the dosages of training or treatment and the effectiveness of participant outcomes. From previous studies, researchers

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have defined the dose as the amount of treatment, and the response has been defined as the normalized probability of accomplishing measurable participant improvements (Robinson et al., 2019; Stulz et al., 2013). In terms of the research design in dose-response studies, researchers have typically examined response levels to different dosages (Holland-Letz & Kopp-Schneider, 2015), with dose-response studies in a broad range of disciplines, such as medicine, psychology, pharmacology, and exercise science (e.g., Allami et al., 2008; Evangelista et al., 2017; Howard et al., 1986; Robinson et al., 2019; Sanders et al., 2019; Stulz et al., 2013; Wylie et al., 2013). The systematic determination of dose-response relationships in sport imagery, however, is somewhat limited. Morris et al. (2012) stated that a systematic dose-response protocol should be applied in sport imagery training research, as has been conducted extensively, for example, on the most effective training loads for enhanced fitness in exercise physiology. To achieve this, imagery researchers should systematically examine the key dose variables that are related to imagery training effects. Morris et al. proposed three key imagery dose variables for discrete sport and exercise tasks, namely the number of repetitions in an imagery session, the duration of imagery sessions, and the frequency of sessions per week. In addition, they suggested that for research to be considered to be dose-response studies, one dose variable should be varied systematically in each study, based on the most promising range of effects on sport performance identified in previous studies, while researchers should hold the other dose variables constant.

For exercise and physical health contexts, researchers have applied the protocol of dose-response to examine whether different variables have effects on physical activity on and, thereby, identify the effective amount of physical exercise are necessary for achieving a goal outcome (Bond Brill et al., 2002; Evangelista et al., 2017; Galloway et al., 2019; Jennings et al., 1991; Sanders et al., 2019). For example, Jennings et al. (1991) determined the dose-response relationship between exercise training and blood pressure. Researchers varied the dose variable of frequency, in which they compared three-days of sessions and seven-days of sessions per week with an exercise intervention of one-month in length, but they held intensity (60%–70% of maximum work capacity) and duration (30 minutes) of the bicycling exercise constant. Hence, their research aim was to compare the impact of different frequencies of sessions per week on participants' blood pressure. The results showed that training three times for 30 minutes per week reduced supine blood pressure that was close to the response obtained with seven sessions per week, providing information on how practitioners can effectively manipulate exercise frequency in terms of blood pressure. Bond Brill et al. (2002) examined the dose-response relationship between walking exercise and the outcome variable of weight loss. They varied the dose variable of walking exercise duration at 30 minutes or 60 minutes, but they held exercise frequency constant at five sessions per week for 12 weeks. Both durations in walking exercise (30 minutes or 60 minutes) had positive effects on weight loss; supporting the development of recommendations on how to provide effective exercise duration for weight loss. Dose-response studies in exercise science disciplines, therefore, have facilitated understanding of the amount of exercise for designing exercise programs for achieving specific exercise outcomes. Such approaches to understanding exercise interventions may potentially also be applied to understanding effective does of imagery in imagery interventions.

There is a limited number of studies that directly examined the frequency of imagery sessions in imagery interventions. Specifically, the important point about imagery dose-response studies is that researchers must compare different levels under the same conditions. Wakefield and Smith (2009b) determined empirically whether different frequencies of imagery based on the PETTLEP model of imagery have varying effects on netball shooting. The 32 female participants were allocated into one of three PETTLEP imagery conditions, involving one, two, or three imagery sessions per week over four weeks, or a control condition, in which participants did not experience an imagery intervention. They concluded that three imagery sessions per week was the most effective frequency, leading to a significantly greater increase in shooting performance than one or two sessions per week. Wakefield and Smith (2011) also investigated the frequency of imagery sessions for biceps curl performance. They found that three imagery sessions per week was significantly more effective than one or two sessions per week, in terms of increase in number of biceps curls performed. Thus, these two dose-response studies suggest that three imagery sessions per week may be more effective than one or two imagery sessions per week for one strength task, namely biceps curls, and one sport skill, namely netball shooting. Although it shows promise, there are a number of problems with this research. First, because the largest value of the imagery dose variable, that is, a frequency of three sessions per week was the most effective, this leaves open the question of whether this pattern reflects a cumulative effect, so that four sessions per week might be yet more effective, and five sessions could be more effective still. The meta-analytic review of imagery in sports by Simonsmeier et al. (2020), while not directly exploring session frequency, concluded that imagery effectiveness was higher the more total sessions an implementation included, this may also indicate a cumulative effective of imagery training. In addition, Wakefield and Smith did not systematically control other imagery variables, such as the number of repetitions per session, and the duration of each session. The studies by Wakefield and Smith showed potential, particularly in demonstrating the same most effective frequency across two quite dissimilar discrete tasks, but it is necessary to conduct many more studies that compare frequencies, while at the same time reporting systematic control of other dose variables, to produce patterns that are robust and replicable.

The central aim of the present study was to determine whether frequency of imagery sessions per week affects performance of a discrete task. The imagery dose-response protocol (Morris et al., 2012) was applied in this study, in which we systematically manipulated the imagery dose variable of frequency, while we held constant other key dose variables of repetition and duration. In the present study, we compared 3, 4, and 5 imagery sessions per week, while keeping number of repetitions and session duration constant at 20 repetitions and 13 minutes, based on the results of the previous dose-response study of repetitions (Itoh et al., submitted, a) and of session duration (Itoh et al., submitted, b), respectively. In all studies, the task, FTS, was the same, participants skill level, that is, moderate FTS performance, was very similar, and we controlled for gender variations by restricting the study to males. Previous researchers have found that a frequency of three imagery sessions per week was likely to be more effective than frequencies of one and two imagery session (Wakefield & Smith, 2009b, 2011). By further extrapolating their results, which suggested a cumulative pattern, we predicted that the more imagery dose sessions per week participants experienced, the significantly greater would be the imagery dose effect.

Method

Participants

Male basketball players (*N* = 40; mean age 20.92 years, *SD* = 3.01) volunteered to participate in this study. The players all played basketball at local basketball clubs, the university basketball club, or recreational community basketball at least one-day per week. We controlled for any potential gender variations in imagery ability or use by restricting the study to males (Burhans et al., 1988; Watt et al., 2018; Williams & Cumming, 2011). The sample size was based on power analysis and previous research. With a significance level of .05, power of 70%, and a large effect size, the G Power analysis software indicated 60 to 80 participants would be appropriate. However, previous research on the effects of imagery dose variables on performance of discrete tasks typically has shown significantly larger effect sizes (d = .84, .71, and 1.82) with substantially smaller samples (Wakefield & Smith, 2009b). Given the duration of intervention studies, we decided to test for significance at a sample size equivalent to previous studies and conclude data collection when results indicated significant differences with appropriate effect sizes.

We screened all participants for skill level and imagery ability. To be eligible, players had to score between 49 (41% FTS accuracy) and 72 (60% FTS accuracy) out of 120 at pre-test on FTS, which was to ensure they had moderate FTS skill, and to prevent ceiling effects (Hall et al., 2001). We checked whether participants had appropriate imagery ability using the Sport Imagery Ability Measure (SIAM; (Watt et al., 2018). Participants were required to have a minimum score of 150 out of 400 on the key imagery dimension subscales (vividness, control) and imagery sense modality subscales (visual, kinaesthetic, tactile, and auditory) of the SIAM. These modalities have been related to basketball FTS performance in previous studies (De Groot et al., 2012; Fazel, 2015; Neumann & Hohnke, 2018).

Study design

In this study, the aim was to determine whether different frequencies of imagery per week (the dose) have different effects on FTS performance (the response) by using a pre-test, imagery intervention, post-test research design. We allocated participants into one of three imagery frequency conditions, 3-, 4-, and 5-sessions of imagery per week, or a control condition with no imagery. The imagery training program in all three conditions was designed to have a constant number of 20 repetitions, and 13-minute imagery-session duration over four weeks based on previous repetitions per session and imagery session duration studies (Itoh, 2020). FTS performance was measured for all four conditions at pre-test, at the end of each week of imagery, and one-week after conclusion of the imagery training program (retention), providing six measures (pre-test, Week 1, 2, 3, 4, and retention test in Week 5).

Measures

Demographic Form. Participants provided general demographic information, including age, gender, basketball performance level, and years of competition performance.

Sport Imagery Ability Measure (SIAM: Watt et al., 2018; Watt et al., 2004). The SIAM measures 12 imagery ability subscales, which are based on a three-factor framework, with a general imagery-ability factor leading to image generation, feeling, and single-sense factors that are based on five individual dimensions (vividness, control, ease, speed, and duration of images), six sense modalities (visual, kinaesthetic, auditory, tactile, gustatory, and olfactory senses), and the emotion associated with imagery. Participants imagined four different sport performance scenes in 60 seconds for each scene. They reported on the quality of their imagery experience by placing a cross on a 100-mm analogue scale from 0 (*left end of the analogue line, representing no imagery on that subscale*) to 100 (*right end of the analogue line, representing very rich imagery on that subscale*). Ratings for the four scenes were summed to produces a total score for each subscale, so the total scores could be between 0 and 400. The internal consistency alpha values for the 12 sub-scales were from .66 to .87 in the original validation (Watt et al., 2018).

Basketball free-throw shooting (FTS). The FTS test followed standard basketball rules, in which all participants performed their FTS from the free throw line at a distance of 4.22 metres perpendicular to the ring. The basket was 3.05 metres from the ground, and the diameter of the ring was from 450 mm to 459 mm. In the FTS procedure, participants had 10 warm-up shots, then they conducted 40 FTS with a 2-minute break after the first 20 FTS to minimize fatigue. For each FTS test, participants conducted the FTS test on their own with a researcher present. Moreover, we scheduled all FTS tests either before training time or non-training day for avoiding the influential factor of fatigue for the FTS test. We applied an FTS scoring system that has been widely used in research to increase sensitivity to changes in performance, in which each shot scored 3 points for a clean basket, 2 points for the ball going in the basket off the ring, 1 point for missing the basket off the ring, and 0 points for the ball completely missing the basket (De Groot et al., 2012; Fazel et al., 2018; Neumann & Hohnke, 2018). In terms of the total FTS score in each test, we summed scores for 40 FTS giving a score range from 0 to 120 points. Participants in all four conditions took the FTS test at pre-test, Week 1, 2, and 3, post-test (Week 4), and retention test (Week 5).

Imagery log and imagery manipulation check. Participants used a self-report imagery log to rate their images of FTS, rating how well they saw (visual imagery) and felt the images (kinaesthetic imagery), on 5-point Likert scales from 1 (*not at all*) to 5 (*very much*). Furthermore, we checked whether participants performed extra imagery training sessions at the end of each week, including during the retention period.

General basketball practice log. Throughout the study, participants reported their general basketball practice, by writing the date, time, and duration of practice sessions in a general basketball practice log. This permitted us to check whether there was any systematic difference in amount of practice between research conditions, during the course of the study.

Imagery intervention conditions

We gave participants in the imagery conditions the same instructions, except for the difference in the number of imagery sessions per week. We used 20 repetitions of FTS imagery and a 13-minute imagery session duration as constants for all three imagery conditions, based on our previous studies of repetitions (Itoh, Morris, & Spittle, submitted a), and session durations (Itoh, Morris, & Spittle, submitted b), with designs equivalent to the present study. Participants undertook the allocated number of three, four, or five imagery sessions per week, depending on their condition. We chose these session frequency because previous research (Itoh, 2020; Schuster et al., 2011; Wakefield & Smith, 2009a; Wakefield & Smith, 2011) has indicated that three imagery sessions per week produced significantly superior outcomes than one or two sessions. This suggested that the effect of number of sessions might be cumulative. We conducted an introduction to imagery use in sport with each participant alone except for the researcher in a meeting room, in which we presented information about imagery in sport, especially imagery use in basketball, how imagery works for FTS performance, and imagery ability, to motivate participants to work hard on the imagery training. This included citation of research evidence and famous sports persons' reports of their effective use of imagery. We instructed participants to listen to the imagery training program on an MP3 player. Furthermore, we encouraged participants to imagine each FTS as realistically as possible based on the audio instruction. Their aim was to imagine FTS with actual movements speed. Participants were instructed to perform imagery in a comfortable position with limited distractions present. During each session, an audio track involving signals (the sound of a bouncing basketball) that occurred every 39 seconds, each cueing one of the 20 FTS images during every session. Participants undertook a cognitive interference task during the interval between the end of each trial and the next auditory signal (bouncing basketball), which cued the following imagery trial. This was done to minimize the opportunity for them to create extra imagery repetitions of FTS between the imagery trials. In the interference task, participants listened to color words (e.g., blue, yellow, and red) continuously, but non-color words that are closely associated with colors (e.g., sky, lemon, blood) were presented occasionally. When they heard a non-color word, participants wrote the word in a box on the imagery experience check sheet. We used a pilot test with four recreational and competitive basketball players and a basketball coach, to check whether basketball players could follow the procedure of cue, imagery trial, interference task repeat.

The imagery script was based on a previous study of FTS in basketball (Fazel et al., 2018) using similar skill-level participants. For the imagery script, we asked participants to imagine themselves on the basketball court, standing behind the free-throw line, and to imagine the basketball ring. We asked them to imagine feeling the basketball in their hands and to use imagery in the tactile sense to feel the dimples on the basketball. Then, they imagined looking at the basketball ring, while bending their knees to get power in their legs with a stable body position. After that they imagined feeling the power in their legs thrusting, as they raised their upper arm to vertical position and propelled the ball toward the ring. Then, they imagined that their shoulder flexion angle is moved to above horizontal and elbow flexion held ideally, as well as mid flexion of their wrist at release. Finally, we asked them to imagine watching the ball as it looped though the air and dropped through the ring for a clean basket, then feeling the positive emotion associated with a perfect shot. We instructed participants to use all their senses during the creation of FTS images, generating their imagery from an internal imagery perspective. We used MP3 players to guide participants to perform the imagery training appropriately. In particular the recording was able to keep participants closely on track for the number of repetitions, session duration, and timing of the cues, the imagery trials, and the interference task. This recorded material was identical for all imagery conditions. All that varied was the number of times that participants in the 3, 4, and 5 imagery sessions per week conditions performed the recorded intervention.

Control condition

The control condition participants continued their usual basketball training with no imagery training sessions during the intervention period. They completed the demographic form and the SIAM, and the FTS test at pre-test, then repeated the FTS test each week at times that corresponded to the timing in the imagery conditions for Weeks 1 to 5.

Procedure

Following approval from Victoria University Human Research Ethics Committee (VUHREC), all participants were recruited from local basketball teams or clubs in Melbourne. We carried out a standard informed consent procedure for participants, then they completed the demographic form, the SIAM, and the FTS test at pre-test. Then participants were randomly allocated to one of the three imagery conditions or the control condition. We only gave participants in the three imagery conditions information and instruction in terms of the 4-week imagery training program. We did this in a quiet room, in which they learnt how to use the MP3 auditory instructions. Imagery-condition participants conducted imagery sessions for four weeks, so those in the 3 sessions per week condition did a total 12 sessions, those in the 4 sessions per week condition did a total of 16 sessions, and those in the 5 sessions per week condition did a total of 20. Each session lasted approximately 18 minutes, guided by an MP3 player audio track. Each session was completed on a different day of the week. Participants rated the quality of their FTS images on the imagery manipulation check sheet, then they completed the imagery logbook after the session. Participants also reported their total general basketball practice hours in each week in a logbook. Participants in all research conditions took the FTS test at the end of each week. At the end of their participation in the study, we offered participants in the control condition, the opportunity to undertake the imagery-training program. Finally, we debriefed all participants about the purpose of the study.

Analysis

To ensure that there were no systematic differences between conditions in imagery ability, we conducted multivariate analysis of variance (MANOVA) on the 12 SIAM subscales at pre-test. We examined whether there was any systematic difference in FTS level between conditions in the FTS scores at the pre-test with a one-way analysis of variance (ANOVA), and found no significant difference. At the end of the study, we also tested whether there were any differences in total general basketball practice time across the duration of the study between the four conditions, using one-way ANOVA. The differences of imagery quality on the imagery manipulation check were examined, using a mixed-design, two-way ANOVA, testing the three imagery frequency conditions (3, 4, and 5 imagery sessions per week), and the five occasions (repeated measures at Week 1, 2, 3, and 4), as well as the conditions x occasions interaction effect.

In terms of the main analysis, we calculated means and standard deviations of FTS scores in all conditions at pre-test, Weeks 1, 2, 3, post-test (Week 4), and retention test (Week 5). We tested FTS accuracies between the four conditions in each week using two-way, mixed-design ANOVA, with four conditions (3, 4, and 5 imagery sessions per week, and the control condition), and six occasions (repeated measures at pre-test, and Weeks 1, 2, 3, 4, and the retention test). Importantly, the interaction effect (conditions x occasions) was also examined. Tukey's HSD post-hoc tests were conducted the identify any main effects between the four conditions, any main effects between the six occasions, and any conditions x occasions interaction effects. All statistical analysis was examined, using the Statistical Package for the Social Sciences (SPSS: version 24.0) software.

Table 1
Means and standard deviations for the sport imagery ability measure for all conditions.

SIAM subscales	CONDITION	*M*	*SD*
AUDITORY	3 sessions	301.25	78.75
	4 sessions	313.63	80.49
	5 sessions	339.56	88.38
	Control	272.90	109.71
VISUAL	3 sessions	393.63	58.36
	4 sessions	392.63	86.78
	5 sessions	368.89	97.81
	Control	358.80	94.99
KINESTATIC	3 sessions	324.50	94.55
	4 sessions	277.88	122.22
	5 sessions	314.33	95.34
	Control	314.10	78.29
TACTILE	3 sessions	312.38	124.76
	4 sessions	291.50	124.01
	5 sessions	314.44	91.06
	Control	327.00	105.97
CONTROL	3 sessions	357.63	59.74
	4 sessions	332.50	83.47
	5 sessions	339.00	82.71
	Control	327.30	92.17
VIVIDNESS	3 sessions	378.00	53.45
	4 sessions	369.63	65.46
	5 sessions	368.78	84.81
	Control	347.30	110.06

Results

Imagery ability

The mean and SDs of SIAM subscales in each condition are presented in Table 1. The one-way MANOVA comparing SIAM subscale mean differences between the four research conditions at pre-test revealed no significant differences between the conditions, F (9, 36) = .646, p = .85; Wilk's Λ = .704, partial η^2 = .11, with a large effect size.

Total general basketball practice time

The mean of total reported general basketball practice time for the 3 imagery sessions per week condition was 15.90 hours (SD = 7.46); the mean for the 4 imagery sessions per week condition was 17.50 hours (SD = 7.01); the mean for the 5 imagery sessions per week condition was 16.30 hours (SD = 4.85); and the mean for the control condition

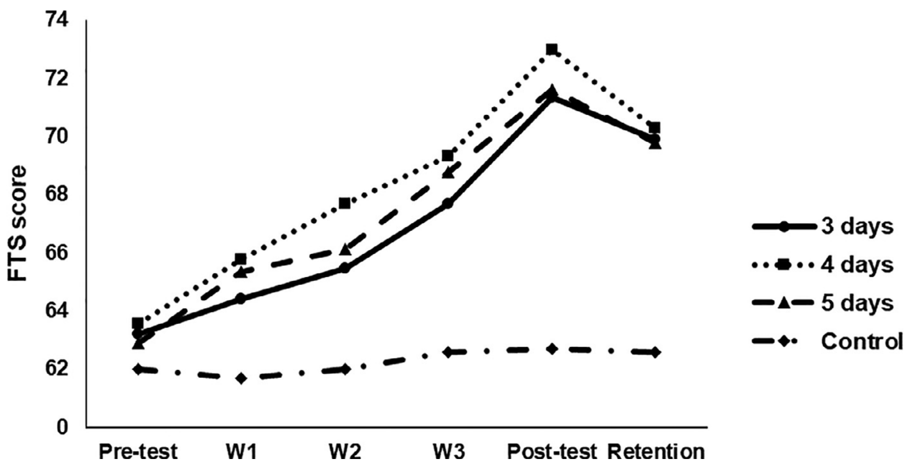

Fig. 1. Free throw shooting scores of the 3-, 4-, and 5-imagery sessions per week conditions and the control condition on six occasions.

Table 2
Means and standard deviations for imagery quality ratings for the imagery conditions in weeks 1 to 4.

Conditions	Week 1		Week 2		Week 3		Week 4	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
3 days	3.30	.59	3.52	.44	3.65	.28	4.06	.24
4 days	3.00	.38	3.27	.57	3.51	.43	3.72	.46
5 days	3.37	.75	3.43	.70	3.91	.40	3.94	.39

was 12.40 hours (*SD* = 3.98). We used a one-way ANOVA to compare the total general basketball practice hours in all four conditions during the imagery training periods. The results showed that there were no significant differences between the conditions F (3, 36) = 1.33, p = .28, η^2 = .01, with a small effect size. It should be noted that the mean general basketball practice hours for the control condition was noticeably lower than for the three imagery conditions, but was still a substantial duration of practice per week.

Imagery manipulation check

We instructed participants to rate the quality of their visual and kinaesthetic imagery on 5-point Likert scales. We summed the ratings for visual and kinaesthetic imagery, then averaged them. The means and SDs for each condition on each of the four weeks of the imagery training program are presented in Table 2. We used a mixed-design, two-way ANOVA, and found no significant main effect of conditions, F (2, 27) = 1.666, $p > .05$, η^2 = .21, with a very large effect size. However, there was a significant main effect of occasions, F (3, 81) = 22.879, $p < .001$, η^2 = .15, with a very large effect size. There was no significant interaction between conditions and occasions, F (6, 81) = .597, p >.05, η^2 = .04, with a small effect size. Tukey's post-hoc tests showed that imagery manipulation check means at Week 3 (p = .01) and Week 4 (p = .001) were significantly higher than at Week 1, and the means at Week 3 (p = .05) and Week 4 (p = .001) were also significantly higher than Week 2. Moreover, the mean of Week 4 (p = .05) was significantly higher than Week3.

Performance outcome

The means and standard deviations in the four research conditions across the six weeks of the study (pre-test, Weeks 1, 2, 3, and 4, and the retention test at the end of Week 5) are illustrated in Table 3. Overall, the FTS scores in the three imagery conditions increased monotonically throughout the weeks when participants performed imagery (See Fig. 1), that is, from Week 1 to Week 4. Then, in Week 5, when there was no formal imagery training, means in all three conditions declined in comparison to Week 4 means. Importantly, for all three imagery conditions, means in Week 5 were still higher than they were in Week 1, at pre-test. FTS scores in the control condition did not improve at all from week to week (see Fig. 1). One-way ANOVA results showed that there was no significant difference between FTS performance in the four research conditions at pre-test, F (3, 36) = .082, $p > .05$, η^2 = .01, with a small effect size.

A two-way mixed-design ANOVA showed that there was a significant main effect of conditions, F (3, 36) = 3.215, $p < .05$, η^2 = .21, on FTS performance data, with a very large effect size. In addition, there was a significant main effect of occasions, F (5, 180) = 20.746, $p < .001$, η^2 = .37, with a very large effect size. Finally, there was also a significant interaction between conditions and occasions, F (15, 180) = 1.886, $p < .05$, η^2 =.14, with a very large effect size.

Tukey's HSD post-hoc tests showed that, at post-test, participants in the 3 imagery sessions per week condition (p = .004), 4 imagery sessions per week condition (p = .005), and 5 imagery sessions per week condition all had significantly higher FTS means than the control condition (p = .035). For the retention test, the 4 imagery sessions per week condition was the only condition that was significantly higher than the control condition (p = .005), with no significant differences between the three imagery conditions. Tukey's post-hoc tests revealed that all the imagery conditions' FTS means at post-test were significantly higher than the corresponding pre-test means. Moreover, the 4 imagery sessions per week condition and the 5 imagery sessions per week condition had significantly higher retention test means than their pre-test FTS means. The control condition showed no significant changes from pre-test to Weeks 1, 2, 3, 4 or the retention test.

Discussion

The aim in this study was to examine the effects of three different frequencies of imagery sessions per week (3-, 4-, 5-days) on FTS performance. The results showed that, during the 4-week imagery training program, all three imagery frequency conditions positively affected basketball FTS performance. This is in line with the previous research literature supporting positive effects of imagery training on sports or motor skill performance (Calmels et al., 2004; Lindsay et al., 2021; Post et al., 2015; Simonsmeier et al., 2020; Toth et al., 2020). Participants in all three imagery conditions did continue their usual general basketball practice of FTS during imagery training, which might have improved imagery training effects (Driskell et al., 1994; Fazel et al., 2018; Post et al., 2010) or supported improved FTS performance. Participants in the control condition, however, also continued their usual general basketball practice of FTS but did not improve their FTS performance during the same period, suggesting that the effects for the three imagery conditions reflect more

Table 3
Means and standard deviations of FTS scores from pre-test to retention test in all four conditions.

	Pre-test		Week 1		Week 2		Week 3		Week 4		Retention test (Week 5)	
Conditions	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
3-day frequency	63.20	5.59	63.80	4.10	65.50	5.54	67.70	5.76	71.70	5.14	69.90	5.07
4-day frequency	63.10	3.93	66.10	6.49	67.30	3.65	69.60	5.91	73.00	5.58	70.30	2.50
5-day frequency	62.90	8.06	65.00	10.03	66.10	7.98	68.50	7.44	71.60	6.75	69.80	6.89
Control	62.00	5.94	61.70	8.38	61.80	4.57	62.50	4.03	62.60	2.71	62.50	4.40

than a general basketball practice effect. A noteworthy result was that 4 imagery sessions per week had the greatest effect on FTS performance in this study. Therefore, subject to replication, we conclude that using 20 repetitions in a 13-minute session for four days a week over 4 weeks would be an appropriate imagery training program design to enhance basketball FTS performance.

The FTS performance increase in the 3 imagery sessions per week condition supported previous research that found 3 sessions of imagery training per week was more effective than 1 or 2 sessions per week (Schuster et al., 2011; Wakefield & Smith, 2009b, 2011) by showing a strong increase at post-test, much of which was sustained at retention. However, the findings that both 4 and 5 imagery training sessions per week were more effective than 3 sessions per week are new findings in sport imagery research. Although visual inspection of the results in Fig. 1 indicates that the effects of the three imagery intervention conditions were similar, we drew this conclusion because both the 4 and 5 imagery sessions per week conditions showed significantly higher performance at post-test than the control condition, but the 3 imagery sessions per week condition was not significantly different to the control condition at post-test. All participants already had skill in FTS before participating in this imagery training program, but their skill level was moderate rather than high-level, as evidenced by their FTS accuracy, which was between 41% and 60% at pre-test. Hence, these participants had potential to increase their skill by participating in the imagery training program. This is supported by the results, which showed that mean basketball FTS performance in all three imagery intervention conditions increased by 7.2% from 63.2 (52.6%) at pre-test to 71.70 (59.8 %) at post-test for the 3 imagery sessions per week condition, 8.1% from 63.1 (52.7%) at pre-test to 73.00 (60.8%) at post-test for the 4 imagery sessions per week condition, and by 7.1% from 62.9 (52.6%) at pre-test to 71.60 (59.7%) at post-test for the 5 imagery sessions per week condition.

Basketball FTS means for all the imagery training conditions decreased from post-test to retention test, when there was no-imagery training for a week. This result was expected for several reasons. First, there is a long history of research on motor skills that has used retention tests to examine how effectively various interventions, including imagery, were sustained during periods when the interventions were removed (Harris & Hebert, 2015; Ste-Marie et al., 2011). The vast majority of such studies show decreases in performance of the skill during the retention period (Spittle & Kremer, 2010). This has also been reported in imagery research (Wright & Smith, 2007), where decrements during retention periods appear to vary with the length of the retention period; the longer the retention period the greater the decrement from post-test (Arnaud et al., 2013; Dunsky et al., 2008; O et al., 2019). Another reason this decrease was expected was that participants' FTS performance accuracy was not at the elite level after the imagery training program; in other words, the participants still had potential to improve FTS accuracy. However, for 1-week retention periods, percentage decrements typically vary from 1.5% to 2.3% (Ram et al., 2007). The percentage decrements from post-test to retention test for the three imagery intervention conditions in the present study were about 1.5% for the 3 imagery sessions per week condition; about 2.3% for the 4 imagery sessions per week condition; and about 1.5% for the 5 imagery sessions per week condition. Thus, the 3 and 5 imagery sessions per week showed smaller reductions at retention test than the 4 imagery sessions per week condition. The smaller decrease shown in the retention period for 3 and 5 sessions could in part be due to the higher scores for the 4 imagery session condition at post-test. However, for the 4 imagery session per week condition, it had a significantly higher FTS score at the retention test than the Control condition. In addition, the mean of FTS at the retention test in 4 session frequency was the highest between conditions. By comparison with previous imagery research that has included a retention period, this represents relatively strong retention in all three imagery intervention conditions in the present study.

Previous research comparing 1, 2, and 3 sessions per week, on shooting performance in netball (Wakefield & Smith, 2009b), and on strength performance in the biceps curl activity (Wakefield & Smith, 2011) reported that 3 imagery sessions per week were more effective than 1 or 2 imagery sessions per week. The main findings of the present study were that 4 imagery sessions per week was more effective than 3 and 5 imagery sessions per week, while 5 sessions was also somewhat more effective than 3 sessions. A noteworthy aspect of these results is that effectiveness of the imagery training did not simply increase with the number of sessions per week because we found that 4 sessions was more effective than 5 sessions. Tests of dose effects, such as those for frequency of imagery sessions, are more informative when they include maximum performance outcomes that are not the largest frequency tested in the study. Thus, for example, the studies by Wakefield and Smith (2009b, 2011), which found 3 sessions per week to be superior to 1 or 2 sessions, left open the possibility that 4, 5, or more sessions would be even more effective. In the present study, we found that 4 sessions was more effective than 3 or 5 sessions, suggesting that 4 sessions per week might be the optimal number, at least for enhancing FTS performance. It must be acknowledged that differences between the effectiveness of 3, 4, and 5 sessions per week were relatively small. This reinforces the conclusion that there is a need for further studies to be conducted with a variety of discrete skills to determine whether 4 sessions per week is the optimal number for this type of task.

There are a number of possible reasons why the 4 sessions per week frequency was the most effective in the present study. The total number of imagery training sessions was different between imagery conditions. In other words, participants in the 4 imagery sessions per week condition had a total of 16 sessions in the 4-week imagery training program, which was more than the 3 imagery sessions per week condition, which had 12 sessions, so that the 4 sessions per week participants had more experience of imagery overall, which might be related to a greater increase in their FTS accuracy. However, participants in the 5 imagery sessions per week condition had even more experience of imagery training sessions overall at 20 sessions, but the 5 sessions condition was not as effective as the 4 sessions per week condition. Thus, a simple explanation that more sessions leads to greater improvement in performance is not viable. It is possible that increasing the number of sessions per week leads to an increase in performance up to 4 sessions per week, based on the findings for 1, 2, and 3 sessions in the studies by Wakefield and Smith (2009b, 2011) and the present study, but that participants in the present study found that 5 imagery training sessions per week was too demanding for their commitment level. In addition, all participants had no systematic imagery training experience before participating in this study. Thus, it is possible that a combination of limited commitment to improving performance of the skill, and a lack of experience of performing a large amount of non-physical training, in this case imagery, might have led participants in the 5 sessions of imagery per week condition to attain a performance outcome a little lower than participants in the 4 imagery sessions per week condition. Thus, the results of the present study might be explained by an increase in the effect of imagery up to a tipping point, dependent on the skill level and experience with imagery of participants. Beyond that tipping point, effectiveness reduced. This explanation can be examined in future research, which varies skill level and imagery experience independently, along with the frequency of imagery sessions.

The imagery dose-response protocol applied in this study has not previously been used to examine frequency of imagery sessions. Based on the proposition made by (Morris et al., 2012), we have also examined number of repetitions (Itoh et al., submitted, a) and duration of imagery sessions (Itoh et al., submitted, b), but the present study is the first to our knowledge to examine frequency using this protocol. Thus, there is now mounting evidence that this approach can be employed to examine the effectiveness of imagery dose variables, including frequency. This can be achieved in a context that will make different studies comparable. In previous imagery training studies, researchers examined different imagery frequency dosages in their imagery training, but they left other key imagery variables uncontrolled, especially the number of repetitions and imagery duration in a session (Ely et al., 2020; Lindsay et al., 2021; Paravlic et al., 2018; Schuster et al., 2011; Simonsmeier et al., 2020; Wakefield & Smith, 2009b, 2011). This meant that there could have been very different combinations of imagery dose variables, potentially explaining the great diversity of results in earlier research (Smith et al., 2007; Smith et al., 2008; Tenenbaum et al., 1995; Yue & Cole, 1992). Hence, it is important to control imagery dose variables, by systematically varying the imagery variable of interest, while other key dose variables are held constant (Morris et al., 2012). In the present study, we compared 3, 4, and 5 imagery sessions per week, while keeping number of repetitions and session duration constant at 20 repetitions and 13 minutes, based on the results of the previous dose-response study of repetitions (Itoh et al., submitted, a) and of session duration (Itoh et al., submitted, b), respectively. In all studies, the task, FTS, was the same, participants skill level, moderate FTS performance, was very similar, and we controlled for gender variations by restricting the study to males. This substantially limits the number of variables that could explain the differences between the 3, 4, and 5 imagery sessions per week conditions, aside from frequency of sessions. It is important that researchers conducting imagery dose-response research in the future clearly describe at least the variables controlled in the present study, so that a strong evidence base can be constructed by examining a large number of studies, in which variations between studies are limited, and, because those variations are stated, researchers who review this topic can factor them into their analyses.

Inevitably, there were several limitations in this study. A potential limitation of the study is the number of participants. This is the limitation associated with recruiting the appropriate number of participants to ensure that a significant result is found, if a real effect exists. The number of participants in the current study was not large but was sufficient to find an effect of imagery training and was more than in previous imagery frequency research (e.g., Wakefield & Smith, 2009b), which also reported significant effects. Further research with larger samples would be beneficial to further explore the imagery dose-response relationship and help support the generalisability of the initial findings on the dose-response relationship reported in this study. We employed only male basketball players to control for the influential variable of gender (Burhans et al., 1988; Watt et al., 2018; Williams & Cumming, 2011), but this limits generalizability of the findings to females. The study was limited to a specific skill (basketball FTS), with a specific skill level (recreational level basketballers) of a specific gender (male), who were over 18 years old (M = 20.92, *SD* = 3.01). Thus, there is a need for further research on imagery dose-response relationships exploring a range of potential moderators on the imagery-dose response relationship. In addition, we only used the discrete task of FTS. It is necessary to examine different discrete tasks in future research to determine whether the type of discrete skill affects the effectiveness of different frequencies. Hence, researchers should replicate studies, in which they use the same research design as the current study, but they should use different tasks from different sports. Thus, more imagery dose-response studies should be conducted to determine optimal levels of the key dose variable of frequency, so that it is possible to describe the most effective imagery frequency per week for designing imagery training programs, under a range of conditions.

Another limitation is that we limited comparison frequencies of imagery training sessions per week to frequencies of 3, 4, and 5 imagery sessions per week, but examining a larger range of sessions per week, including 6 or more imagery sessions, would make it possible to discern patterns more definitively. The explanation we posited for slightly stronger results with 4 than 5 sessions, that individuals performing in a moderate level league might not be highly committed to improving their FTS performance, was based on post-study interviews with participants. Those in the 5 sessions per week condition complained that 5 imagery sessions per week was excessive. They observed that, outside their sport practice and competition commitments, club athletes who are non-elite, like the basketball players in the present study, have limited time to devote to practice and competition in their sport. They are also working or studying, as well as undertaking domestic activities (Farrow & Robertson, 2017). Thus, asking non-elite players to perform imagery on 6 or 7 days per week might create stress or pressure for these athletes, leading to a loss of motivation. They might even drop out of the imagery program. Elite or professional athletes have greater potential to include, in their schedule, an imagery training program comprising 6 or 7 sessions per week, as their priority is their sport training, and they spend most of their time on activities related to enhancing sport performance. Cumming and Ramsey (2009) found that high-level athletes used imagery every day. Orlick and Partington (1988) indicated that Canadian Olympic athletes used imagery every day in their preparation for training and competition. The results for this study suggest that 5 sessions was less effective for recreational athletes, but It is possible that this may different for different level athletes. For example, 5, 6, or even 7 imagery sessions per week might produce greater imagery training effects than 4 imagery sessions per week over a 4-week imagery training program among elite athletes, who are likely to have the motivation and the time to do more imagery training, if they think it will make a noteworthy difference to their performance. Thus, further research is needed on the dose-response relationship with different levels of performer.

In conclusion, the key imagery variable of frequency should be considered in the design of imagery training programs. In this study, 4 and 5 imagery sessions per week were more effective than 3 sessions, while 4 sessions per week was the most effective frequency. We found the new imagery dose-response protocol to be useful for examining the relative effectiveness of different imagery frequencies, in terms of FTS performance. Further research is required to apply the current results to discrete sports skills in general. We propose that researchers should adopt the new imagery dose-response protocol in their imagery training research, to increase comparability and generalizability of findings.

References

Allami, N., Paulignan, Y., Brovelli, A., & Boussaoud, D. (2008). Visuo-motor learning with combination of different rates of motor imagery and physical practice. *Experimental Brain Research, 184*(1), 105–113. doi:10.1007/s00221-007-1086-x.

Anton, N. E., Howley, L. D., Pimentel, M., Davis, C. K., Brown, C., & Stefanidis, D. (2016). Effectiveness of a mental skills curriculum to reduce novices' stress. *Journal of Surgical Research, 206*(1), 199–205. doi:10.1016/j.jss.2016.07.019.

Arnaud, S., Martin, F. L., Francine, M., Carol, L. R., Julien, D., & Philip, L. J. (2013). The comparison between motor imagery and verbal rehearsal on the learning of sequential movements. *Frontiers in Human Neuroscience*. doi:10.3389/fnhum.2013.00773.

Bond Brill, J., Perry, A. C., Parker, L., Robinson, A., & Burnett, K. (2002). Dose-response effect of walking exercise on weight loss. How much is enough? *International Journal Of Obesity, 26*(11), 1484–1493. doi:10.1038/sj.ijo.0802133.

Burhans, R. S., Richman, C. L., & Bergey, D. B. (1988). Mental imagery training: Effects on running speed performance. *International Journal of Sport Psychology, 19*(1), 26–37.

Calmels, C., Berthoumieux, C., & d'Arripe-Longueville, F. (2004). Effects of an imagery training program on selective attention of national softball players. *The Sport Psychologist, 18*(3), 272–296.

Cherappurath, N., Elayaraja, M., Kabeer, D. A., Anjum, A., Vogazianos, P., & Antoniades, A. (2020). PETTLEP imagery and tennis service performance: an applied investigation. *Journal of Imagery Research in Sport and Physical Activity*, (1), 15. doi:10.1515/jirspa-2019-0013.

Coelho, R. W., De Campos, W., Da Silva, S. G., Okazaki, F. H. A., & Keller, B. (2007). Imagery intervention in open and closed tennis motor skill performance. *Perceptual and Motor Skills, 105*(2), 458–468. doi:10.2466/PMS.105.2.458-468.

Cumming, J., & Ramsey, R. (2009). Imagery interventions in sport. In S. D. Mellalieu, & S. Hanton (Eds.), *Advances in applied sport psychology* (pp. 5–36). Routledge. doi:10.13140/2.1.2619.2322.

Dana, A., & Gozalzadeh, E. (2017). Internal and external imagery effects on tennis skills among novices. *Perceptual & Motor Skills, 124*(5), 1022–1043. doi:10.1177/0031512517719611.

De Groot, S., Balvers, I. M., Kouwenhoven, S., & Janssen, T. J. (2012). Validity and reliability of tests determining performance-related components of wheelchair basketball. *Journal of Sports Sciences, 30*(9), 879–887. doi:10.1080/02640414.2012.675082.

Driskell, J. E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance? *Journal of Applied Psychology, 79*(4), 481–492.

Dunsky, A., Dickstein, R., Marcovitz, E., Levy, S., & Deutsch, J. (2008). Home-based motor imagery training for gait rehabilitation of people with chronic poststroke hemiparesis. *Archives of Physical Medicine and Rehabilitation, 89*(8), 1580–1588. doi:10.1016/j.apmr.2007.12.039.

Ely, F. O., Munroe-Chandler, Krista, J. O. J., & McCullagh, P (2020). The practice of imagery: a review of 25 Years of applied sport imagery recommendations. *Journal of Imagery Research in Sport and Physical Activity, 15*(1). doi:10.1515/jirspa-2020-0018.

Evangelista, L. S., Cacciata, M., Stromberg, A., & Dracup, K. (2017). Dose-response relationship between exercise intensity, mood states, and quality of life in patients with heart failure. *Journal of Cardiovascular Nursing, 32*(6), 530–537. doi:10.1097/JCN.0000000000000407.

Farmer, T., & Matlin, M. (2019). *Cognition (10th Ed.)*. Wiley.

Farrow, D., & Robertson, S. (2017). Development of a skill acquisition periodisation framework for high-performance sport. *Sports Medicine, 47*(6), 1043–1054. doi:10.1007/s40279-016-0646-2.

Fazel, F. (2015). *The effects of different types of imagery delivery on performance and self-efficacy [Doctoral dissertation, Victoria University]*.

Fazel, F., Morris, T., Watt, A., & Maher, R. (2018). The effects of different types of imagery delivery on basketball free-throw shooting performance and self-efficacy. *Psychology of Sport and Exercise, 39*, 29–37. doi:10.1016/j.psychsport.2018.07.006.

Feltz, D., & Landers, D. (1983). The effects of mental practice on motor skill learning and performance. *A Meta-analysis, 5*(1), 25–57.

Galloway, M., Marsden, D. L., Callister, R., Erickson, K. I., Nilsson, M., & English, C. (2019). What is the dose-response relationship between exercise and cardiorespiratory fitness after stroke? A systematic review. *Physical Therapy, 99*(7), 821–832. doi:10.1093/ptj/pzz038.

Haight, C., Moritz, S., & Walch, T. (2020). Time of imagery's effect on performance and self-efficacy in college baseball players. *Journal of Imagery Research in Sport and Physical Activity*, (1), 15. doi:10.1515/jirspa-2020-0019.

Hall, C., Singer, R., Hausenblas, H., & Janelle, C. (2001). *Handbook of sport psychology*. John Wiley.

Harris, J. E., & Hebert, A. (2015). Utilization of motor imagery in upper limb rehabilitation: a systematic scoping review. *Clinical rehabilitation, 29*(11), 1092–1107. doi:10.1177/0269215514566248.

Hashmi, S., Akhtar, T., & Hashmi, M. (2020). Effects of PETTLEP imagery technique on precision skills: a study on drag flick in Pakistan hockey. *Journal of Imagery Research in Sport and Physical Activity*, (1), 15. doi:10.1515/jirspa-2020-0001.

Hinshaw, E., & Karin (1991). The effects of mental practice on motor skill performance: Critical evaluation and meta-analysis. *Imagination, Cogni*tion and Personality*, 11*, 3–35. doi:10.2190/X9BA-KJ68-07AN-QMJ8.

Holland-Letz, T., & Kopp-Schneider, A. (2015). Optimal experimental designs for dose-response studies with continuous endpoints. *Archives Of Toxicology, 89*(11), 2059–2068. doi:10.1007/s00204-014-1335-2.

Holmes, P. S., & Collins, D. J. (2001). The PETTLEP approach to motor imagery: A functional equivalence model for sport psychologists. *Journal of Applied Sport Psychology, 13*(1), 60–83. doi:10.1080/10413200109339004.

Howard, K. I., Kopta, S. M., Krause, M. S., & Orlinsky, D. E. (1986). The dose-effect relationship in psychotherapy. *American Psychologist, 41*(2), 159–164. doi:10.1037/0003-066X.41.2.159.

Itoh, S. (2020). Effect of imagery dose variables on performance in sport *[Thesis*. Victoria University Research Repository.

Jennings, G. L., Deakin, G., Korner, P., Meredith, I., Kingwell, B., & Nelson, L. (1991). What is the dose-response relationship between exercise training and blood pressure? *Annals of Medicine, 23*(3), 313–318. doi:10.3109/07853899109148066.

Lindsay, R. S., Larkin, P., Kittel, A., & Spittle, M. (2021). Mental imagery training programs for developing sport-specific motor skills: a systematic review and meta-analysis. *Physical Education and Sport Pedagogy*, 1–22. doi:10.1080/17408989.2021.1991297.

Marshall, E. A., & Gibson, A.-M. (2017). The Effect of an Imagery training intervention on self-confidence, anxiety and performance in acrobatic gymnastics - A pilot study. *Journal of Imagery Research in Sport & Physical Activity, 12*(1), 13–22. doi:10.1515/jirspa-2016-0009.

Morris, T., Fazel, F., Maher, R., Azizuddin Khan, T. K., Kuan, G., & Spittle, M. (2012). *How much imagery is enough? Developing a research protocol the 3rd Chinese Conference on Sport Psychology* Macau.

Morris, T., Spittle, M., & Watt, A. P. (2005). Imagery in sport. *Human Kinetics*.

Munroe-Chandler, K. J., Hall, C. R., Fishburne, G. J., & Strachan, L. (2007). Where, when, and why young athletes use imagery: an examination of developmental differences. *Research Quarterly for Exercise and Sport, 78*(2), 103–116. doi:10.1080/02701367.2007.10599408.

Munroe, K. J., Giacobbi, P. R., Hall, C., & Weinberg, R. (2000). The four Ws of imagery use: Where, when, why, and what. *The Sport Psychologist, 14*(2), 119–137.

Neumann, D. L., & Hohnke, E. (2018). Practice using performance goals enhances basketball free throw accuracy when tested under competition in elite players. *Journal of Human Sport & Exercise, 13*(2), 296–304. doi:10.14198/jhse.2018.132.05.

Nordin, S. M., & Cumming, J. (2005). Professional dancers describe their imagery: Where, when, what, why, and how. *The Sport Psychologist, 19*(4), 395–416. doi:10.1123/tsp.19.4.395.

O, J., Ely, F. O., & Magalas, S (2019). It's all about timing: An imagery intervention examining multiple image speed combinations. *Journal of Applied Sport Psychology*. doi:10.1080/10413200.2019.1570391.

Orlick, T., & Partington, J. (1988). Mental Links to Excellence. *Sport Psychologist, 2*(2), 105–130.

Paravlic, A. H., Slimani, M., Tod, D., Marusic, U., Milanovic, Z., & Pisot, R. (2018). Effects and dose-response relationships of motor imagery practice on strength development in healthy adult populations: a systematic review and meta-analysis. *Sports Medicine, 48*(5), 1165–1187. doi:10.1007/s40279-018-0874-8.

Post, P. G., Williams, C. D., Simpson, D., & Berning, J. M. (2015). The effects of a PETTLEP imagery intervention on the learning of a complex motor skill. *Journal of Imagery Research in Sport & Physical Activity, 10*(1), 19–30. doi:10.1515/jirspa-2015-0007.

Post, P. G., Wrisberg, C. A., & Mullins, S. (2010). A field test of the influence of pre-game imagery on basketball free throw shooting. *Journal of Imagery Research in Sport and Physical Activity, 5*(1), 1–15. doi:10.2202/1932-0191.1042.

Ram, N., Riggs, S. M., Skaling, S., Landers, D. M., & McCullagh, P. (2007). A comparison of modelling and imagery in the acquisition and retention of motor skills. *Journal of Sports Sciences, 25*(5), 587–597. doi:10.1080/02640410600947132.

Robinson, L., Delgadillo, J., & Kellett, S. (2019). The dose-response effect in routinely delivered psychological therapies: A systematic review. *Psychotherapy Research*. doi:10.1080/10503307.2019.1566676.

Sanders, L. M. J., Hortobagyi, T., la Bastide-van Gemert, S., van der Zee, E. A., & van Heuvelen, M. J. G. (2019). Dose-response relationship between exercise and cognitive function in older adults with and without cognitive impairment: A systematic review and meta-analysis. *PloS one, 14*(1), e0210036. doi:10.1371/journal.pone.0210036.

Sardon, D. Z. N. A., Mazaulan, M., & Mohamed, M. N. (2015). Effect of imagery intervention on flow state and performance in tennis. In *Proceedings of the 2nd International Colloquium on Sports Science, Exercise, Engineering and Technology* 2015 (ICoSSEET 2015).

Schuster, C., Hilfiker, R., Amft, O., Scheidhauer, A., Andrews, B., Butler, J., & Ettlin, T. (2011). Best practice for motor imagery: a systematic literature review on motor imagery training elements in five different disciplines. *BMC Medicine, 9*, 75. doi:10.1186/1741-7015-9-75.

Shambrook, C. J., & Bull, S. J. (1996). The use of single-case research design to investigate the efficacy of imagery training. *Journal of Applied Sport Psychology, 8*(1), 27–43. doi:10.1080/10413209608406306.

Simonsmeier, B. A., Androniea, M., Buecker, S., & Frank, C. (2020). The effects of imagery interventions in sports: a meta-analysis. *International Review of Sport and Exercise Psychology*. doi:10.1080/1750984X.2020.1780627.

Smith, D., Wright, C., Allsopp, A., & Westhead, H. (2007). It's all in the mind: PETTLEP-based imagery and sports performance. *Journal of Applied Sport Psychology, 19*(1), 80–92. doi:10.1080/10413200600944132.

Smith, D., Wright, C. J., & Cantwell, C. (2008). Beating the bunker: the effect of PETTLEP imagery on golf bunker shot performance. *Research Quarterly for Exercise and Sport, 79*(3), 385–391. doi:10.1080/02701367.2008.10599502.

Sordoni, C., Hall, C., & Forwell, L. (2000). The use of imagery by athletes during injury rehabilitation. *Journal of Sport Rehabilitation, 9*(4), 329–338. doi:10.1123/jsr.9.4.329.

Spittle, M., & Kremer, P. (2010). Mental practice and the retention of motor learning: A pilot study. *Perceptual and Motor Skills, 110*(3), 888–896 Pt1. doi:10.2466/pms.110.3.888-896.

Ste-Marie, D. M., Vertes, K., Rymal, A. M., & Martini, R. (2011). Feedforward self-modeling enhances skill acquisition in children learning trampoline skills. *Frontiers in Psychology, 2*, 155 155. doi:10.3389/fpsyg.2011.00155.

Strachan, L., & Munroe-Chandler, K. (2006). Using Imagery to Predict Self-Confidence and Anxiety in Young Elite Athletes. *Journal of Imagery Research in Sport & Physical Activity, 1*(1), 1–19. doi:10.2202/1932-0191.1004.

Stulz, N., Lutz, W., Kopta, S. M., Minami, T., & Saunders, S. M. (2013). Dose–effect relationship in routine outpatient psychotherapy: Does treatment duration matter? *Journal of Counseling Psychology, 60*(4), 593–600. doi:10.1037/a0033589.

Tenenbaum, G., Bar-Eli, M., Hoffman, J. R., Jablonovski, R., Sade, S., & Shitrit, D. (1995). The effect of cognitive and somatic psyching-up techniques on isokinetic leg strength performance. *Journal of Strength & Conditioning Research, 9*(1), 3–7.

Toth, A. J., McNeill, E., Hayes, K., Moran, A. P., & Campbell, M. (2020). Does mental practice still enhance performance? A 24 Year follow-up and meta-analytic replication and extension. *Psychology of Sport and Exercise, 48*, 101672. doi:10.1016/j.psychsport.2020.101672.

Wakefield, C., & Smith, D. (2009a). Impact of differing frequencies of PETTLEP imagery on netball shooting performance, 4. doi:10.2202/1932-0191.1043.

Wakefield, C. J., & Smith, D. (2009b). Impact of differing frequencies of PETTLEP imagery on netball shooting performance. *Journal of Imagery Research in Sport and Physical Activity, 4*(1). doi:10.2202/1932-0191.1043.

Wakefield, C. J., & Smith, D. (2011). From strength to strength: A single-case design study of PETTLEP imagery frequency. *The Sport Psychologist, 25*(3), 305–320. doi:10.1123/tsp.25.3.305.

Watt, A., Klep, D., & Morris, A. (2018). Psychometric analysis of the sport imagery ability measure. *Journal of Physical Education and Sport, 18*(1), 138–148.

Watt, A. P., Morris, T., & Andersen, M. B. (2004). Issue in the development of a measure of imagery ability in sport. *Journal of Mental Imagery, 28*, 149–180.

Williams, S. E., Cooley, S. J., & Cumming, J. (2013). Layered stimulus response training improves motor imagery ability and movement execution. *Journal of Sport and Exercise Psychology, 35*(1), 60–71. doi:10.1123/jsep.35.1.60.

Williams, S. E., & Cumming, J. (2011). Measuring athlete imagery ability: the sport imagery ability questionnaire. *Journal of Sport & Exercise Psychology, 33*(3), 416–440. doi:10.1123/jsep.33.3.416.

Wright, C. J., & Smith, D. K. (2007). The effect of a short-term PETTLEP imagery intervention on a cognitive task. *Journal of Imagery Research in Sport and Physical Activity, 2*(1). doi:10.2202/1932-0191.1014.

Wylie, L. J., Kelly, J., Bailey, S. J., Blackwell, J. R., Skiba, P. F., Vanhatalo, A., & Jeukendrup, A. E. (2013). Beetroot juice and exercise: Pharmacodynamic and dose-response relationships. *Journal of Applied Physiology, 115*(3), 325–336. doi:10.1152/japplphysiol.00372.2013.

Yue, G., & Cole, K. J. (1992). Strength increases from the motor program: Comparison of training with maximal voluntary and imagined muscle contractions. *Journal of Neurophysiology, 67*(5), 1114–1123. doi:10.1152/jn.1992.67.5.1114.