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Effects of motor imagery and action observation on respiratory function in mild smokers: a randomized single-blind controlled pilot trial

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ABSTRACT

Background: Motor imagery (MI) and action observation (AO) training can activate brain areas involved in planning, adjusting, and automating voluntary movement in a manner similar to that when these activities are being performed.
Aim: The main objective of this study was to assess the effects of MI and AO training on respiratory function in mild smokers.
Methods: A single-blind placebo-controlled pilot trial was designed. A total of 27 mild smokers were randomized into three groups: MI (n = 9), AO (n = 9), and sham observation (SO; n = 9) groups. The MI and AO groups performed mental training of breathing exercises while the SO group observed a landscape without a human agent. The primary outcomes were pulmonary function parameters (forced expiratory volume during the 1st s [FEV_1], forced vital capacity [FVC], FEV_1/FVC ratio, maximum voluntary ventilation [MVV], and peak expiratory flow [PEF]), and the secondary outcomes were maximal inspiratory/expiratory pressures (MIP/MEP) and perceived fatigue. All outcome measures were assessed at baseline and post-intervention.
Results: Regarding the pulmonary function parameters, only the AO group showed significant within-group differences in FEV_1 (mean differences [MD] = 0.37 L (0.17 – 0.56), P = 0.001), FVC (MD = 0.1 L (0.02 – 0.16), P = 0.008), and PEF (MD = 0.74 L/s (0.29 – 1.18), P = 0.002) with a small-to-moderate effect size. No differences were found in FEV_1/FVC ratio and MVV. With regard to the maximal static pressures, only the AO group showed significant within-group differences in MEP with a small effect size (MD = 11.22 cm H_2O (0.19 – 22.2), P = 0.046). Finally, both AO and MI groups showed significantly greater perceived fatigue with regard to SO group with a large effect size ($P < 0.05$).
Conclusion: AO training has a slight impact on some pulmonary function parameters, such as FEV_1, FVC, or PEF, as well as on MEP when applied in isolation and in a single session.
Relevance for Patients: Although it is still early to draw some solid conclusions, AO training could be used in combination with respiratory exercises to see if the effect is greater than exercises in isolation. The study of movement representation strategies on pulmonary function is a field that has been sparingly explored so far. This paper offers some interesting data to be considered for further research.

1. Introduction

Motor imagery (MI) is defined as the creation and maintenance of a movement image without actually executing it [1]. In addition, action observation (AO) training is defined as the real-time visualization of a motion image without actually performing it [2]. Both neurosensory-motor training tools cause an activation of the cortical areas related to the planning, adjustment, and automation of voluntary movement that is qualitatively equal to,

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but quantitatively less than, the action actually being performed [3]. Regarding the neurophysiology behind these neurosensory-motor training tools, there appears to be an overlap in the activity of some brain areas during MI, AO, and actual performance [4]. Hardwick *et al.* [4] found that MI and AO training recruited similar premotor-parietal cortical networks but, while MI recruited a subcortical network similar to that found during actual movement execution, AO training showed no activity in any subcortical area.

In addition, AO training and MI generation processes can be carried out in different modalities. Both methods of movement representation can be implemented in two perspectives. First, there is the first-person perspective, where the person observes or imagines him/herself showing his/her own point of view. On the other hand, based on the third-person perspective, the person observes or imagines him/herself from the outside, as an external observer. Both forms have been described and studied in the scientific literature [5-11]. In addition to the first-person or third-person perspective, also called internal or external perspective, respectively, MI is specifically subclassified into two other modalities, namely visual MI and kinesthetic MI [12,13]. Theoretically, the differences between these two modalities of construction and generation of MI lie in their execution. On the one hand, in kinesthetic MI, the ability to feel is incorporated at the same time as the MI task is performed, causing, at the neurophysiological level, some differences with respect to visual MI [14]. For example, during kinesthetic MI, there is a greater increase in electromyographic activity than in the visual modality [15]. These findings were also found in the stimulation of the corticospinal system evaluated by neuroimaging [16]. Even at the level of neurovegetative system activity, the kinesthetic modality has also been found to elicit higher levels of heart rate, respiratory rate, skin conductance, *etc.* [17,18]. Visual MI refers to creating a motor image being, therefore, a representation devoid of any stimulation of the somatosensory system [12,14].

Interest in the study of the effects of MI and AO training on some sensorimotor variables has grown in recent years. For example, Cuenca-Martínez *et al.* [19] found that adding MI to an usual treatment improved active range of motion in patients subjected to immobilization. Furthermore, they also showed that MI maintained significantly greater strength and speed in patients undergoing surgery [19]. In addition to this, it has been found that adding MI to an usual treatment improved pain intensity and strength to a greater degree than usual treatment alone in patients undergoing a total knee arthroplasty [20]. Both techniques have been shown to improve the motor learning process both in isolation [21,22] and in combination with physical exercise [23]. Losana-Ferrer *et al.* [24] found that both AO and MI, in combination with actual practice, elicited higher levels of strength as well as electromyographic activity than physical practice in isolation. This increase in strength has also been found when AO and MI training were combined in isolation, without the presence of actual practice [25]. It seems therefore that MI and AO training, both in isolation and in combination with physical practice, leads to improvements in some clinical variables of interest.

Physical training has been widely used in respiratory rehabilitation. In fact, some systematic reviews have shown that respiratory muscle training improves several pulmonary function parameters and maximal static pressures in some clinical populations such as patients with chronic obstructive pulmonary disease [26], lung cancer survivors [27], asthma [28], obstructive sleep apnea [29], or tobacco smokers [30,31]. Therefore, we believe that the addition of mental practice along with the performance of respiratory muscle training could have an impact on these clinical populations. However, it is too early to be certain of this statement. To date, we believe that there is no study that has evaluated the effect of MI and AO on pulmonary function parameters and maximal static pressures. There are a few studies that have evaluated the effect of MI on breath-holding performance [32,33]. Therefore, we set out the following pilot study with the aim to evaluate the effect of MI and AO training in isolation to see if it had any impact on maximal static respiratory pressures and several pulmonary function parameters. The authors hypothesize that mental practice in isolation may have a significant impact on these variables and in future studies, it could be combined with respiratory muscle training to see if it increases its clinical effect.

Because there are currently no studies that aim to assess the impact of movement representation techniques in isolation on pulmonary function, the main aim of this pilot study was to assess the effects of MI and AO in isolation on respiratory function in mild smokers.

2. Methods

2.1. Study design

This study was a randomized, single-blind, placebo-controlled pilot trial, which was planned and conducted in accordance with Consolidated Standards of Reporting Trials (CONSORT) requirements and was approved by The Ethics Committee of Research in Humans of the Ethics Commission in Experimental Research of University of Valencia (number: 2301127). This study was registered in the United States Randomized Trials Registry on clinicaltrial.gov (trial registry number: NCT05662072). All the participants were briefed on the study procedures, which were planned according to the ethical standards of the Helsinki Declaration.

2.2. Participants

All data were collected at the University of Valencia (between November 2022 and February 2023) by email and social networks. All participants were currently smokers aged >18 years and had a pack per year index of <5 (mild smoking index). This population was chosen because we were looking for a population as close as possible to healthy subjects but with room for improvement in the assessment tests. This study excluded those who presented a respiratory pathology, cardiac, systematic (hypertension, diabetes, viral infections, *etc.*), or metabolic disease, history of recent surgery (in the last year), vertebral fracture, or osteoarticular disorders of the spine area.

2.3. Randomization

Randomization was performed using a computer-generated random sequence table with a balanced three-block design (GraphPad Software, Inc., CA, USA). An independent researcher generated the randomization list, and a member of the research team who was not involved in the assessment of the participants or the intervention was in charge of the randomization and maintained the list. The patients included were randomly assigned to one of the three groups using the random sequence list, ensuring concealed allocation.

2.4. Blinding

The assessments and interventions were performed by different physical therapists. The evaluator was blinded to the participants' group assignment. All the intervention procedures were performed by the same physical therapist who had experience in the field and was blinded to the purpose of the study. All participants were blinded to their group allocation.

2.5. Interventions

2.5.1. MI

The participants who carried out the MI training performed 10 sets of 1 min per set. In each minute of imagining, participants had to imagine themselves, as the first person, kinesthetically (*i.e.*, trying to feel at all times what they were imagining), forcibly taking in air and pulling it out by inflating a balloon as hard as they could. The imagination process lasted for an uninterrupted duration of 50 s. For the remaining 10 s, participants had to imagine taking in as much air as possible by expanding their chest box as much as they could to perform a forced expiration technique (high expiratory flow technique known as FET). During the intervention, the physical therapist gave small neutral guidelines such as "*keep imagining*," or "*try to feel what you are imagining*" (Figure 1).

2.5.2. AO

The participants in the AO group performed the same exercise intervention as the MI group, but instead of imagining the motor gestures, they had to observe a person performing the respiratory exercises. The duration and distribution of the intervention were the same as in the MI group (10 sets of 1 min per set) (Figure 1).

2.5.3. Sham observation (SO)

Participants in this group underwent a SO protocol. A video only composed of nature images was visualized for 10 min, without visualizing any motor gesture. This kind of SO protocol has been used in previous research [34,35] (Figure 1).

2.6. Smoking index

The pack per year index is a smoking load tool for lifetime tobacco exposure. A pack per year index is defined as 20 cigarettes smoked every day for 1 year. It was calculated using the formula (number of smoked cigarettes per day × number of years smoking)/20 [36]. The levels of the smoking index were mild (<5 packs), moderate (5 – 15 packs), or strong (>16 packs).

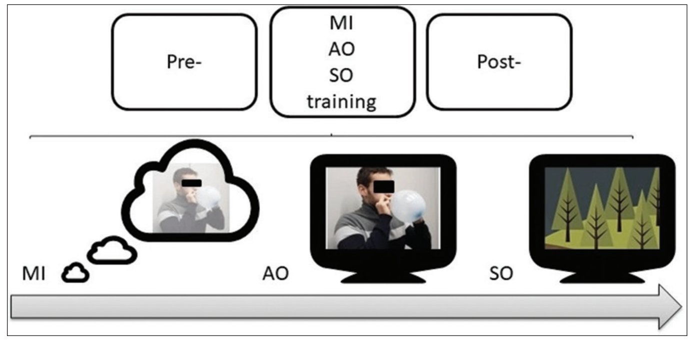

Figure 1. An illustration of the intervention.
Abbreviations: AO: Action observation; MI: Motor imagery; SO: Sham observation.

2.7. Outcome measures

2.7.1. Baseline variables

(A) Physical activity levels

The level of physical activity was objectified through the International Physical Activity Questionnaire (IPAQ), which allows the participants to be divided into three groups according to their level of activity: high, moderate, and low or inactive [37]. This questionnaire has shown acceptable validity and psychometric properties to measure total physical activity. Therefore, the psychometric properties of the questionnaire were accepted for use in studies that required the measurement of physical activity; reliability was approximately 0.65 (r = 0.76; 95% CI 0.73 – 0.77) [38].

(B) Imagery ability

The movement imagery questionnaire-revised (MIQ-R) is an 8-item self-report inventory used to assess visual and kinesthetic MI ability. Four different movements are included in the MIQ-R, which comprises four visual and four kinesthetic items. Each participant rated the ease or difficulty of generating the mental image on a 7-point scale in which 7 indicated "very easy to see/feel" and 1 "very difficult to see/feel." The internal consistencies of the MIQ-R have been adequate, with Cronbach's α coefficients ranging above 0.84 for the total scale, 0.80 for the visual subscale, and 0.84 for the kinesthetic subscale [39].

2.7.2. Primary outcomes

(A) Pulmonary function

Pulmonary function was assessed by performing forced spirometry (Spirodoc, Medical International Research, Roma, Italy) following the American Thoracic Society's (ATS) criteria [40] to obtain the following parameters: forced expiratory volume during the 1st s (FEV_1), forced vital capacity (FVC), forced expiratory ratio (FEV_1/FVC), maximum voluntary ventilation (MVV), and peak expiratory flow (PEF). The patient was seated in a chair with the backrest supporting his back, and during the respiratory maneuvers required to perform spirometry, nasal clips were placed to prevent air leakage through the nose. The participant was then instructed to undertake an initial maximal inspiration to reach total lung capacity, followed by a forced maximal expiration for at least 6 seconds until its expiratory limit was reached. To ensure proper test execution, the maneuver was repeated at least three times (up to a maximum of eight times), with a 1-min break in between repetitions. As advised by the ATS, spirometry maneuvers with performance artifacts or variations of more than 0.150 L between the highest FEV_1 and/or FVC values were discarded. The three repeats' greatest value was recorded (Figure 2).

2.7.3. Secondary outcomes

(A) Maximal inspiratory (MIP)/expiratory pressure (MEP)

The MIP and MEP pressures were measured using a digital respiratory dynamometer (MicroRPM, CareFusion, Basignstoke, UK) [41]. To minimize air leakage through the nose during testing, nasal clips were placed on the subjects who were seated. Patients were instructed to exert their hardest possible inhalation and exhalation efforts and hold them for at least 1.5 seconds. To obtain the maximum value of three maneuvers with <10% variation, MIP was evaluated at residual volume and MEP at total lung capacity according to the ATS statement [41] (Figure 2).

(B) Perceived fatigue

We employed the Visual Analog Scale of fatigue (VAS-f) to quantify the participants' perceived fatigue after performing the training session. The VAS-f uses an analog scale of 0 – 100 mm, with 0 representing minimum fatigue (no fatigue) and 100 representing maximum fatigue. The VAS-f scale is useful, sensitive, and easy to apply [42].

2.8. Procedures

Each participant completed an informed consent document to participate in the study, in addition to a set of questionnaires to complete before starting the intervention. These questionnaires included the IPAQ form and a questionnaire about age, gender, weight, height, and smoking index. Then, MIQ-R was assessed. Each participant was then seated and underwent an assessment of pre-intervention outcome measures (pulmonary function tests through forced spirometry and maximal static respiratory pressure). At this time and in a sitting position, patients performed the MI training, AO protocol, or SO according to the randomized allocation. Immediately after the intervention, a blinded evaluator measured all outcome measures (post-intervention). In addition, just at the end of the intervention, perceived mental training fatigue was also assessed.

Figure 2. An image of a participant performing the pulmonary function tests. On the left, the maximal static pressure strength is assessed. On the right, forced spirometry is performed.

2.9. Data analysis

The statistical data analysis was performed using statistical SPSS software version 25.0 (SPSS Inc., Chicago, IL, USA). The normality of the variables was evaluated by the Shapiro – Wilk test. Descriptive statistics were used to summarize the data for continuous variables and are presented as mean ± standard deviation, with 95% confidence interval. The categorical variables are presented as absolute (number) and relative frequencies (percentage). A two-way repeated measures analysis of variance (ANOVA) was conducted to study the effect of the between-participant "intervention group" factor on each of the three categories (MI, AO, and SO) and the within-participant "time" factor, as well as on each of two categories (pre- and post-intervention) of all the dependent variables. A *post hoc* analysis with Bonferroni correction was performed in the case of significant ANOVA findings for multiple comparisons between variables. Effect sizes (*d*) were calculated according to Cohen's method, in which the magnitude of the effect was classified as small (0.20 – 0.49), moderate (0.50 – 0.79), or large (0.8) [43]. The α level was set at 0.05 for all tests. In addition, we compared the baseline variables between groups with a one-factor ANOVA to explore whether the groups were homogeneous at the start of the study. The perceived fatigue outcome measure was also explored with a one-factor ANOVA.

3. Results

A total of 27 mild smokers participants were included and were randomly allocated into three groups of 9 participants per group. All the variables presented a normal distribution. No statistically significant differences were found between groups for any of the primary variables, demographic data or self-report variables were present at baseline between the groups (Table 1). There were no adverse events reported in either group.

3.1. Pulmonary function

3.1.1. FEV_1

The ANOVA revealed significant changes in the FEV_1 (L) parameter during time ($F = 10.52$, $P = 0.003$, $\eta_p^2 = 0.305$) and also during group * time interaction ($F = 3.39$, $P = 0.049$, $\eta_p^2 = 0.221$). The *post hoc* analysis revealed significant within-group differences in the AO group with a moderate effect size

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(mean differences [MD] = 0.37 L (0.17 – 0.56), P = 0.001, d = 0.51). In addition, the *post hoc* analysis revealed significant inter-group differences between the AO and MI group with a large effect size (MD = 0.724 L (0.07 – 1.37), P = 0.026, d = 1.41) (Figure 3).

Moreover, the ANOVA revealed significant changes in the FEV_1 (%) parameter during time (F = 6.74, P = 0.016, η_p^2 = 0.22) but not, during group * time interaction (F = 1.93, P = 0.16, η_p^2 = 0.11). The *post hoc* analysis revealed significant within-group differences in the AO group with a large effect size (MD = 8.55% (2.69 – 14.4), P = 0.006, d = 0.99). This implies that participants who underwent AO training significantly increased their expiratory air volume in the 1st s after the end of the intervention.

3.1.2. FVC

The ANOVA revealed significant changes in the FVC (L) parameter during time (F = 6.35, P = 0.019, η_p^2 = 0.20) but not, during group * time interaction (F = 1.68, P = 0.20, η_p^2 = 0.10). The *post hoc* analysis revealed significant within-group differences in the AO group with a trivial effect size (MD = 0.1 L (0.02 – 0.16), P = 0.008, d = 0.13).

Moreover, the ANOVA revealed significant changes in the FVC (%) parameter during time (F = 5.08, P = 0.033, η_p^2 = 0.17) but not, during group * time interaction (F = 1.19, P = 0.32, η_p^2 = 0.08). The *post hoc* analysis revealed significant within-group differences in the AO group also with a trivial effect size (MD = 1.89% (0.30 – 3.47), P = 0.021, d = 0.17). The results seem to show that the forcibly assessed vital capacity increased slightly in the participants who undertook AO training.

3.1.3. FEV1/FVC ratio

The ANOVA revealed no significant changes in the FEV_1/FVC ratio parameter during time (F = 3.2, P = 0.08, η_p^2 = 0.12) and during group * time interaction (F = 0.57, P = 0.56, η_p^2 = 0.04).

3.1.4. MVV

The ANOVA revealed no significant changes in the MVV parameter during time (F = 1.73, P = 0.20, η_p^2 = 0.06) and during group * time interaction (F = 0.51, P = 0.60, η_p^2 = 0.041).

3.1.5. PEF

The ANOVA revealed significant changes in the PEF parameter during time (F = 13.77, P = 0.001, η_p^2 = 0.36), but not during group * time interaction (F = 1.61, P = 0.21, η_p^2 = 0.11). The *post hoc* analysis revealed significant within-group differences in the AO group with a small effect size (MD = 0.74 L/s (0.29 – 1.18), P = 0.002, d = 0.42) (Figure 4). The results showed that peak exhaled airflow increased slightly after AO training.

3.2. Maximal respiratory pressure

3.2.1. MIP

The ANOVA revealed no significant changes in the MIP measurement during time (F = 0.35, P = 0.55, η_p^2 = 0.01) and during group * time interaction (F = 1.79, P = 0.18, η_p^2 = 0.13).

Table 1. Descriptive statistics of sociodemographic and baseline data

Measures	MI (*n*=9)	AO (*n*=9)	SO (*n*=9)	*P*-value
Age	21.6±3.6	24.6±4.2	20.9±1.1	0.057
BMI (kg/m²)	24.5±3.7	21.6±3.8	23.9±2.5	0.173
Smoking index	2.3±1.5	2.2±1.7	1.4±1.0	0.314
IPAQ	2517.1±407.0	1861.6±397.7	2326.5±836.8	0.069
MIQR-T	46±4.6	47.0±4.0	46.5±4.7	0.895
MIQR-K	22.7±2.4	23.0±2.5	23.3±2.6	0.88
MIQR-V	23.2±2.4	24.0±1.8	23.2±2.5	0.71
Gender				0.09
Male	1 (11.1)	2 (22.2)	5 (55.6)	
Female	8 (88.9)	7 (77.8)	4 (44.4)	

Abbreviations: AO: Action observation; MI: Motor imagery; SO: Sham observation; m: Meter; kg: Kilogram; BMI: Body mass index; MIQR: Movement Imagery Questionnaire-Revised; T: Total; K: Kinesthetic subscale; V: Visual subscale; IPAQ: International physical activity questionnaire.

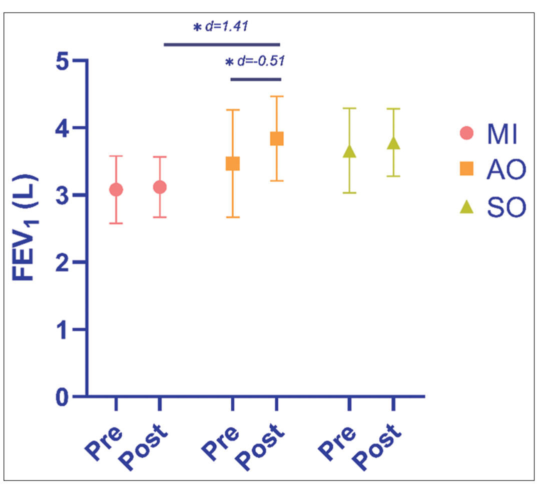

Figure 3. Results of FEV_1.
Abbreviations: FEV_1: Forced expiratory volume during the 1st s; L: liters; AO: Action observation; MI: Motor imagery; SO: Sham observation.

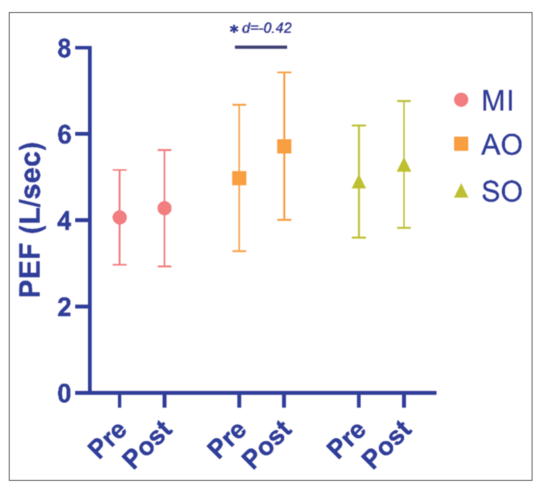

Figure 4. Results of PEF.
Abbreviations: PEF: Peak expiratory flow; L/s: Liters per second; AO: Action observation; MI: Motor imagery; SO: Sham observation.

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3.2.2. MEP

The ANOVA revealed significant changes in the MEP measurement during time (F = 3.95, P = 0.048, η_p^2 = 0.144) but not, during group * time interaction (F = 1.26, P = 0.30, η_p^2 = 0.09). The *post hoc* analysis revealed significant within-group differences in the AO group with a small effect size (MD = 11.22 cmH_20 (0.19 – 22.2), P = 0.046, d = 0.33). The MI group showed an increase in MEP variable, but it was not statistically significant (MD = 5.33 cmH_20 (−5.7 – 16.3), P = 0.33) (Figure 5). The results showed that peak expiratory pressure increased slightly after AO training.

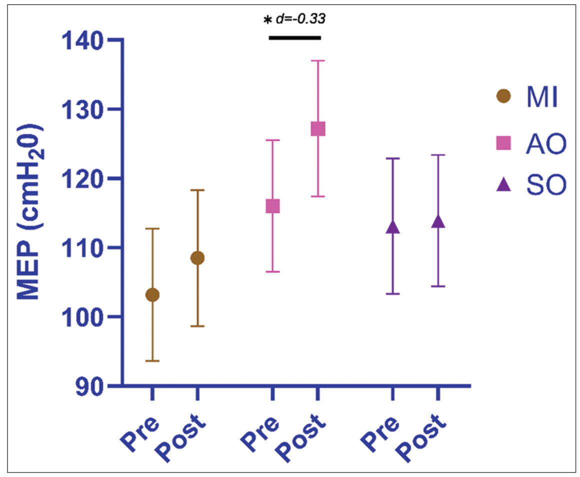

Figure 5. Results of maximal expiratory pressure variable. Abbreviations: MEP: Maximal expiratory pressure; AO: Action observation; MI: Motor imagery; SO: Sham observation; cmH_20: Centimeters of water pressure.

3.3. Perceived fatigue

With regard the perceived fatigue, the one-way ANOVA showed statistically significant differences (F = 10.6, P < 0.001). The *post hoc* analysis showed statistically significant between-group differences in AO group in comparison with SO group and also in MI group in comparison with SO group both with a large effect size (MD = 17.5 (1.8 – 33.3), P = 0.026, d = 1.45, and MD = 28.0 (12.2 – 43.7), P < 0.001, d = 2.58, respectively), showing greater levels of perceived fatigue in mental practice groups (Figure 6).

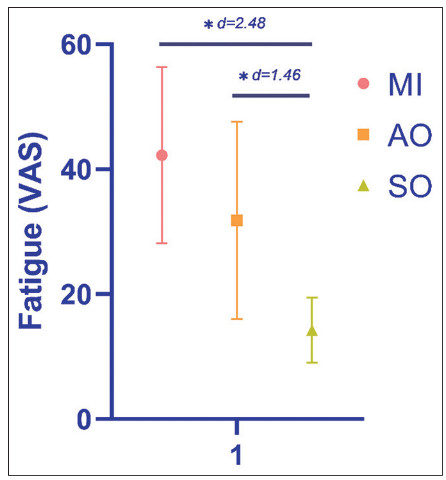

Figure 6. Results of post-intervention perceived fatigue. Abbreviations: VAS: Visual Analog Scale; AO: Action observation; MI: Motor imagery; SO: Sham observation.

3.4. Sample size calculation

The sample size was estimated with the program G * Power 3.1.7 for Windows (G * Power© from University of Dusseldorf, Germany) [44]. The sample size calculation was considered as a power calculation to detect between-group differences in a primary outcome measure (FEV_1). We considered 3 groups and 2 measurements for primary outcomes to obtain 95% statistical power (1-β error probability) with an α error level probability of 0.05 using ANOVA of repeated measures, between factors, and an effect size of η_p^2 = 0.221 obtained from our results. This generated a sample size of a total of 45 participants (15 per group).

4. Discussion

The main objective of this pilot study was to assess the effects of MI and AO in isolation on respiratory function in mild smokers. Regarding pulmonary function parameters, the results showed that AO training caused a significant increase in the FEV_1 pre-post-intervention as an absolute value with a moderate effect size. This result was not observed for either the MI group or the SO group. Furthermore, if we look at the FEV_1 value as a percentage of the theoretical values, the AO group showed a statistically significant pre-post intervention increase with a large effect size. This result was also not found in the MI and SO groups. Moreover, this increase in FEV_1 in absolute value was significantly greater than that found by the MI group at the post-intervention time. With respect to FVC, significant pre-post-intervention differences were found only in the AO group, although with an almost negligible effect size. Concerning the PEF parameter, only the AO group showed a significant pre-post-intervention increase with a small effect size. Neither the MI group nor the SO group showed significant intra-group differences in these variables. However, no significant differences were found in either group for FEV_1/FVC ratio parameter nor for MVV. Regarding the maximal static respiratory pressure, only the AO group showed statistically significant differences with respect to MEP with a small effect size. However, these differences were not statistically superior to the MI and SO groups. In relation to MIP, no significant differences were found in either intervention group. Finally, both mental training groups (AO and MI) showed greater perceived fatigue than the SO group, featuring differences with a large effect size.

These results seem to indicate that AO training has a slight impact on some pulmonary function parameters, as well as on MEP. It is likely that the improvement in MEP will translate into an improvement in some parameters of forced spirometry such as PEF or FEV_1. As the improvement in strength seems to be slight, the improvement in some pulmonary parameters also seems to be minimal. At this point, it is important to answer the question why mental training, such as AO training in isolation, could have an

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impact on maximal strength variables and pulmonary volumes and flows. Several research studies indicate that both mental practice techniques (MI and AO) provoke a neurophysiological activation of the areas related to the planning and adjustment of voluntary movement in a way very similar to when the execution is carried out [3,4,45]. This is due to the activity of mirror neurons, discovered by Rizzolatti *et al.* in the 1990s [46]. This mirror neuron system seems to function more efficiently through AO training than through MI, as it is less demanding, in terms of cognitive load, to maintain an image than to create and also maintain it [45]. This could be a justification for why AO training elicits greater changes than MI when both are applied in isolation. In previous research, we found that AO elicits greater and longer-lasting motor learning than MI [21], as well as a better sense of short-term cervical joint repositioning [22]. With respect to the other variables, AO training appears to lead to greater pain modulation, as well as greater heart rate response in patients with cervical pain, as compared with MI [47]. In addition, Cuenca- Martínez *et al.* [45] commented that some variables could influence the process of building a movement image, such as motor experience. The musculature involved in breathing seems difficult to train, and therefore, visual input could be more effective than direct imagination when a motor gesture is complex to perform, as could be the training of the respiratory musculature, both at tidal volume and in a forced manner. This could also partly justify why the MI group did not show intra-group differences. Movement is a cortical expression because it is planned before it is executed. The voluntary initiation of both imagined/observed and actual action is linked to breathing. It is suggested that the respiratory system is involved in these processes of voluntary movement planning regardless of whether it culminates in overt movements [48].

Perceived fatigue was also assessed, with the aim of confirming that the participants undergoing mental practice training, specifically the MI group, were actually performing the MI protocol. It has been widely reported that mental fatigue could be the main determinant of MI [45,49], because the person would stop imagining in conditions of high mental fatigue, especially in motor gestures with great difficulty, or if the time of the imagining task is maintained in a sustained manner. This was also argued earlier by Buccino [2], who advocates that MI has some intrinsic limits that AO training does not exhibit because MI is a more demanding tool, in terms of attention and concentration, compared with AO training. The loss of attention, as well as the difficulty of the breathing training exercises, could explain the poor effect of MI in this study.

At the clinical level, it appears that AO training has an impact on the activity of the expiratory musculature that results in a slight improvement in maximal strength that also appears to translate into small improvements in some pulmonary function parameters. Although it is still early to draw solid conclusions, AO training could be used in combination with respiratory exercise to see if the effect is greater than exercise alone. For example, in other populations such as patients with acute cerebral infarction, mental practice in combination with a conventional rehabilitation program has been shown to elicit a greater clinical effect, including improved blood oxygen to brain tissue, than the conventional rehabilitation program alone as assessed with functional near-infrared spectroscopy (fNIRs) technology [50]. In addition, in patients where actual therapeutic exercise is not possible (e.g., bedridden, or after surgery), mental practice training could be performed with the aim of minimizing the impact of immobilization. However, research studies should be carried out to determine these effects in different clinical populations with ventilatory disorders, such as chronic obstructive pulmonary disease, asthma, and lung cancer, and also to evaluate the medium- and long-term impact.

The present study has some limitations that should be taken into consideration. First, the main limitation is the small sample size. Probably, a larger sample would give slightly different results although this is only an assumption. This pilot study was used to make an estimate of the sample size and we found that the final study should contain at least 15 participants for each group. Second, this study has a theoretical perspective with the aim of looking at the impact of mental practice in isolation. To have a more clinical perspective, future studies should evaluate whether the combination of movement representation techniques with actual respiratory training would lead to an improvement of exercise capacity or assess the impact of airway disease on health status and perceived wellbeing, as compared to actual exercise in isolation. Finally, the results were derived from the analysis of the very short-term data. Future studies should include a follow-up to see if the changes generated by the intervention are sustained over time. For all these reasons, the results should be interpreted with caution as this is a preliminary study.

5. Conclusions

AO training has a slight impact on some pulmonary function parameters, such as FEV_1, FVC, or PEF, as well as on MEP when applied in isolation and in a single session. The impact of MI seems almost non-existent, at least in isolation and in a single session. At the clinical level, it seems that AO training has an effect on the activity of the expiratory musculature, resulting in a slight improvement in maximal strength that also appears to translate into small improvements in some pulmonary function parameters. Future studies should combine AO with breathing exercises to assess whether the effects are more pronounced than those stemming from breathing exercises in isolation.

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Conflict of Interest

None declared.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of Research in Humans of the Ethics Commission in Experimental Research of

University of Valencia (number: 2301127). Signed written consent was obtained from the participants before the start of this study.

Consent for Publication

Signed consent was obtained from the participants to use their images and their data for this study.

Availability of Data

Data are available from the corresponding author upon reasonable request.

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