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"Will you draw me a pelvis?" Dynamic neuro-cognitive imagery improves pelvic schema and graphic-metric representation in people with Parkinson's Disease: A randomized controlled trial

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ABSTRACT

Background: Body schema (i.e., the mental representations of the body), vital for motor and cognitive functions, is often distorted in people with Parkinson's disease (PD). Deficits in body, and especially pelvic, schema can further exacerbate motor and cognitive deficits associated with PD. Such deficits, including those in graphic and metric misjudgments, can manifest in drawing tasks. Mental imagery is a recommended approach for PD rehabilitation with potential for ameliorating body schema.

Objective: To investigate the effect of a two-week dynamic neuro-cognitive imagery (DNI) training versus in-home learning and exercise control (learning/exercise) on pelvic schema and graphic representation (i.e., drawing height and width).

Design: Twenty participants with idiopathic PD (Hoehn&Yahr I-III; *M* age: 65.75 ± 10.13) were randomly allocated into either a DNI or a learning/exercise group. Participants were asked to complete the "Draw Your Pelvis" test in which they drew their pelvis at pre- and post-intervention. Drawings were assessed for pelvic schema score and drawing dimensions (i.e., height and weight).

Intervention: DNI anatomical and metaphorical imagery focusing on pelvic anatomy and biomechanics.

Results: No difference ($p > .05$) was detected at baseline between drawn pelvis height and width. Following intervention, improvements were greater in the DNI group for pelvic schema ($p < .01$), drawn pelvic width ($p < .05$) and width-height difference ($p < .05$).

Conclusions: This study suggests that DNI could serve as a rehabilitation path for improving body schema in people with PD. Future studies should explore DNI mechanisms of effect and the effect of enhanced pelvic schema on motor and non-motor deficits in this population.

1. Introduction

Body schema refers to the mental representations of the body and its parts, including anthropometric and metric aspects,[1] in relation to each other and to the environment.[2,3] As such, body schema inherently involves mental imagery[3] (MI; i.e., the cognitive process of creating and using images and metaphors in the mind,[4] including of one's own body[5,6]). Complementary to that, MI is thought to activate body schema-related brain pathways.[1,2] Whole-body schema consists of representations of the individual body parts[1,5] and is induced by and relies on motor and sensory inputs (e.g., visual, auditory, tactile),[1] both real and imaged.[3,7] Thus, body schema can be modified by sensorimotor experiences through somatosensory integration.[1,8] Body schema is a vital component for motor planning, execution, and control,[9,10] and is a prerequisite for efficient human function.[1,11]

Inaccurate body schema may affect the one million Americans with Parkinson's disease (PD). Up to 63% of people with PD experience sensory/perceptual deficits,[12,13] including impaired proprioception and kinesthesia.[12,13] Such faulty inputs, observed in people with PD,[3] facilitate physical misperceptions,[13] impaired bodily sensations,[14] and inaccurate body schema.[15–18] Deficits include the metric perception of one's own body parts (e.g., hand).[1] Body schema deficits[3,17,19] can

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further exacerbate motor and cognitive deficits associated with PD,[15,20,21] including deficits in MI.[22] For example, people with PD have exhibited deficits in judging aperture width and passability relative to their body size.[21,23] Such deficits may be related to body, and especially pelvic, schema misperception and, specifically, a potential faulty metric judgement of the width of the body/shoulders/pelvis. Thus, accurate body, and especially pelvic, estimation and schema seem to be important for motor-related decision-making processes.

Drawing tests are thought to represent the stereotypical image (i.e., perceived schema) of the drawn object in the drawing person's mind.[24] Specifically, the drawing of figures (e.g., a clock or a pelvis) requires motor and cognitive skills, including visuospatial functions[25] and MI.[26] Therefore, deficits in body parts schema, including graphic and metric judgments, may manifest in drawing tasks.

Drawing tests have been used for assessing cognitive functions, including visuospatial skills, in PD.[27] Specifically, dimensions (i.e., height and width) of drawings have been used as a measure for identifying cognitive impairments in neurological populations.[28] Faulty graphic representations, such as graphic hypometria (i.e., small graphic depictions) reported in people with PD,[29] could, therefore, reflect faulty metric (thus perceptual) representations and judgements of the body or its parts, potentially also linked with PD-related hypometric movements. Faulty metric representation in people with PD could likewise take the form of graphic dysmetria (i.e., distorted drawn dimensions);[30] for example, equal magnitude of drawn pelvic height and width could imply overestimation of height compared to width, given the rectangular shape of the pelvis with a width:height ratio of 1.37-1.46.[31] Such graphic dysmetria was evident in pelvic drawings done by people with PD, where drawn pelvic width did not significantly differ in magnitude from its height (Abraham et al., under review). This investigation also found that drawn pelvic width was negatively correlated with, and predicted, pelvic schema in this population. That said, metric overestimation could be considered as a "normal" phenomenon which can be found in healthy adults.[1]

Among the suggested factors affecting drawing dimensions are attentional and MI deficits,[32] which could be explained by the latter involved in initiating the imaged inputs (including awareness) that affect body schema and drawing dimensions.

The pelvis has a fundamental role in human posture and locomotion. The high prevalence of postural deformities and pelvic dysfunctions, including in gait,[33] exhibited by people with PD could be associated with pelvic schema deficits or misperceptions. Obtaining more accurate pelvic schema, therefore, seems to be important for a variety of functions in this population. Yet, to date pelvic schema has received limited attention in PD assessment and rehabilitation.[14] It is not clear whether or to what extent pelvic schema deficits and graphic hypometria in people with PD can improve following therapy.[34] Some anecdotal evidence suggests that there have been improvements in whole-body schema (as exhibited by human figure drawings) following electromagnetic fields therapy.[17,18] The development of innovative, non-pharamcological therapies focusing on pelvic awareness and schema for people with PD is thus warranted.[13,19]

MI, and especially kinesthetic MI, is a recommended approach for PD rehabilitation[35–37] due to its potential for using and recruiting attentional/cognitive strategies. Thus, MI can affect motor learning and execution[36,38] and address the inferiority of kinesthetic information and cues and their processing in people with PD.[1] The advantages of MI include high availability for participants with physical limitations, low financial costs, and no need for special equipment. MI-based rehabilitation regimens for people with PD show promise[36] of being highly relevant with potentially better cost-effectiveness than physical therapy in PD.[38] Specifically, MI training targeting proprioceptive and kinesthetic awareness holds potential for enhancing body awareness[1,2] and affecting formation of body schema.

Dynamic Neuro-Cognitive Imagery (DNI; also known as "The Franklin Method"[6]) is a systematic imagery-based training method for postural and movement retraining.[39] DNI teaches participants functional human anatomy and biomechanics, and how to integrate this knowledge into movement and activities of daily living. DNI emphasizes kinesthetic and cognitive self-awareness, thus addressing and promoting more accurate body schema. For this purpose, DNI uses different types of MI (e.g., anatomical, metaphorical, etc.).[6,40] While the feasibility of DNI as a rehabilitative training method for people with PD and its efficacy in improving motor and non-motor functions in people with PD has been demonstrated,[39] its effect on improving body schema has not been explored to date.

The goals of the current study were the following: 1) Provide data regarding pelvic schema scores in people with PD; and 2) Investigate the effect of an intensive, 2-week DNI training (experimental) versus an in-home learning and exercise program (control) on pelvic schema and drawn dimensions (i.e., pelvic width, height, and width:height ration) in this population.

We hypothesized that participants in the DNI group would exhibit gains in pelvic schema and drawn dimensions (i.e., pelvic height, width, and width:height ratio), with no such gains exhibited in the control group.

2. Methods

The study was approved by Emory University School of Medicine Institutional Review Board. All participants provided written informed consent prior to participating in the study.

2.1. Participants

Power analysis was based upon a previous study on motor imagery conducted in 23 people with PD (H&Y: 1.5–3).[36] The observed improvement in TUG was ($t = 3.80$, $df = 40$, $p = 0.0005$, Cohen's $d = 1.2$). Thus with a total of $n = 16$ participants (8 in each group), a repeated measures Analyses of Variance (ANOVA) with 2 levels of repeat (time-points) will be sensitive to between-within interaction main effect size of $f = 0.6$ ($F_{(1,6)} = 5.98$) with a power of 0.80 at $\alpha = .05$. 20% attrition was assumed, and therefore an additional 4 participants (2 more per group) were recruited.

Participants were recruited from the local community through patient support groups, educational events, word of mouth, and the Michael J. Fox Foxfinder website. Inclusion criteria comprised a clinical diagnosis of PD based upon established criteria,[41] 40 years of age and more; asymmetric manifestations of at least 3 of the 4 PD cardinal signs (i.e., rigidity, bradykinesia, tremor, and postural instability); demonstrated, clear symptomatic benefit from antiparkinsonian medications (e.g., levodopa);[42] Hoehn and Yahr stages I-III; a score of 27 or greater on the Montreal Cognitive Assessment (MoCA) indicating sufficient cognitive level;[43] sufficient communication skills to engage in group practice and enable following verbal instructions; and an ability to walk three meters or more with or without assistance. Exclusion criteria were other medical conditions prior to the PD onset causing persistent disability. After participants were assessed for eligibility, they were randomly allocated (using computer software) to DNI (experimental) or in-home learning and exercise intervention (control; herein referred to as "learning/exercise") with an equal number of participants allocated to each group. Participants were notified about their group allocation only retrospectively for maintaining allocation concealment.

2.2. Design

Participants were assessed at pre-intervention (one week before the intervention began) and post-intervention (2–5 days after the intervention ended) while in the self-reported, optimal "ON" state. Participants were asked to maintain their medical and physical routines for the duration of the study. Raters were blinded to participant group allocation during both assessments.

Participants' assessment at baseline included: The Movement Disorders Society Unified Parkinson's Disease Rating Sub-Scales I-IV (MDS-UPDRS I-IV);[44] The Montreal Cognitive Assessment (MoCA)[27] for assessing cognitive impairment and is valid and reliable in people with PD[27] with a score of 27 or greater is considered a normal screen for cognition;[43] Beck Depression Inventory-II (BDI-II)[45] for assessing depression severity; The Activities-Specific Balance Confidence Scale (ABC)[46] for measuring balance-related confidence. More details about these tests can be found in Appendix 1.

Mental imagery ability was measured using the Movement Imagery Questionnaire–Revised Second Version (MIQ-RS)[47] for assessing level of visual and kinesthetic imagery ease/difficulty in people with movement limitations; the Kinesthetic and Visual Imagery Questionnaire (KVIQ-20)[48,49] for assessing clarity of the visual imagery and intensity of the sensations associated with a movement imaged in people with restricted mobility; and the Vividness of Movement Imagery Questionnaire-Revised Version (VMIQ-2)[50] for assessing the vividness of three modes (i.e., external visual, internal visual, and kinesthetic) of movement imagery. More details about these tests can be found in Appendix 1.

The "Draw Your Pelvis" test was delivered to all participants at pre- and post-intervention. The "Draw Your Pelvis" test is a drawing test for quantitatively assessing pelvic schema in people with PD (Abraham et al., under review). The test is based on the "Human Figure Drawing" test[17,51] and other drawing assessment methods for conditions associated with specific body parts,[52] with excellent inter- and intra-rater reliability and content validity (Abraham et al., under review). The participant sat on a chair in front of a desk and was asked to draw a freehand rear view of his/her own pelvis (Fig. 1) using a black ink pen on a half blank A4 page (with no frame). The exact instruction was, "In the space below, please draw a view of your pelvis from behind. You may draw the external frame/shape of it only or add as many details as you can."

Pelvic schema was scored by raters (see "Raters and rating procedure") using a 0–5 Likert scoring scale, with greater values representing better pelvic schema. A score of 0 was given in the case of lack of a drawing. Pelvic graphic-metric representation (i.e., dimensions of the pelvic drawings; width and height) were determined by locating and marking with a pencil the highest, lowermost, rightmost, and leftmost spots of each drawing, as identified by the raters' naked eye. Then, using the points, parallel lines were drawn around the image to represent its farthest boundaries of its greatest area. The distances (in cm) between the upper and lower lines (i.e., "height") and the right and left (i.e., "width") ones were then measured using a rigid ruler. Then, width:height difference and ratio were calculated.

2.3. Raters and rating procedure

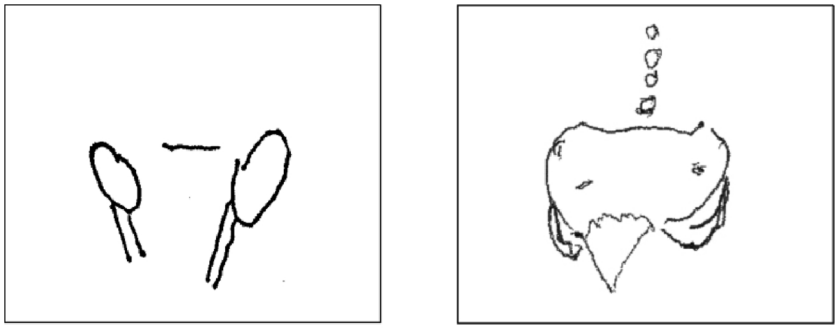
Pelvic schema was determined using the mean rating of 12 raters who scored participants' pelvic drawings individually. All raters were anatomical illustration university students (9 females, 3 males, *M* age = 20 ± 0.83 years) who were experienced in anatomical drawing (*M* education = 1.48 ± 0.36 years) and blinded to participant group allocation and measurement time (i.e., pre- or post-intervention). The researcher (AA) introduced the raters to the study goals and the "Draw Your Pelvis" rating scale. Before beginning the scoring session, raters were familiarized with the rating scale and process, and were given an opportunity to ask questions. Pelvic drawing dimensions (i.e., width and height) were measured by two additional raters (a third year doctorate of physical therapy student and a third year pre-medical undergraduate student; 2 females, *M* age = 26 ± 8.48 years). Mean values for width and height were calculated for each drawing.

2.4. Intervention

Both interventions for the experimental and control groups were conducted at the same time period and lasted for two weeks (five 2-hr sessions per week; a total of 10 sessions). During all training sessions, participants were "ON" (i.e., optimally medicated). Participants were asked to attend a minimum of 4 sessions per week (a total of 8 sessions) and to report to the researchers of any changes in their mental or physical states.

2.5. Dynamic Neuro-Cognitive Imagery (DNI)

The DNI intervention focused on MI techniques and tools for enhancing pelvic-related knowledge, kinesthetic and proprioceptive sense, and spatial self-awareness. Contents included anatomy and biomechanics of the pelvis as well as pelvic motor and cognitive impairments associated with PD,[15,21,35] such as axial kinesthesia,[53] haptic perception,[54,55] and center of mass.[13] More details about the intervention's contents are presented in Table 1. Topics were practiced using various imagery perspectives (e.g., 1st- and 3rd-person), methods (e.g., visual, kinaesthetic, auditory, etc.), and types (e.g., anatomical, metaphorical, etc.) and during different positions (e.g., standing, sitting, lying supine) and daily-living tasks (e.g., sitting down, stepping over, walking, turning.). All contents were practiced through series of exercises that included mental imagery with or without actual movement, and were frequently accompanied by self-touch, to reinforce the imagery-based contents. No drawing-related activities of any kind were practiced during the intervention.



A. Pelvic Drawing with a mean score of "1"

B. Pelvic drawing with a mean score of "2.9"

Fig. 1. An Example of Pelvic Drawings and Their Scores at Pre (*A*) and Post (*B*) Dynamic Neuro-Cognitive Imagery Intervention.

Table 1
Contents of Dynamic Neuro-Cognitive Imagery (DNI) Intervention[†]

Element	DNI Contents
Hip Joint Accurate Location	• Self-touch (touching the closest points to the actual location of the hip joint) • Using pelvic plastic models • Using DNI anatomical visual and kinesthetic imagery of the actual location of the hip joints (Fig. 2) • Embodiment of this knowledge into function (e.g., sitting, walking): imaging the movement of the lower extremities originating from the hip joint
Three-Dimensional Pelvic Structure and Motion	• DNI Metaphorical imagery: "pelvis as a bowl filled with water" (Fig. 3) • DNI anatomical and metaphorical ("sacrum and innominate shaking hands"; Fig. 4): imagery of the accessory (relative) movements between the innominate bone and sacrum • DNI metaphorical imagery for facilitating pelvic anterior and posterior tilt: "pushing the pelvis into a big pillow"
Axial Kinesthesia	• DNI anatomical and kinesthetic imagery of "Central Axis" (i.e., the axis around which body parts are organized; Fig. 5) for facilitating a better body schema
Haptic Perception	• Hand-modelling of the sacrum and innominate bones (Fig. 6)

[†] All drawings are presented with permission from Mr. E. Franklin.

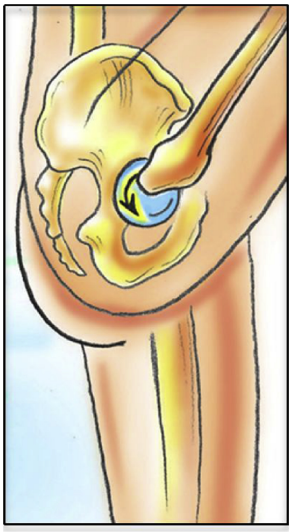


Fig. 2. DNI Anatomical-Visual Imagery of the Hip Joint.

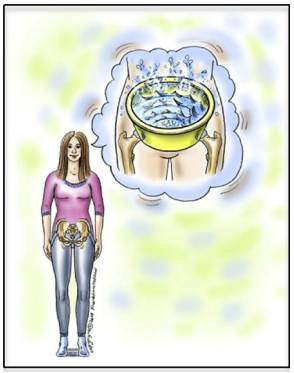


Fig. 3. DNI Metaphorical Imagery of the 3-Dimensional Shape of the Pelvis.

All sessions followed the same structure: warm-up (15 min.), DNI training–part A (35 min.), a break (10 min.), DNI training–part B (35 min.), DNI movement session using balls and elastic bands (20 min.), and a cool-down/wrap-up (5 min.). Participants were encouraged to train according to their physical competence and without risking safety. Able-bodied volunteers experienced in fall detection and prevention participated in all sessions to assure participants' safety, including offering participants manual assistance, if needed. Participants were also encouraged to practice the learned DNI exercises and techniques at home in between sessions. More details about the DNI intervention can be found elsewhere.[39]

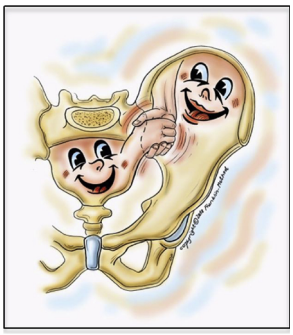


Fig. 4. DNI Metaphorical Imagery: Accessory (Relative) Movements Between the Sacrum and Innominate Bone.

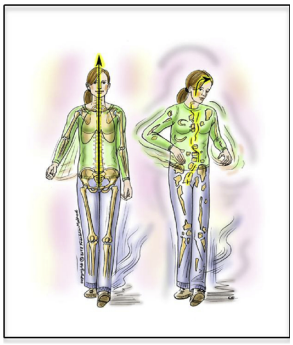


Fig. 5. DNI Kinesthetic-Metaphorical Imagery for the "Central Axis".

Fig. 6. DNI Hand Modelling for Haptic Perception of the Sacrum.

2.6. In-home learning and exercise

The learning/exercise intervention, which included frequent staff checkups, matched the time engagement and number of sessions required for the DNI group. Participants were provided with a binder of 8th-grade reading level lessons related to health and wellness, and a 30-minute exercise video consisting of standing and stepping gross and fine motor

Table 2
Participant Base-Line Demographics[†]

Sex (females:males)	4:16
Age (years)	65.75 (10.13)
Education (years)	13.6 (2.0)
Number of comorbidities	3.0 (1.7)
Number of prescription medications	4.4 (3.4)
Use of assistive device (yes:no; (percent))	7:13 (35:65)
History of ≥1 falls in past year (yes:no; (percent))	10:10 (50:50)
Duration of PD (years)	7.3 (4.2)
BDI-II	13.70 (8.77)
MDS-UPDRS Subscale I	13.45 (6.39)
MDS-UPDRS Subscale II	17.35 (5.46)
UPDRS Subscale III	35.25 (13.13)
UPDRS Subscale IV	4.05 (3.85)
UPDRS Total Score	70.10 (21.86)
Hoehn & Yahr stage, (median; first, third quartiles)	2.0 (2.0; 2.5)
MoCA (/30)	27.4 (1.9)
ABC (%)	75.70 (16.40)
MIQ-RS (/7)	
Visual	4.86 (1.64)
Kinesthetic	4.68 (1.63)
Total	4.77 (1.21)
KVIQ-20 (/5)	
Visual	3.19 (1.04)
Kinesthetic	2.86 (0.93)
Total	3.03 (0.72)
VMIQ-2 (/12-70)[Ω]	
External Visual	23.30 (12.68)
Internal Visual	30.35 (13.86)
Kinesthetic	32.05 (13.55)

[†] Values are mean (SD), unless otherwise noted; *PD* = Parkinson's disease; *BDI* = Beck Depression Inventory; *MDS-UPDRS* = Movement Disorders Society Unified Parkinson's Disease Rating Scale; *MoCA* = The Montreal Cognitive Assessment; *ABC* = The Activities-Specific Balance Confidence Scale; MIQ-RS = Movement Imagery Questionnaire – Revised Second Version; KVIQ-20 = Kinesthetic and Visual Imagery Questionnaire; VMIQ-2 = Vividness of Movement Imagery Questionnaire-2.
[Ω] Lower values represent better scores.

exercises that target PD impairments.[56] Participants were instructed to read one lesson per day (estimated time: 1.5 h) and also to do 30-minute video provided via a password-protected access to a secured internet website. If participants didn't have internet access, they were provided a DVD for viewing. Lesson topics included Research, Creativity, Exercise, Nutrition, Infectious Disease, Family Caregiving, Kidney Disease, and Health Disparities. A research assistant called participants on the telephone 3 times over the 2 weeks (evenly spaced) to confirm compliance and discuss educational content from the lessons. One participant received two calls but could not be reached for the third phone call.

2.7. Statistical analysis

The last observation (i.e., pre-intervention) was carried forward for participants (N = 2; one from each group) who did not complete a minimum of 8 of the 10 offered sessions before post-intervention. Descriptive statistics were used to calculate participant characteristics. Mean scores were calculated for pelvic schema scores (thirteen raters) and dimensions of drawings (two raters). Two-way [GROUP (DNI, learning/exercise) x TIME (pre, post)] mixed design analysis of variance (ANOVA) was used to assess the effect of the interventions on pelvic schema and graphic dimensions. Paired-samples *t* tests were used to assess the differences between pelvic drawing height and width within groups and the difference in width:height ratio between groups. Two-tailed hypotheses were used with *p* value of .05 or less regarded as significant. Effect sizes (η_p^2) and confidence intervals (95% CI) were also calculated. Data were analyzed using *SPSS* (Version 19.0, *Armork, NY: IBM Corp.*).

3. Results

Twenty participants matched inclusion criteria and participated in the study. Participant characteristics are described in Table 2. Participant recruitment and randomized group allocation is described in Fig. 7.

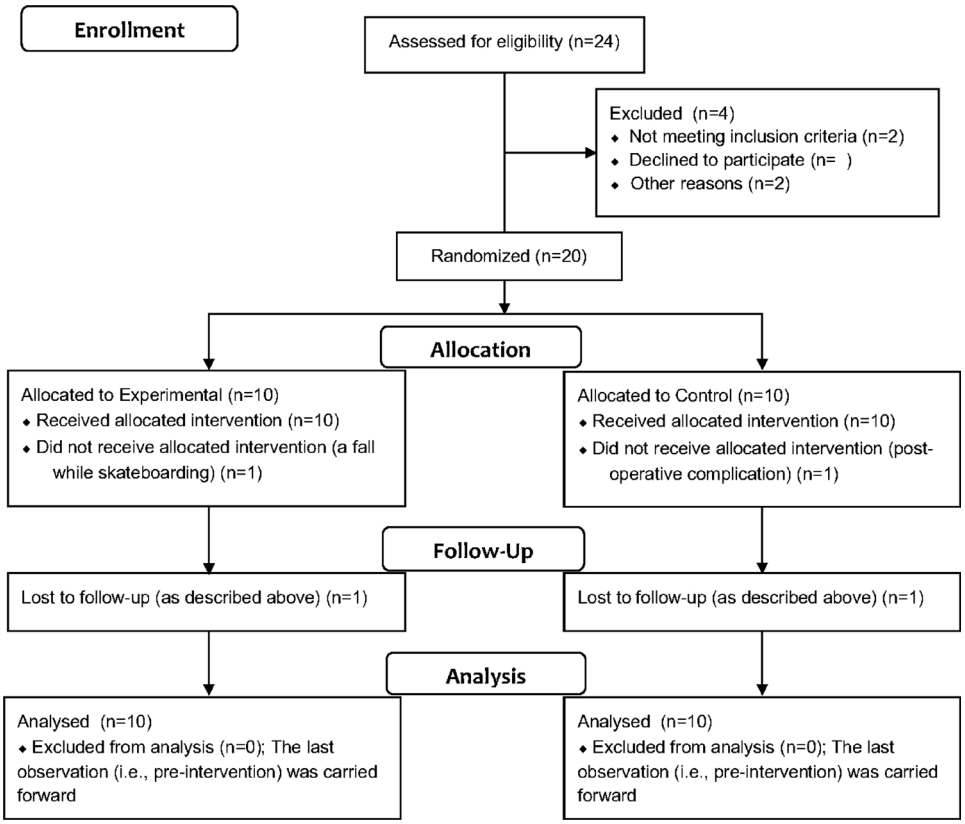


Fig. 7. Flow Chart of Participants' Recruitment and Group Allocation.

Table 3
Pelvic Drawings Dimensions and Schema at Pre- and Post-Intervention[Ω]

	DNI *M* (SD) [95% CI]	Learning/Exercise *M* (SD) [95% CI]	$F_{(1,18)}$	*P*	η_p^2
Drawn Pelvic Dimensions (cm)					
Width					
Pre	3.70 (1.21) [2.86-4.54]	3.63 (1.31) [2.79-4.47]	5.97	.02*	.249
Post	4.98 (2.05) [3.73-6.22]	3.52 (1.67) [2.27-4.77]			
Height					
Pre	4.18 (1.78) [3.08-5.27]	3.23 (1.49) [2.13-4.33]	0.54	.81	.003
Post	4.24 (1.81) [2.94-5.53]	3.48 (2.07) [2.19-4.77]			
Width-Height Difference (cm)[†]					
Pre	−0.47 (2.11) [−1.64-0.69]	0.59 (1.31) [−0.57-1.76]	4.14	.05*	.187
Post	0.74 (0.92) [−.05-1.53]*	0.04 (1.40) [−0.75-0.83]			
Width:Height Ratio					
Pre	1.01 (0.45)	1.26 (0.61)	1.31	.26	.068
Post	1.20 (0.27)	1.19 (0.30)			
Pelvic Schema (/5)					
Pre	1.66 (0.48) [1.24-2.09]	1.93 (0.77) [1.51-2.36]	8.41	.01**	.319
Post	2.66 (0.85) [2.14-3.17]	1.96 (0.68) [1.44-2.47]			

[Ω] All values were calculated using two-way mixed design ANOVA, unless otherwise stated.
* $P < 0.05$.
** $P < 0.01$.
[†] Paired-samples *t*-test.

At baseline, pelvic schema score was $1.80^{\pm}0.64$ (out of 5), pelvic drawing width and height were $3.66^{\pm}1.23$ cm and $3.70^{\pm}1.67$ cm, respectively, with no statistically significant difference between width and height ($0.04^{\pm}1.79$; $p > .05$). The width:height ratio of the drawn pelvis was $1.14^{\pm}0.54$.

Results at pre- and post-intervention based on group allocation are presented in Table 3.

Following intervention, group x time interactions were detected for pelvic drawing width ($p < .05$), pelvic drawing width:height difference ($p < .05$), and body schema score ($p < .01$), suggesting significantly greater improvements in the DNI group. An example of pelvic drawings and their scores at pre and post DNI-training is presented in Fig. 1.

4. Discussion

The current study aimed to explore the effect of DNI compared to in-home learning and exercise training on pelvic schema and graphic-metric representation in people with PD. The results suggest that the DNI, but not the learning/exercise, intervention had a beneficial effect in increasing pelvic drawing width ($p < .05$) and in improving pelvic schema score ($p < .01$). These findings suggest improvements (or reversal[17]) in pelvic schema and graphic dysmetria. Thus, the current results support pelvic schema and its graphic representation being plastic and malleable, as was previously suggested for whole-body schema.[1]

The DNI protocol followed previous recommendations in the literature for using MI[35,36] and for incorporating kinesthetic and body awareness and schema in PD rehabilitation.[13,37] Furthermore, the DNI protocol addressed specific pelvic-related schema and motor deficits associated with PD. In this way, the DNI training could serve as a similar cognitive and kinesthetic facilitator to other MI techniques.

DNI mechanisms of effect may lie in being a student-centered, experience-based method which combines cognition, tactile-kinesthesia, movement, and mental imagery. Such an approach can provide a diverse, plastic experience[57] of one's body shape, size, motion, and awareness.[1] With an allegedly improved ability to access, retrain, and modify the computations constructing body schema, a more accurate and normalized body schema can be promoted.[1] Specifically, DNI strengthened participants' internal, kinesthetic competence, thereby providing them with relevant information and skills that added to the already-existing ones. Furthermore, insofar as training in DNI directs participants' attention, awareness, and MI to key embodiment factors, such as those associated with their pelvis, pelvic schema accuracy is improved.

Attention and MI were previously shown to affect drawing dimensions,[32] thus potentially explaining the current findings regarding pelvic drawings dimensions and schema. However, the detected gains in pelvic schema and drawing dimensions could also be attributed to gains in MI ability following DNI training.[39] Another potential mechanism of effect includes DNI activating compensatory neural circuits and mechanisms to bypass the basal ganglia-supplementary motor area circuit, thus helping to compensate for self-driven, movement generation deficits. The feasibility, acceptability and clinical utility of DNI as a rehabilitative training approach for people with PD was previously established and demonstrated both motor and non-motor benefits as well as positive attitudes from the participants.[39] The current results add to these benefits and encourage further exploration of mental imagery, and DNI in particular, as a beneficial rehabilitative path for this population.

As discussed above, it is unclear at this point whether the lack of significant difference between pelvic drawing width and height evident in both groups at pre-intervention reflects pelvic graphic dysmetria[1] or a normal phenomenon.[58] Either way, at post-intervention, a significant ($p < .05$) width-height difference was detected in the DNI group only. This suggests an improved graphic-metric representation in this group (with the width greater that the height). Also interestingly, at both pre- and post-intervention, pelvic drawing width:height ratios in both groups were only slightly lower than the actual ratios found for human pelvis.[31] This finding may imply that graphic-metric representation of the pelvis, as drawn by people with PD, shares some similarities with and correlates with actual pelvic design. These ratios, however, did not change significantly in both groups following the intervention.

This study has limitations: 1) a small sample size; and 2) lack of long term follow-up. As such, this study should be considered a preliminary investigation and the results should be interpreted with caution, acknowledging the impact of these limitations on the level of evidence of this study. The above-mentioned limitations should be addressed in future studies, which should also explore the associations between improvements in body schema and reduced motor (e.g. freezing of gait[21]) and kinesthetic[13] deficits. Also, future studies should investigate the effect of DNI in other neurologic populations, such as stroke

survivors, as the current results should not be generalized to these populations in which this training approach has not been tested.

In conclusion, this study suggests that people with PD may benefit from DNI training in improving their pelvic schema and potentially graphic-metric dysmetria. DNI training approach could serve as a rehabilitation path for coping with the inferiority of kinesthetic information and cues and their processing in the PD population.[1]

5. Conclusions

This study expands knowledge regarding the role of MI training in general, and DNI in particular, in people with PD for improving pelvic schema and potentially graphic-metric representation. Future studies should further explore the associations between enhanced body schema and PD motor and non-motor deficits.

Potential conflict of interest statement

Amit Abraham is working in collaboration with the International Franklin Method Institute on developing DNI contents.

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Appendix 1. Descriptions of the Tests Administered to All Participants at Pre-Intervention

Disease Severity and Symptoms

1. The Movement Disorders Society Unified Parkinson's Disease Rating Sub-Scales I-IV (MDS-UPDRS I-IV).[44]
2. The Montreal Cognitive Assessment (MoCA)[27]–a 30-point test providing a measure of global status of cognitive impairment through the assessment of a range of executive functions including orientation, memory recall, visuospatial function, attention/concentration, and language. The MoCA achieves high sensitivity and specificity for detecting mild cognitive dysfunction[43] and is valid and reliable in people with PD.[27] If an individual had fewer than 12 years of education, they received an additional point. A score of 27 or greater is considered a normal screen for cognition.[43]
3. Beck Depression Inventory-II (BDI-II)[45]–a 21-item, self-reported questionnaire providing a measure of depression severity. The score is a sum of all ratings, with answers for each question (symptom) ranging from 0 to 3. Total scores range from 0 to 63, with higher scores represent greater depression severity.
4. The Activities-Specific Balance Confidence Scale (ABC)[46]–a 16-item questionnaire providing a self-reported measure of balance-related confidence. The questions ask about an individual's confidence in "not losing his/her balance" in life situations. Participants rate their confidence for each situation on a scale of 0% to 100%. Scores are averaged, and overall percent confidence was used for analysis.

Mental Imagery Ability

1. The Movement Imagery Questionnaire–Revised Second Version (MIQ-RS)[47]–a 14-item questionnaire that assesses visual (7 items) and kinesthetic (7 items) imagery ability in people with movement limitations, using gross movements of the trunk and extremities. The examiner first reads the task, then the participant executes the movement physically first and then imagines performing the movement visually or kinesthetically. Then, the participant scores his/her imagery ease/difficulty. A Visual Analogue Scale (VAS) ranging from 1 ("Very hard to see/feel") to 7 ("Very easy to see/feel") is used, with higher scores representing better ability/increased ease.
2. The Kinesthetic and Visual Imagery Questionnaire (KVIQ-20)[48]–a 20-item questionnaire that assesses visual (10 items) and kinesthetic (10 items) imagery ability in people with restricted mobility, using gross and fine motor tasks of the trunk and extremities. First, the examiner describes the movement and then demonstrates it. Then, the participant is asked to perform the movement, imagine it (using a first-person perspective), and rate the clarity of the visual imagery or the intensity of the sensations associated with a movement imaged. A VAS ranging from 1 ("No image/sensation") to 5 ("Image as clear as seeing/As intense as executing the action") is being used, with higher scores reflecting greater imagery ability. The KVIQ-20 was previously used to assess imagery ability in people with PD.[49]
3. The Vividness of Movement Imagery Questionnaire-Revised Version (VMIQ-2)[50]–a 36-item questionnaire that assesses the vividness of 3 modes (i.e., external visual, internal visual, and kinesthetic) of movement imagery using 12 actions. The VMIQ-2 was previously used in people with PD.[59] A VAS ranging from 1 ("Perfectly clear and as vivid as normal vision or feel of movement") to 5 ("No image at all, you only "know" that you are thinking of the skill") is used. Low scores reflect greater imagery ability.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ctim.2018.11.020.

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