**Supplementary Material**

**Implementation of a Community-Based Exercise Program for Parkinson Patients: Using Boxing as an Example**

**Supplementary Table 1.** Outline for Group Boxing Training Specific to Parkinson’s Disease

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| **OUTLINE FOR GROUP BOXING TRAINING SPECIFIC TO PARKINSON’S DISEASE** |
| **RECOMMENDED TARGET POPULATION** * Individuals with a diagnosis of Parkinson’s disease between stages Hoehn & Yahr I-III.
* Able to walk independently without major safety issues related to balance or risk of falling.
* Without significant active psychiatric problems (for example: hallucinations, confusion, or psychosis, etc.) that may be aggravated when doing boxing exercises; ability to correctly participate in the classes according to the boxing instructor’s judgment.
* Motivated and able to communicate with the trainer, to understand and comply with the boxing exercises in a group format.
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| **RECOMMENDED ASSESSMENTS** * Medical clearance before starting any type of exercise, especially if the participant has one or more risk factors for heart disease or if they have previously been inactive.
* Evaluation of the history and risk of falling, due to increased risk associated with dual task interference when boxing and standing or walking. Quick standardized assessment tools such as the Timed Up and Go test (High Risk ≥13.5s) and 5 times sit to stand test (High risk ≥16s) can be used to provide data about gait and fall risk.
* Individual exercise assessments prior to the program are useful to know participant’s general health and current and past fitness and activity levels. Identification of any physical limitations of the participant (e.g., pain associated with shoulder movement) and considering these in the individual tailoring of exercises in circuit training is recommended.
* Exercise training intensity should be defined and evaluated using the Borg RPE scale or heart rate monitors. Define overall volume of training for the group (assessed by number of prescribed exercises and repetitions).
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| **BOXING INTERVENTION GOALS*** General goals may include promoting (1) exercise for general health and wellbeing; (2) social interaction; and (3) feelings of belonging to a group.
* Performance of specific exercises to improve PD core areas such as: (1) Physical capacity; (2) Stepping and balance; (3) Gait; (4) Transfers and (5) Posture.
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| **CORE AREAS AND PRINCIPLES OF THE INTERVENTION & CONTENT OF A CLASS*****Disease specific principles:**** Preferably, focus upon combining boxing with functional-task exercises, for example: (1) sit, stand and boxing sequences; (2) walking around and over obstacles with changes in walking direction and sudden stopping in conjunction with punching; and (3) turning around in large and small spaces.
* Provide continuous augmented feedback by using verbal or non-verbal cues that may aid in maintaining amplitude, good posture and balance in movements (for example: visual cues like tape on the floor that shows where feet are to be placed in order to keep a wide base of support).
* Focus on stimulating the more affected side with additional movement repetitions on that side (learned use). Enhance body awareness to ease functionality and avoid compensation.
* Be flexible regarding learning boxing techniques. Avoid anxiety and stress due to cognitive or physical overload when teaching new activities.
* Music is a key motivator and facilitates movement. However, it is difficult to hear both the music and the instructions. Use music only during specific activities. Lower music when giving instructions.
* Allow for conversations and socialization among participants to occur.
* Inform Patients to try to work-out during ON periods or at those times of the day when they feel best and their medication is working well. Make sure they take their medication.
* Encourage ongoing vigorous exercise and physical fitness.

***Boxing-derived principles and modifications:**** Focus on punching actions that combine high-speed arm motions with trunk rotation and lower extremity stepping in different directions. Integrate movements that directly enhance physical and cognitive function.
* A more upright vertical-armed guard should be used, as opposed to the semi-crouched and full crouched positions common in contact boxing, in order to avoid exacerbating a flexed, kyphotic posture.
* Use bobbing defense maneuvers, commonly used to evade or block punches, for more effective lower limb strength training. Add isolated resistance exercises addressing large muscle groups and multiple-joints first, then include smaller muscle group exercises as well as single-joints.
* Pad training is one of the preferred training modes for Patients. Placing numbers on the pads can facilitate initial learning of the boxing sequences.
* Group activities are enjoyed and preferred over individualized circuit exercises. Increase time of activities done as a whole group such as warm-ups, collective strength training and cool down.
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| **PROGRESSING THE LEVEL OF DIFFICULTY** * Progress physical capacity by considering the number of repetitions, load or speed. Aerobic challenges should be progressed by increasing the total time spent boxing, up to 30 minutes, as well as the duration spent at moderate and vigorous intensity.
* Progressively focus on maintaining the amplitude during exercises and then add in speed-based challenges (e.g., maintaining a stable the base of support, defined by a cue/lines on the floor, reach out to punch at a given distance (amplitude), when increasing speed make sure to keep the amplitude by keeping feet in the defined base of support).
* Progressively address motor learning, from a stable to a variable task and context, from single (e.g., punch right then left) to dual task (punch right left but say out loud the opposite, i.e., punch left then right).
* The exercises should not be too difficult inducing frustration, but also not too easy for better motor learning and motivation. Consider increasing the difficulty of cognitive exercises following criteria such as: 2 or 3 errors – increase difficulty; 4 or 5 errors – maintain difficulty; or ≥ 6 errors – reduce difficulty. Additionally, a patient perceived difficulty visual analogue scale can be considered to get patient feedback on how difficult it is.
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| **PD-SPECIFIC PROBLEMS that might arise during training*** Excessive sweating with gloves might be perceived as uncomfortable. Boxing hand wraps may reduce this discomfort but imposes fine motor challenges for being able to put them on.
* Patients may report that tremor might increase during or after training due to fatigue. Typically, this will return to normal levels after the session is over.
* Alert Patients on risks of compulsive exercise behavior and excessive fatigue. Highlight the need for resting periods. If fatigue persists after sessions with prolonged recovery, training dosage should be adjusted.
* Impaired attention and executive functions may exacerbate difficulties with multitasking, which may contribute to compensation using bad postures and increase the risk of losing balance and falls. If the goal is not dual task training, avoid talking to Patients when they are moving around or exercising in less safe situations.
* Keeping balance and feet apart is difficult when distracted to punch. Place visual tape on the floor to facilitate foot correction and increase safety.
* Pair activities may generate anxiety due to fear of failure. Reduce complexity of activities when working in pairs.
* Always respect the person’s autonomy and ask what specific guidance they would like to have from the instructors and others.
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| **EMERGENCIES IN PARKINSON’S DISEASE*** Be aware of PD medical emergencies and know when to seek help or referral to other professionals, for example with:
* Significant motor fluctuations (uncontrolled violent dyskinesias; severe on-off fluctuations);
* Active psychiatric problems (for example: hallucinations, confusion, psychosis);
* Excessive daytime sleepiness and sleep attacks; or
* Orthostatic hypotension.
* Seek immediate medical attention if the Patients:
* Becomes diaphoretic;
* Reports chest pain or tightness, nausea and/or vomiting for more than a few minutes;
* Experiences unusual breathlessness, dizziness or light headedness;
* Experiences any sensation of the heart skipping or adding beats.
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| **GROUP SIZE*** A group size of 6 to 8 people at comparable levels of physical function is recommended per therapist/instructor in order to ensure positive group dynamics and safety.
* Additional helpers/volunteers may further enhance safety. Consider the help of care partners (if the Patients agrees).
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| **ORGANIZATION OF A CLASS*** Frequency and duration: Ideally it is ongoing. The program could last a minimum of 8 weeks, twice a week, for 1 hour to perceive benefits.
* Consider warming-up by walking or bicycle training.
* Consider cooling-down (relaxation) progressing from a standing to seated position.
* Circuit training can be done individually or in pairs. Should include exercises relevant to Patients but also be guided for reaching the individual goals (personal diaries can help Patients to register what exercises have been done and what progress has been made).
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| **ADAPTATIONS IN THE GYM SPACE*** Consider analyzing potential changes in the gym environment in order to positively influence the functional performance of each Patients, for example:
	+ Using cueing to minimize problems with the accessibility and mobility throughout the building and gym;
	+ Avoiding placing objects on the floor that may become a tripping hazard; and
	+ Allowing for sufficient walking space throughout the gym.
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PD, Parkinson disease; Patients, person with Parkinson’s disease.

**Supplementary Figure 1.** An example of the structure of a PD-specific boxing exercise group class.



**Adapted BOXING session for Parkinson’s disease**



**Group Warm-up** (10 minutes) **|**

Start with walking with large steps, along with large arm swings and incorporating stops and turns. Integrate whole-body amplitude movements of upper limbs with trunk rotation and stepping in multiple directions. Teach and train 4 to 6 of the traditional boxing punches in a simple rhythmic routine using music as a cue.

**ROUND 1**



**Group workout guided by coach** (20 minutes) **|**

Working together on boxing bags, Patients will alternately perform combinations provided verbally by the coach. (Example: One Patients is “A” and the other Patients is “B”; instructions are given by coach, such as A 112; then B 123; A & B 1234). Progress to speed-based movements while maintaining amplitude.

**ROUND 2**



**Group pad workout by 2 Patients** (20 minutes) **|**

Changing roles: one Patients plays the boxer (using gloves), the other Patients is the coach (using pads), then change. Includes decision-making skills using: (a) combination practice – taking turns in calling out number combinations; and (b) target practice - no talking at all; only reacting to pads that are shown by the acting coach.

**ROUND 3**

**Circuit Training** (20 minutes) **|**

Working out at specific boxing training stations that incorporate functional training activities (for example sitting and standing; walking and turning; lower limb strength with bobbing maneuvers; adding cognitive loads, etc.). 90 seconds training, 30 seconds rest and change. Reinforce large amplitude movements and progress to speed-based movements at all stations. Create new rewarding training situations every week (element of change).



**ROUND 4**

**Cool down**

 **& Breathing**

Patients, person with Parkinson’s disease