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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Characterizing intensity of a non-contact boxing session for individuals with Parkinson's disease: a cross-sectional pilot study

Zacha Ceuppens
Febe Peeters

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij neurologische aandoeningen

PROMOTOR :
Prof. dr. Peter FEYS

BEGELEIDER :
Mevrouw Louise DECLERCK

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Acknowledges

We would like to express our sincere gratitude to several people who played an essential role throughout this process. First and foremost, we are deeply thankful to our promotor Prof. Dr. Peter Feys for granting us the opportunity to be part of this study. His expert guidance, critical insights, and valuable feedback have greatly contributed to the development and quality of our thesis.

We would also like to thank Prof. Dr. Bruno Bonnechère for his assistance with the data processing. His contribution was crucial and provided a solid foundation for our research.

Nevertheless, we are very grateful to Dr. Louise Declerck for her trust in us, her invaluable support, and her close collaboration throughout this journey. Her involvement greatly enriched our work and made this experience all the more meaningful.

Lastly, we would also like to express our sincere gratitude to the organization Parkiboks Turnhout, a member of the Flemish Boxing Liga, for their cooperation and trust in the study. In particular, we thank Filip Pluym for his clear communication as the main point of contact with Hasselt University, and Kris Gabriels for his expertise as an experienced trainer during the boxing sessions. Furthermore, we would like to extend our thanks to all members of the sports club for their interest and valuable participation.

Finally, we wish to acknowledge that we consulted ChatGPT to assist us in the academic writing and formulation of certain sections of this thesis.

Research context

Over the past year, we conducted our thesis research at the Faculty of Rehabilitation Sciences and Physiotherapy at Hasselt University within the context of neurological disorders.

During our scientific internship last year, we actively contributed to the development of a new project, the submission to the ethical committee of Hasselt University and the recruitment of participants. The project is a stand-alone non-granted pilot study aimed at gaining further insights into community-based physical activity for people with Parkinson's disease.

This research initiative emerged within a broader context of growing academic and clinical interest in adaptive sports as a complementary approach to neurological rehabilitation. In recent years, the Parkiboks initiative, which combines non-contact boxing with tailored physical activity for individuals with Parkinson's disease, has gained significant visibility. This study is built on prior work by our supervisor, Dr. Louise Declerck, whose thesis focused on the role of adaptive sports in neurological rehabilitation in Belgium. Her expertise and ongoing research in this area provided important context and guidance throughout our project.

This study represents a new partnership between Hasselt University and Parkiboks Turnhout, one of nineteen locations where Parkiboks Flanders organizes sessions. Parkiboks Flanders is a collaboration between vzw Parkili.be, the Flemish Boxing Liga and the Flemish Parkinson Liga In Flanders. Throughout the research process, we remained in close contact with Filip Pluym, the coordinator of Parkiboks Turnhout. Our engagement in this collaboration further deepened our interest in the topic, ultimately leading to the designation of this research subject as our master's thesis.

Testing was held at two locations: Turnhout and Oud-Turnhout. Subsequent data analysis was carried out at Hasselt University's Diepenbeek campus by Prof Dr. Bruno Bonnechère, Febe Peeters and Zacha Ceuppens.

Overall, this project has been a unique and enriching experience, allowing us to expand our understanding of adaptive, community-based rehabilitation strategies for people with Parkinson's disease, while contributing to a field of growing scientific and societal relevance.

Abstract

Background: Parkinson's disease (PD) is a progressive neurodegenerative disorder with motor and non-motor symptoms. While no treatment alters the course of neurodegeneration, symptoms can be managed through medication, exercise, and physical therapy (PT). Non-contact boxing shows promising therapeutic effects in people with PD (PwPD).

Objectives: Assess exercise intensity and movement quantity during a standardized Parkiboks session.

***Methods*:** Twelve participants completed a 60-minute Parkiboks session, including a warm-up, technical boxing part, PD specific part, and a cool down. Heart rate (HR) was measured using Polar sensors and categorized into intensity zones (0-5) based on age-predicted HRmax. Movement quantity (active time) was recorded using five Movella DOT sensors. PD severity and symptoms were assessed using self-reported questionnaires and Hoehn and Yahr (H&Y) staging. Non-parametric statistics were used.

***Results*:** Twelve male participants (Mdn age = 67 years, IQR = 4.25; H&Y stage = 2, IQR = 0; disease duration = 4.5 years, IQR = 4.5) were included. Average active time was 32 min and 36 s with most activity during technical boxing. Seven participants provided valid HR data. On average 23.97% (SD = 35.40) of time was spent in zone 0, 47.39% (SD = 31.43) in zone 1, and 26.59% (SD = 32.01) in zone 2, with only three briefly reaching zone 3, suggesting low-to-moderate cardiovascular load. Most movement occurred during the technical boxing component. Moderate positive correlations were found between Borg RPE and average HR ($\rho = .6728$), and between MDS-UPDRS Part II and average HR ($\rho = .5946$), though not statistically significant ($p > .05$).

***Conclusion*:** Parkiboks sessions elicited a predominantly low-intensity exercise, not reaching PA guidelines for PwPD. However, the average active duration met general recommendations for session length. Participants reported high enjoyment, suggesting potential for sustained engagement.

***Keynotes*:** Parkinson disease (PD), Physical activity (PA), Physical therapy (PT), non-contact Boxing

Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder, characterized by gradual loss of dopaminergic neurons in the substantia nigra pars compacta (de Rijk et al., 1997; cited in Balestrino & Shapira, 2020). Its etiology is multifactorial, involving both genetic and environmental factors (e.g. pesticides, air pollution) (Atterling Brolin et al., 2025). The global prevalence of PD has increased markedly, with an estimated 11.7 million people affected worldwide in 2021 (Luo et al., 2024). This rise is predominantly attributed to an aging population, with a slightly higher prevalence observed among males compared to females. Age remains a key risk factor, particularly in individuals over 60. Between 1980 and 2023, PD prevalence increased by approximately 4.65% annually (Zhu, 2023). Projections suggest that the number of cases will nearly double from 2015 to 2060 (Savica et al., 2018). The promotion of physical activity (PA) serves as a key component in primary prevention strategies aimed at reducing the risk of developing PD (Ascherio & Schwarzschild, 2016; Ben-Shlomo et al., 2024).

Individuals with PD exhibit a diverse range of motor symptoms, including resting tremors, bradykinesia (slow movements), rigidity, postural instability, locomotor dysfunction, and freezing of gait (feeling of being stuck to the ground when initiating walking/turning) (FOG). Additionally, PD comprises a variety of non-motor symptoms like psychiatric symptoms such as depression, anxiety and apathy, as well as sleep disturbances, gastrointestinal symptoms (e.g. drooling, swallowing problems, constipation, taste impairments), cardiovascular impairments, speech difficulties and cognitive impairments. (Balestrino & Schapira, 2020; Fasano et al., 2015; Kalia & Lang, 2015). All these factors may substantially influence overall quality of life (QOL).

Available treatments for PD are symptomatic, mainly targeting the dopaminergic pathway. Levodopa is considered the benchmark in managing motor symptoms (Balestrino & Schapira, 2020), although its effects do not address all symptoms. If pharmacological treatments fail to adequately manage symptoms, surgical interventions like deep brain stimulation may be considered for select patients (Sveinbjornsdottir, 2016). In addition to pharmacological treatment, physiotherapy, occupational therapy, and speech therapy are used to manage (non) motor symptoms (Church, 2021).

Rehabilitation in PD primarily aims to optimize exercise tolerance, improve gait patterns, maintain or enhance mobility independence, and reduce fall risk (Tomlinson et al., 2013). According to strong recommendations of Osborne et al. (2022) physical therapy (PT) should implement aerobic exercise, resistance exercise, balance training, external cueing, community-based exercise, gait training, integrated care, and task specific training. Various other studies have examined the efficacy of different rehabilitative interventions, including conventional physical therapy, body weight-supported treadmill training (BWS-TT), dance, yoga, and aerobic exercise. PT has been shown to be most effective in improving motor symptoms, while dance and yoga yield greater benefits for non-motor symptoms, particularly in reducing depression and anxiety (Radder et al., 2020). Tomlinson et al. (2013) highlighted the short-term (< three months) benefits of these interventions on motor symptoms, balance, gait parameters, and QOL, while acknowledging that each modality may elicit distinct effects. Furthermore, Okada et al. (2021) reported that long-term PT (≥ six months) can reduce medication dependence and enhance motor function in the off-medication state.

Beyond its impact on motor and non-motor symptoms, exercise also exhibits neuroprotective properties. Animal studies suggest exercise may preserve nigrostriatal dopaminergic neurons, increase brain-derived neurotrophic factors (BDNF), protect mitochondrial integrity, and reduce pro-inflammatory markers, indicating neuroprotective potential (Church, 2021; Ishaq et al., 2024; Romero Garavito et al., 2025). Human studies support these findings, showing that moderate exercise improves QOL in patients with Parkinson disease (PwPD), while vigorous exercise may provide additional neuroprotective effects (Church, 2021). In this context, regular exercise is essential for improving balance, posture, and gait while reducing fall risk in both the short and long term (Lauzé, 2016; Shen, 2015). Kim et al. (2019) recommended that PwPD engage in moderate-intensity exercise three to five times per week, targeting an RPE of 13/20, 60–80% of maximum heart rate (HRmax), or 40–60% of heart rate reserve (HRR). Exercise sessions should initially last 20–30 minutes, progressively increasing to 60 minutes, with a structured combination of aerobic and resistance training. This is in line with recommendations made by the American College of Sport Medicine for the global population, stating that adults should engage in 150 minutes of moderate-to-vigorous exercise per week, with a 30-minute aerobic exercise session three days per week (DeSimone, 2024).

Alternative exercise-based therapies such as non-contact boxing have gained interest over the past years as a potential intervention for PwPD. Research has examined its effects on motor symptoms and QOL. Boxing training encompasses elements including weight shifting, dissociation of upper and lower body, postural adjustments, multidirectional stepping, speed variations, and cardiovascular demands (Combs, 2011). González-Devesa et al. (2024) conducted a systematic review showing significant positive effects were noted on non-motor symptoms, including quality of life, depression, sleep disturbances, and executive function. However, the authors reported inconclusive evidence on the effect of boxing on motor symptoms, mobility, balance, and gait in PwPD. Additionally, Ramos et al. (2024) reported that boxing did not lead to significant improvements in cardiorespiratory fitness in PwPD. In contrast, one other study has looked at the cardiovascular load of non-contact boxing in PwPD, showing that during a session, heart rate (HR) can increase up to 33% post-exercise in PwPD. This suggests that non-contact boxing entails an intensity of approximately 67% of HRmax (Salvatore et al., 2022), corresponding to a moderate-intensity activity level in line with aerobic exercise prescriptions for PwPD, as outlined by Kim et al. (2019). Altogether, although interest in boxing for PwPD is increasing, research on the movement intensity demands and movement quantity of Parkiboks remains scarce and conflicting.

This study aims to investigate the movement intensity, in terms of (1) cardiovascular load, and (2) quantity in terms of active time during 60-minute non-contact community-based Parkiboks session. These sessions are provided to the community through an initiative launched in 2019 in Turnhout, Belgium, developed in collaboration with Parkili.

Method

Ethical approval for this study was granted by the medical ethical committee of the university of Hasselt with reference number CME2024/009 (Comité voor Medische Ethiek - UHasselt. (n.d.)). Participants were informed about the study objectives and provided with an informed consent form. After signing, they received questionnaires to complete at home before testing began.

Study design

A cross-sectional pilot study was performed on PwPD during Parkiboks sessions. To ensure standardization of the sessions, three researchers observed two different Parkiboks sessions. Given that each session consisted of various exercises, the researchers focused on the exercises that encompassed multiple movement elements. By integrating these diverse activities into a cohesive session structure, ranging from a warm-up to a cool-down phase, a standardized Parkiboks session was developed to appropriately reflect the content of a typical session. The documentation was transmitted to the coach for reference. This approach ensured consistency in the session structure across all testing instances.

Participants

A total of 15 PwPD (n = 15) were selected through convenience sampling. All participants were recruited from the same organization, named Parkiboks network in Turnhout, which is located in Flanders, Belgium. The organization provides two one-hour sessions per week at two different locations, namely Turnhout and Oud-Turnhout, serving a total of approximately 40 participants. Recruitment occurred through flyers distributed at the gatherings, the newsletter hosted by the organizer and word of mouth.

The study defined specific criteria to ensure a relevant and well-characterized study population. Inclusion criteria were as followed: participants must be aged between 30 and 80 years old, report a neurologist-confirmed diagnosis of PD, and must be an active member of Parkiboks for at least one month prior to the study. Individuals were excluded if they were showing severe cognitive impairments manifesting as being unable to comprehend and read Dutch. Additionally, individuals that were wheelchair bound, equivalent to a Hoehn & Yahr (H&Y) score 5, were excluded.

Procedure

The sessions took place at two locations, namely Sporthal De Hoogt, located in Oud-Turnhout, on Monday evenings (5-6PM) and Sporthal Stadspark, located in Turnhout, on Friday mornings (10-11AM). Both locations had a small sports hall where tatami mats covered the floor. During the session the participants wore socks or participated barefoot. To ensure high quality data collection and minimize the risk of measurement error, one to two participants were assessed per measurement session.

Demographic information, namely age, sex, duration of the disease, type of medication, and hour of medication intake was collected prior to the session. In addition, participants were asked to fill in three self-reported questionnaires. The initial questionnaire provided was a Dutch adaptation of the falls efficacy scale international (FES-I), designed to evaluate concerns related to both physical and social aspects of falling among PwPD. It consists of 16 items and is scored on a four-point scale (1= not at all concerned; 4= very concerned) (Kempen et al., 2007; Yardley et al., 2005). Secondly, the MDS-unified Parkinson's Disease Rating Scale (MDS-UPDRS) Part II (Motor aspects of Experiences of Daily Living) assesses the disability by using a self-completed Dutch questionnaire with a maximum score of 52 (Goetz et al., 2008; Rodríguez-Blázquez et al., 2017). Lastly, participants were requested to complete the Dutch version of the fatigue severity scale (FSS), which consists of 9 items assessing fatigue. This scale employs a seven-point rating system (1= strongly disagree; 7= strongly agree) to evaluate the impact of fatigue on daily life (Krupp et al., 1989; Rietberg et al., 2010). The pre-distributed questionnaires were returned to the researchers at the start of the testing session.

At the start of to the session, the Hoehn and Yahr stage (0-5) was determined by a certified physiotherapist. The stages and descriptions for classification can be found in Table 1.

Table 1

Hoehn and Yahr Scale

Stage	Description	Functional impact
1	Unilateral involvement	Minimal or no functional disability
2	Bilateral or midline involvement	No balance impairment
3	Mild to moderate disability	Impaired postural reflexes; physically independent
4	Severely disabling disease	Able to walk or stand unassisted
5	Confinement to bed or wheelchair unless aided	Requires assistance for mobility

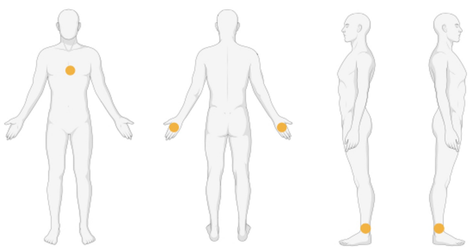
Note. Adapted from Goetz, C. G., Poewe, W., Rascol, O., Sampaio, C., & Stebbins, G. T. (2008). The Hoehn and Yahr Scale. In Parkinson's Disease and Movement Disorders (pp. 19-23). Oxford University Press. Retrieved November 1, 2024 from *https://academic.oup.com/book/30072/chapter-abstract/256465560?redirectedFrom=fulltext#no-access-message*

Furthermore, shoulder flexion strength, an important large muscle group of the upper extremity, was defined by using a handheld dynamometer (MicroFET 2). The participants were asked to gradually increase to their maximum force during a timeframe of five seconds for three times. The average of these three trials was used as the resultant. The measurements of the shoulder were conducted with the participant seated and the humerus in an elevated position. According to McLaine (2016), good intrarater reliability (ICC .87-.99) was achieved for flexion-and extension strength, performed in humeral elevation and in a seated position. To minimize the possibility of bias, muscle strength was always conducted by the same physiotherapy student, under supervision of a certified physiotherapist.

Afterwards, lightweight, high accuracy, wearable inertial sensors by Movella DOT, were used to record the data. The sensors were applied and utilized in a standardized manner, by the same two physiotherapy students over time. This standardized approach involved the correct application of sensors, ensuring they were oriented properly and securely placed on the appropriate locations. Figure 1 shows the standardized placement of the sensors. After sensors were securely placed, baseline measures and the forward functional reach test (FRT) were taken. These baseline measurements comprised of three boxing-related arm movements. Participants were instructed to first hold their right arm in a static position, resembling a boxing stance, with their right fist positioned close to the sternum for five seconds. Subsequently, they were asked to extend their arm as in a boxing motion, with a slight internal rotation, and maintain this position for five seconds. This sequence was repeated three times for each arm. Following these individual movements, participants performed the sequence three times with both arms simultaneously. Every time, participants were instructed to hold each pose for five seconds. For the FRT, each participant underwent it three times, with their fingers fully extended. The forward displacement of the body, while maintaining extended arms, was quantified by the variance between the initial baseline posture (i.e. arms extended forward with the fingers extended) and the subsequent forward leaning posture. The mean value derived from the three test trials was utilized as the resultant measurement (Duncan et al., 1990).

Figure 1

Standardized Sensor Placement



Note. Sensors were placed on the sternum, both wrists, and both lateral malleoli

After fitting the Movella DOT sensors, a Polar HR strap was applied to the participant. Initially, the strap was humidified with water to enhance its capability to measure electrical signals. It was then securely attached directly to the skin, positioned just below the sternum, ensuring it was tight enough to remain in place during activity. The Polar HR sensor was linked to an application on a smartphone or tablet, enabling researchers to monitor the data continuously for one hour.

The session, divided into four parts, commences after the collection of the descriptive measurements and application of the sensors. Appendix 1 provides an overview of the session content and the baseline measurement. The warm-up consisted of a steady jogging pace and boxing movements, with participants moving calmly forward or backward. The technical boxing section consisted of paired exercises in which participants had to step forward or backward while performing boxing movements with their arms. The Parkinson specific part combined more intensive boxing movement on a punching bag combined with loudly reciting the coach's instructions, while adding cognitive drills. The session ended with a cool-down consisting of basic stretching exercises.

At the end of the session, participants were asked to answer a few questions, regarding perceived exertion and difficulty of the session. The Borg rating scale of Perceived Exertion (RPE) was used to rate their self-perceived exertion on a scale from six to twenty (Lamont et al., 2018). Furthermore, the accompanying questions for perceived difficulty were: "Which exercise was the most challenging?" and "Which exercise was the most fatiguing?".

Descriptive outcome measures

Descriptive outcomes were as followed: the muscle strength of the dominant and non-dominant upper limb (measured with the MicroFET 2), impairment defined by the H&Y stage, self-reported questionnaires (namely, FES, MDS- UPDRS part II and FSS), as well as Borg RPE scale, and the questions for perceived difficulty after the session.

Experimental outcome measures

The Movella DOT sensors contain a three-axis gyroscope, accelerometer and magnetometer, measuring angular velocity, linear acceleration, and magnetic field across three axes (Movella, n.d.). They provide outcome data of the upper-limb, lower-limb and postural movements, encompassing variables such as frequency, active movement time, acceleration and orientation. Baseline measurements were also conducted by the Movella DOT sensors to comprehensively assess the complete range of motion and (a)symmetry in flexion and extension of both elbows during boxing movements. Also, the FRT was employed to establish the extent of a participant's ability to shift their center of pressure (COP). Furthermore, the evaluation of actual PA duration, can be derived from the acquired dataset. Each file was systematically named and stored uniformly throughout the testing period. Each activity was recorded separately and saved, categorized under the four parts, as a separate CSV-file.

In contrast, the Polar HR sensor provides real-time data on the percentage of time spent at various intensities according to HR frequency. Gender, age, weight, and height were entered into the application to ensure personalized data tracking. The Polar application classifies exercise intensity into five HR zones, determined by the percentage of an individual's HRmax. Zone 0 corresponds to 0-50 % of the HRmax, Zone 1 to 50–60% of the HRmax, zone 2 to 60–70%, zone 3 to 70–80%, zone 4 to 80–90%, and zone 5 to 90–100%. HRmax was calculated by the researchers using the formula: HRmax = 220-age (ACSM's Guidelines For Exercise Testing And Prescription, n.d.). This methodology allowed for an analysis of the time spent in each specific training zone during the boxing session.

Data analysis

The Movella DOT data was systematically named and stored per exercise and per sensor throughout the testing period. These data were later collected in CSV files. The Polar HR data were synchronized with the application and subsequently exported as a CSV file. If any data from the Polar device showed an unclear or missing signal for a period shorter than five minutes during the 60-minute session, HR values were interpolated to estimate the average HR per minute, based on the missing values at the start and end of each gap. However, if the total duration of an unclear or missing signal exceeds five minutes, the participant was excluded from the data analysis.

The included HR data were collected on a per-second basis, therefore the average HR per minute was calculated through a formula in Excel. This allowed the estimation of the duration spent in each HR zone, described before under the experimental outcome measures, over the full 60-minute session. Subsequently, these zones were processed for further analysis in the statistical software JMP Pro 17, in order to provide a graphical representation of the time spent in each zone per participant. The distribution of time across these zones is reported in the Results.

Descriptive outcome measures, such as the total score for each questionnaire, H&Y, and Borg RPE were also analyzed by JMP Pro 17.

Shapiro-Wilk test was used to check if the data came from a normal distribution. Based on low sample size (n = 7), a non-parametric test (Spearman's correlation (ρ)) was chosen. This was used to assess the relationship between average HR, H&Y, MDS UPDRS part II, active time and the Borg RPE. The aim was to explore potential associations between disease severity and active time or cardiovascular response. This was done using the statistical program JMP Pro 17. To interpret the strength of the correlations, the following guidelines based on Portney & Watkins (2014) were used: ρ = .00–.25 indicates little or no relationship, .25–.50 a fair relationship, .50–.75 a moderate to good relationship, and .75–1.00 a good to excellent relationship. In addition, JMP Pro 17 was employed to calculate the median, minimum, maximum, quartiles and interquartile range (IQR) of the descriptive outcomes. Correlations between various variables can be visualized through scatter plots, significance values (p-values), and correlation coefficients. All statistical assessments were considered significant with a p-value < 0.05.

Results

Of the fifteen participants initially selected, twelve were ultimately included in the study. One participant withdrew consent prior to the start of the study, and two participants were not tested due to time constraints that did not allow for their testing to be conducted. Demographic characteristics of the participants are described in Table 2. Hypertension was reported in two (ID 2 and ID 3) out of the twelve participants, both of whom were undergoing treatment with beta-blockers.

Table 2

Demographic Characteristics of the Participants

Sample characteristics	*n*	*%*	*Mdn*	*IQR*
Age (Year)	*12*	*/*	*67.00*	*14.25*
Gender (Male)	*12*	*100*		
Disease duration (year)	*12*	*/*	*4.50*	*4.5*
H&Y	*12*	*/*	*2.00*	*0.00*
Medication		*/*		
Levodopa	*12*			
MAO-B inhibitor	*7*			
Dopamine agonist	*5*			
Benzodiazepine	*1*			
Dominant hand				
Right	*9*	*75*	*/*	*/*
Left	*3*	*25*	*/*	*/*

Note. Mdn=median; IQR= Interquartile range; H&Y= Hoehn & Yahr Scale

The median shoulder flexion strength of the eight participants on the dominant hand was 90.08 N (IQR = 50.81). The non-dominant hand had a median strength of 102.20 (IQR = 50.95). The FRT was conducted from eleven participants, yielding a mean reach of Mdn = 26.20 cm (IQR = 7.00). The median score of the MDS-UPDRS-II was 10.50 (IQR = 7.75). The FSS was completed by twelve participants and yielded a median score 3.34 (IQR = 2.45). The FES was also conducted to twelve participants and showed a median score of 20 (IQR = 14.00). Finally, median resting heart rate (RHR) was measured in seven participants of 65 bpm (IQR = 13). An overview is seen is Table 3.

Table 3

Descriptive Outcome Measures

Sample characteristics	*n*	*Mdn*	*IQR*
FRT (cm)	*11*	*26.20*	*7.00*
MDS-UPDRS-II total	*12*	*10.50*	*7.75*
FSS	*12*	*3.34*	*2.45*
FES	*12*	*20.00*	*14.00*

Note. Mdn=median; SD= Standard Deviation; FRT = Functional Reach Test; MDS-UPDRS-II = Movement Disorders Society Unified Parkinson Disease Rating Scale; FSS = Fatigue Severity Scale; FES = Fall Efficacy Scale

Experimental outcome measures

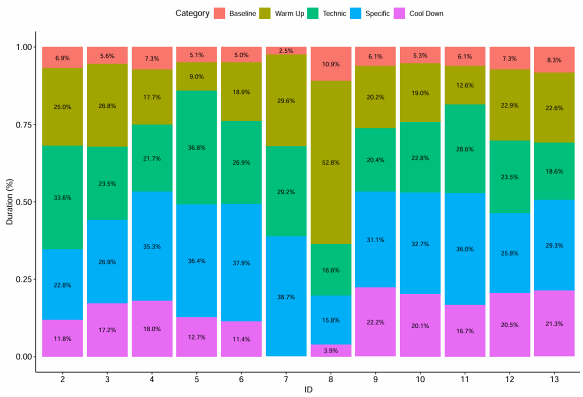
Movella DOT

According to the data recorded by the Movella DOT sensors, participants were actively moving for an average of 32 minutes and 36 seconds during the one-hour session. Activity time varied substantially between individuals, ranging from 17 minutes to nearly 37 minutes. Figure 3 illustrates the effective active time, including time of baseline measurements, per participants across the different phases of the session. As demonstrated in Figure 2 and Figure 3, the highest proportion of active movement time was recorded during the technical boxing exercises and Parkinson-specific phase of the session.

Based on the classifications reported in Table 3 above, excluding the time allocated for baseline measurements, the range of active time among individuals with a mild MDS-UPDRS part II score (ID 6, 7, 8, 9, 10, 12, 13) varied between 17 minutes and 19 seconds and 35 minutes and 16 seconds. In contrast, individuals with moderate MDS-UPDRS part II scores (ID 2, 3, 4, 5, 11) exhibit a range from 29 minutes and 14 seconds to 36 minutes and 52 seconds. A Spearman's correlation between active time during 60 minutes of non-contact boxing, excluding baseline time, and MDS-UPDRS part II scores is presented in Table 5. This analysis revealed a Spearman's rho of 0.4198, indicating a fair correlation between the variables, although this did not reach statistical significance (p = 0,1743).

Figure 2

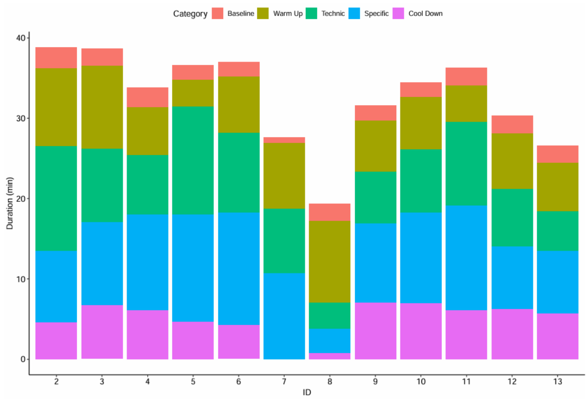
Relative Active Time Spent in Different Parts of the Session



Note. Panel shows the percentage of total session time spent actively in each component

Figure 3

Active Time in Minutes Spent in Different Parts of the Session



Note. Panel shows the corresponding active time in minutes per component.

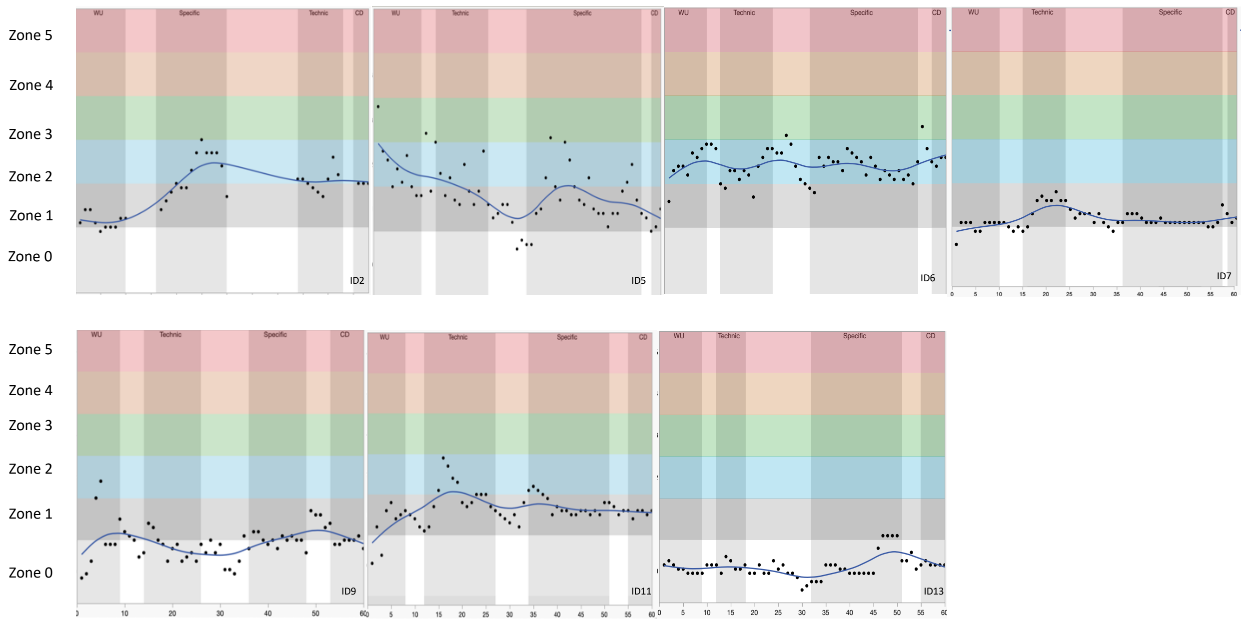
Polar Heart Rate data

Some participants experienced intermittent connectivity issues, resulting in occasional data loss. Specifically, for participant ID 3, approximately 16 minutes of HR data was missing, primarily in short intervals of around 30 to 60 seconds. Similarly, for participant ID 13, a total of three minutes and forty seconds of data was lost. ID 3 exceeded the cutoff point of five minutes of data loss and was therefore excluded from the data analysis. Consequently, the final analysis was conducted with seven participants. No connectivity issues were observed for the other participants, and their data was recorded without interruption.

Appendix 2 presents the percentage of time spent in each HR zone per individual. The mean (M) percentage of the time spent in each zone during a one-hour boxing session was as follows: Zone 0 (M = 23.97%, SD = 35.40), Zone 1 (M = 47.39%, SD = 31.43) , Zone 2 (M = 26.59%, SD = 32.01), and Zone 3 (M = 2,06%, SD = 3.11). No participants reached Zone 4 or Zone 5. Figure 4 demonstrates the time spent in the different parts of the session per individual. Appendix 3 presents the average HR per section for each participant, as well as the overall averages. The mean HR per session component exhibit only limited variation (SD = 2.07). A slight increase is observed during the boxing technical segment.

Figure 4

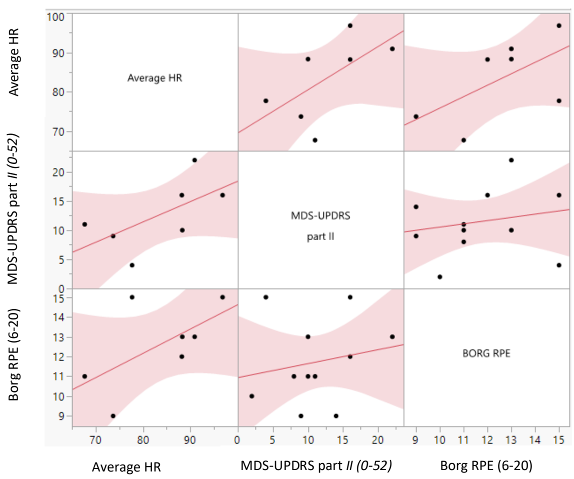
Graphs Of Time Spent In Training Zones Per Participant



Note: WU = warm up. CD = cool down. Zone 0= 35-50 % of HRmax, zone 1= 50-60% of HRmax, zone 2= 60-70 % of HRmax, zone 3=70- 80% of HRmax, zone 4= 80-90% of HRmax, zone 5= 90-100% of HRmax. Grey bars represent the duration spent on each component of the session, while the white spaces between the bars indicate rest periods.

Figure 5

Correlation between Average Heart, MDS-UPDRS part II and Borg RPE



Note. Scatterplot matrix; HR= heart rate; RPE = rate of perceived exertion

Normality was first assessed using the Shapiro-Wilk test, which indicated that the data were normally distributed ($p > .05$). However, despite the assumption of normality, the sample size was small and the data exhibited high variability. Therefore, Spearman's correlation was used.

Spearman's correlations are presented in Table 5, along with the significance levels of the correlations. The scatter plot matrix shows a moderate to good relationship between Borg RPE and average HR ($n = 7$) ($\rho =. 6728$; $p = .0976$), as well as between average HR and the MDS-UPDRS part II score ($\rho = .5946$; $p = .1591$). None of the correlations reached statistical significance ($p > .05$).

Based on Spearman's correlation between Borg RPE and the MDS-UPDRS part II score ($n = 12$), a fair, but not significant, relationship was found ($\rho = .3274$; $p = .2989$).

Additional correlations between active time (excluding baseline time) and other variables are also presented in Table 5. The relationship between average HR and active time ($\rho = .7143$; $p = .0713$) was moderate to good, approaching statistical significance. In contrast, the correlations between active time and Borg RPE ($\rho = .238$; $p = .4571$), and H&Y ($\rho = .078$; $p = .8090$) were rather low to negligible.

Table 5

Correlations Between Variables

Correlation	*Average HR*	*Borg RPE*	*MDS-UPDRS Part* II	*H&Y*
Average HR				
Borg RPE	*.673*			
MDS-UPDRS part II	*.595*	*.327*		
H&Y	*.612*	*.378*	*.5201*	
Active Time	*.7143*	*.238*	.420	*.078*

Note. HR = heart rate; RPE = rate of perceived exertion; MDS-UPDRS-II = Movement Disorders Society Unified Parkinson Disease Rating Scale; H&Y= Hoehn and Yahr
*p <.05. **p <.01.

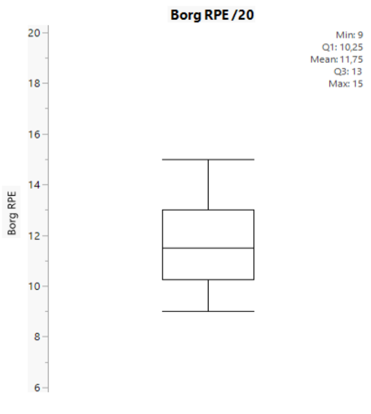
Descriptive outcome measures

Perceived exertion

Perceived exertion was assessed using the Borg Rating of Perceived Exertion (RPE) scale, which ranges from six to twenty, among twelve participants. Figure 6 shows a boxplot with a median score of 11.75. The scores range from 9 (score 9-10 = 'very light') to 15 (score 15-16 = 'hard'). The interquartile range (IQR= 2.75) shows that most participants rated their exertion between 'light' (score 11-12) and 'somewhat hard' (score 13-14). Only two participants (ID 5 and ID 6) reported a perceived exertion of 13 on the Borg RPE scale, while two others (ID 2 and ID 9) reported a score of 15. Of these, the three participants who reported RPE 13 (ID 5 and ID 6) or RPE 15 (ID 2) were the only individuals who reached HR zone 3, albeit for a limited duration (ID 2: 2.8%; ID 5: 8.3%; ID 6: 3.3%). The second participant who reported an RPE of 15 (ID 9) did not exceed HR zone 2, spending only 3.3% of the session in that zone. Participants ID 2, ID 5 and ID 6 spent the majority of the session in zone 1 and zone 2 (ID2: zone 1 = 50%, zone 2 = 44.4%; ID 5: zone 1 = 55%, zone 2 = 30%; ID 6: zone 1 = 8.3%, zone 2 = 88.4%). In contrast, participant ID 9 spent most of the session in zone 0 and 1 (ID 9: zone 0 = 51.7%, zone 2 = 45%).

Figure 6

Boxplot of Perceived Exertion



Note. Min= minimum; Q1= quartile one; Med= median; Q3= quartile three; Max= maximum

Based on the subjective question "What was the most fatiguing exercise?", all twelve participants mentioned the same exercise during the session in their answer. All experienced the exercise, where they had to box on the bag for one minute (40 seconds at their own pace and 20 seconds full pace), as the most fatiguing. When examining the individual data per participant, a consistent increase in HR is observed during the minute of intense boxing, which the participants subjectively described as the most fatiguing. However, during this period, participants predominantly remained within HR zones one to three. Specifically, participant ID 2 was in zone 2; ID 5 in zone 1 and 2; ID 6 in zone 3; ID 7 in zone 1; ID 11 in zone 1; and ID 13 also in zone 1.

Discussion

This study aims to assess the movement intensity and quantity of a Parkiboks session. One of the primary findings, based on data from the Polar HR sensors, indicate that the exercise intensity during the session generally ranges from low to moderate. HR data revealed substantial variability among the seven participants, reflecting differences in physiological responses to the session. Most of the session time was spent in zone 1, with considerably less time in zone 0 and 2, which showed comparable durations. Notably, very limited to no time was spent at intensities exceeding 70% of HRmax during the one-hour session. These findings are supported by the Borg RPE scores, which indicated that participants, on average, perceived the session as 'light' in intensity. While the recommended exertion level of ≥13/20 ('somewhat hard') on the Borg RPE scale (Kim et al., 2019), was reached by only four of twelve participants, three of them rated the session as 'somewhat hard', and two described it as 'hard'. Importantly, these results should be interpreted considering the session's primary aim, which may focus more on promoting movement, engagement, and participation in PA rather than achieving high cardiovascular intensity.

Recommendations for PwPD as proposed by Kim et al. and the ACSM, advises 20-60 minutes of moderate-intensity or 30 minutes of continuous or accumulated exercise (ACSM's Guidelines For Exercise Testing And Prescription, n.d.; Kim et al., 2019). In this study, data showed that participants are physically active for approximately 17 to 37 minutes during the one-hour session, with an average active time of 32 minutes. Overall, the most active time was observed in the technical boxing part. In this study, exercise time did not meet the criterion of 30 minutes continuous exercise, however seven participants achieved a total accumulated exercise time of 30 minutes, aligning with previous recommendations. Additionally, only 28.65 % of the total active time fell within the moderate-intensity threshold, corresponding to HR zone 2 and 3. This translated to just 17 minutes spent in the moderate-intensity threshold, which does not align with the 20-60 minutes of moderate intensity recommended by Kim et al. (2019). Altogether, these observations indicate that the session fell short of consistently reaching the moderate-intensity threshold (60-80% of HRmax), and that the average active time duration did not meet the recommended levels for PwPD (Kim et al., 2019; Osborne et al., 2022).

Among the twelve participants, two were taking beta-blockers, including one of the seven who wore the Polar sensor. The RHR of these two participants did not differ significantly from that of the other participants. However, existing research has demonstrated that both the percentage of HRmax and HRR during aerobic and anaerobic exercise are significantly reduced in individuals taking beta-blockers (Wonisch et al., 2003). This raises important concerns regarding the accuracy of HR-based measurements in the context of this study. More recent evidence further supports this notion, indicating that prescribing exercise intensity based on HR recommendations is not considered appropriate for patients on beta-blockers therapy. This raises concerns in this study regarding the accuracy of HR-based measurements in assessing exercise intensity, given that beta-blockers attenuate the HR response relying on HR-based methods may underestimate actual exertion levels. Therefore, prescribing exercise intensity solely based on heart rate recommendations is not considered appropriate for patients taking beta-blockers (Anselmi et al., 2021).

Most of the included studies refer to moderate-to-high-intensity interventions. While beneficial outcomes are consistently reported, the specific dosage and intensity of the boxing interventions are often not clearly described. In several cases, participants were instructed to train at a self-selected maximal intensity (Combs, 2011; Combs et al., 2013), whereas other studies relied on subjective measures such as the Borg RPE to measure perceived exertion ranged from 13/20 ('somewhat hard') to 17/20 ('very hard') (Blacker et al., 2024; Moore et al., 2021; Sangarapillai et al., 2021; Shearin et al., 2021). A feasibility study on periodized boxing training for PwPD also found that the prescribed intensity zones were too low for most participants, particularly during their first training block. This block, which consisted of technical exercises, is comparable in structure to the technical component of Parkiboks session. Similarly, in their third block, focused on cognitive exercises, which is comparable to the specific phase of a Parkiboks session, the target intensity of 70-80% of the age-predicted HRmax (APMHR) was often exceeded by participants (Blacker et al., 2024). Several guidelines underscore the importance of incorporating moderate- to high-intensity PA as part of routine exercise regimens (DeSimone, 2024; Osborne et al., 2022). According to global health guidelines, adults should engage in at least 150 minutes of moderate-intensity aerobic PA, or 75 minutes of vigorous-intensity activity per week, or an equivalent combination of both. For enhanced health benefits, these volumes should ideally be doubled, reaching 300 minutes of moderate of 150 minutes of vigorous-intensity exercise weekly ("WHO Guidelines Approved by the Guidelines Review Committee," 2010).

A substantial body of evidence supports a positive association between both the volume and intensity of PA and various health outcomes in healthy adults. Higher exercise volumes and higher intensities are consistently linked to improvements in cardiorespiratory fitness, hemodynamic parameters and body composition (H. J. A. Foulds et al., 2014; Wu et al., 2021). Notably, even low-intensity and low-volume exercise has been shown to produce significant benefits in hemodynamic measures, despite more modest changes in other health-related parameters (H. J. Foulds et al., 2014; H. J. A. Foulds et al., 2014). These findings suggest that while greater exercise doses tend to generate more comprehensive benefits, lower doses may yield clinically meaningful effects. Interestingly, the metabolic impact of moderate to vigorous PA appears comparable when the total volume is held constant. In a study by Rey Lopez et al. (2020), both intensity levels were equally effective in reducing all-cause mortality, reinforcing the WHO's position that the total volume of PA is a key determinant of health benefit, irrespective of intensity alone.

Due to the real-world setting of this study, results could vary between the sessions. It was observed that the active movement time during a full session is highly heterogeneous. Participant ID 8 displayed substantially lower active time compared to the other participants. Although the total session duration for ID 8 was 60 minutes, the exceptionally high ambient temperature (30°C) and a larger group size on that day led to more frequent and extended breaks for hydration and rest. Additionally, part of the boxing technical segment was removed due to time constraints.

Disability level varied between the participants, as indicated by their scores on the MDS-UPDRS part II. The findings suggest a potential relationship between self-reported disability, as measured by the MDS-UPDRS Part II, and the amount of time participants spent actively engaged during the session. Participants classified as moderately affected (score 14-29) tended to show longer active durations compared to those with milder impairments (score ≤ 12). However, no clear statistical correlation could be established between MDS-UPDRS and either active time or HR zone data. This may be partly due to inconsistencies in session structure, such as variations in exercise order and timing caused by differing levels of required supervision and feedback. To improve data consistency, future studies should implement a fully standardized exercise protocol with fixed timing and content.

Cardiovascular intensity seemed correlated with perceived exertion. In the present study, moderate to good positive correlations were observed between perceived exertion (Borg RPE) and average HR, suggesting that participants who reported greater subjective exertion also tended to exhibit higher physiological responses during the session. A moderate positive correlation was also found between disease severity, as measured by the MDS-UPDRS part II, and average HR, potentially indicating that individuals with more pronounced functional limitations experienced greater cardiovascular load. In contrast, the relationship between MDS-UPDRS part II scores and Borg RPE was weaker, showing a fair positive correlation, which may reflect individual differences in the subjective perception of effort among participants with varying levels of disability. However, despite these observed trends, none of these results reached statistical significance, which limits the statistical power of the analyses. Therefore, these exploratory findings should be interpreted with caution. Future research with larger cohorts is needed to confirm these associations.

Despite the physical outcome not fully aligning with established cardiovascular guidelines, participants reported a positive overall experience. Informal conversations indicated that they greatly relished sessions and valued the opportunity to stay active alongside others facing similar challenges. Although no formal patient satisfaction assessment was conducted, these qualitative insights suggest that the sessions were perceived as both enjoyable and meaningful. Previous and more recent research has shown that boxing interventions for PwPD positively affect various motor symptoms, including mobility, gait, lower extremity strength, and balance (Combs, 2011; González-Devesa et al., 2024; Moore et al., 2021; Ramos et al., 2024). However, some findings remain inconclusive, particularly regarding the consistency and magnitude of these effects (González-Devesa et al., 2024). Reported benefits are more consistent in the domain of non-motor symptoms, including QOL, mood, sleep, and executive function. In addition, participation in community-based boxing has been shown to foster social support networks, with shared exercise experiences contributing to enhanced motivation, self-worth, and a sense of hope (Borrero, 2020). Thus, even in the absence of high cardiovascular load, the sessions may still offer valuable long-term motor and psychosocial benefits.

Limitations

This study has several important limitations. The small, all-male, sample (n = 12) limits generalizability, particularly to female individuals, who have been shown to exhibit higher HR responses during exercise (Rascon et al., 2020; Wheatley et al., 2014). The use of Polar HR sensors was not consistently reliable. Signal interference was observed during sessions in which two participants simultaneously wore Bluetooth-connected devices. Fewer issues were encountered when only one participant was assessed at a time. Also, excessive chest hair sometimes impeded skin contact, potentially affecting data accuracy. Minor deviations from the standardized session protocol by the coach may also have contributed to inconsistencies in both HR and movement data. Additionally, conducting the session in a real-life setting introduced sources of variability, including deviations in coaching. For example, participant ID 8 demonstrated noticeably lower levels of active time. There were fewer active bouts of time, likely due to the high ambient temperature (30°C) and the presence of a larger group size compared to other sessions, which led to extended rest periods and a shortened technical segment.

Conclusion

The findings of this study suggest that, according to both objective and subjective measurement tools, a Parkiboks session elicits an average of low intensity. Based on these current findings, the session does not meet the intensity and volume thresholds typically associated with the optimal benefits reported in previous research. Nevertheless, it is important to emphasize that all participants reported subjective feelings of enjoyment and happiness following the training session. Therefore, further research is warranted with a larger sample size and under controlled conditions. Recommendations for community-based Parkiboks training should focus on increasing exercise intensity and/or active time to better align with current PA guidelines and potentially contribute to improved health outcomes. Coaches may consider integrating higher-intensity aerobic exercises and short anaerobic bouts to shift cardiovascular load toward a moderate-to-high range.

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Appendix 1

Exercise	Description
Warm-up	
1	Quiet forward running followed by backward running.
2	Lateral stepping: first to the left, then to the right
3	Forward running combined with synchronous boxing movement (same-side arm and leg), followed by backward running.
4	Same as Exercise 3, but with contralateral arm and leg movement (opposite sides).
5	Forward running with overhead boxing using contralateral arm-leg movement.
Box Technical	
1	Forward boxing against a partner holding pads while moving backward; step with left foot and punch, then bring right foot forward.
2	Paired pad boxing with a volunteer: alternating left and right punches.
3	Trunk level pad avoidance: participant dodges a moving pad directed by the volunteer.
4	Backward boxing against a partner holding pads while moving forward; same stepping and punching sequence as in Exercise 1.
Box Specific	
1	Boxing combinations on a punching bag “left-right-left” and “right-left-right”. After completing a couple of combinations, participants switch positions or change sides.
2	Fixed combination on the punching bag: “left-left-right” punches.
3	On a verbal cue (number), participants perform the corresponding combination on the punching bag: 1) Left-right left 2) Right-left-right 3) Left-left-right
4	Same as Exercise 3, with an additional straight punch added to the sequence
5	On a verbal cue (number), participants perform the corresponding combination on the punching bag and simultaneously call out the combination: 1) Left 2) Right 3) Left-right 4) Right-left
6	Cognitive task: recite multiplication tables of 6 while performing punches on the punching bag.
7	Cognitive task: count backward from 60 to 0 while boxing on the punching bag.
8	Cognitive task: recite the alphabet while skipping every other letter, performing punches on the punching bag.

9	Interval boxing on the punching bag: 40 seconds at self-selected pace, followed by 20 seconds of maximal effort.
Cool down	
1	Foot movements: step forward, sideways, and backward; followed by jumping.
2	- Small toe movements, followed by standing on toes. - Alternate inner leg stretches (raising upper leg outward). - Hula hoop motion in both directions. - Stretching triceps. - Shoulder rotations: forward, upward, backward, and downward. - Arm swings forward and backward. - Stretching forearm muscles by pulling the hand towards the body with the elbow extended. - Forward grabbing motion (stretching).
3	- Open fingers and rotate hands from inside to outside. - Shake hands to loosen up
Baseline	
1	- 3x right hand punch movement: hold for 5 seconds
2	- 3x left hand punch movement: hold for 5 seconds
3	- 3x both hands punch: hold for 5 seconds
4	- 3x Functional reach test

Appendix 2

Percentage of Time Spent in Each Zone per Individual

ID	Zone 0 (%)	Zone 1 (%)	Zone 2 (%)	Zone 3 (%)	Zone 4 (%)	Zone 5 (%)
ID2	2.8	50	44.4	2.8	0	0
ID5	6.7	55	30	8.3	0	0
ID6	0	8.3	88.4	3.3	0	0
ID7	10	90	0	0	0	0
ID9	51.7	45	3.3	0	0	0
ID11	3.3	76.7	20	0	0	0
ID13	93.3	6.7	0	0	0	0

Note. Zone 0= 35-50 % of HRmax, zone 1= 50-60% of HRmax, zone 2= 60-70 % of HRmax, zone 3=70-80% of HRmax.

Appendix 3

Mean Heart Rate Across session segments for Each Participant

ID	Warm up	Technic	Specific	Cool down	x̄ HR	Borg RPE /20
ID2	81.8	104.7	98.9	101.9	96.8	15
ID5	98.2	93.5	89.4	79.8	90.9	13
ID6	90.1	88.8	89.3	88.7	88.3	13
ID7	71.0	77.6	73.2	74.1	73.7	9
ID9	78.9	76.1	78.1	78.1	77.7	15
ID11	81.1	92.9	88.3	85.9	88.2	12
ID13	66.6	67.5	69.2	67.4	67.7	11
All ID (n = 7)	81.1	85.9	83.8	82.3		13

Note. x̄ HR = average heart rate across the entire session; Borg RPE scale: 6-20.