CASE STUDY

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The Physiological and Morphological Benefits of Shadowboxing

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Abstract: Is shadowboxing an effective form of functional exercise? What physiological and morphological changes result from an exercise program based exclusively on shadowboxing for 3 weeks? To date, no empirical research has focused specifically on addressing these questions. Since mixed martial arts (MMA) is the fastest growing sport in the world, and since boxing and kickboxing fitness classes are among the most popular in gyms and fitness clubs worldwide, the lack of research on shadowboxing and martial arts-based fitness programs in the extant literature is a shortcoming that the present article aims to address. This case study involved a previously sedentary individual engaging in an exercise program based exclusively on shadowboxing for 3 weeks. Body composition and heart rate data were collected before, throughout, and upon completion of the 3-week exercise program to determine the effectiveness of shadowboxing for functional fitness purposes. An original shadowboxing program prepared by an Everlast Master Instructor and NASM Certified Personal Trainer (NASM-CPT) and Performance Enhancement Specialist (NASM-PES) was used for this 3-week period. The original shadowboxing program with goals, techniques, and combinations to work on throughout the 3-week program is included in this article. This case study demonstrates that a 3-week exercise program based exclusively on shadowboxing can increase aerobic capacity, muscle mass, bone mass, basal metabolic rate, and daily calorie intake, and decrease resting heart rate, fat mass, body fat percentage, and visceral fat rating in a previously sedentary individual. The results of this research demonstrate that shadowboxing can be a safe and effective form of exercise leading to morphological and physiological improvements including fat loss and increased aerobic capacity. The results of this research also demonstrate that the Tanita BC-1500 is a reliable tool for individuals to evaluate their own fitness progress over time.

Keywords: Shadowboxing, Aerobic Exercise, Functional Fitness, Fat Loss, MMA, Martial Arts.

About the Author

Adam M. Croom, Ph.D., is a Senior Lecturer in Cognitive Science at the University of California, Berkeley. He is Associate Editor of *Frontiers in Social Psychology*, Associate Editor of *Philosophies*, and author of over two dozen original publications. Dr. Croom is currently editing a special issue of *Philosophies* that is focused on the philosophy and science of martial arts and his recently published work has focused on the philosophy, psychology, and physiology of martial arts training. In addition to publishing scholarly articles on martial arts in academic journals such as *Discover Psychology*, *Philosophies*, and *Archives of Budo Science of Martial Arts and Extreme Sports*, Dr. Croom also remains an active practitioner of boxing, kickboxing, and Muay Thai. Before joining the faculty at the University of California in 2020, Dr. Croom was a Certified Personal Trainer (CPT) at Equinox South Bay and Master Instructor (MI) at Everlast Worldwide where he focused on teaching boxing, kickboxing, and Muay Thai.

1. Introduction

Mixed Martial Arts (MMA) is currently the fastest growing sport in the world [Reiter, 2011], and with over 450 million fans, MMA is among the top three most watched sports worldwide (along with soccer (football) and basketball [Cover, 2018]). MMA, which incorporates movement patterns and techniques from a variety of martial art disciplines (including boxing, kickboxing, Muay Thai, taekwondo, karate, kung fu, wrestling, judo, and jiu jitsu), has also become increasingly popular among general health

and fitness enthusiasts, since it offers an engaging full-body functional workout that is a fresh change from more traditional exercise routines [Smith, Cherry, 2018]. Traditional exercise programs were largely based on bodybuilding routines that focused on isolated, uniplanar exercises (such as squats and bicep curls which are movements in sagittal plane) to maximize absolute strength gains and hypertrophy [Schwarzenegger, 1998; Clark, Lucett, Kirkendall, 2010; Sutton, Ramsdell, Barefield, 2012]. Although isolated uniplanar training may be effective in building large muscles in isolated areas of the body, it does little to improve the functionally integrated movements of the human movement system (HMS) which are involved in activities of daily living (ADLs) such as getting into and out of bed, completing physical tasks at work, and playing sports with your kids and friends [Clark, Lucett, Kirkendall, 2010; Cedar, 2012]. Further, exercises that are repetitive and isolated to a single plane of motion can lead to increased boredom, muscular imbalances, inefficient movement patterns, fitness plateaus, and increased risk of injury [Clark, Lucett, Kirkendall, 2010; Sutton, Ramsdell, Barefield, 2012; Starrett, 2015; McCall, 2016]. Accordingly, there has been a growing interest in alternative approaches to fitness training, such as functional movement training (Animal Flow, MovNat, Functional Movement Systems, Anatomy Trains), obstacle course training (Ninja Warrior, Spartan Races, Tough Mudder Races), and boxing and kickboxing fitness classes (Box 'N Burn, Mayweather Boxing and Fitness, UFC Gym) [Fitch, 2014; Self, 2017; Fawkes, 2021]. Although these alternative approaches to fitness training differ from traditional exercise programs in their own unique ways, they are all united by their adoption of functional training principles that emphasize training integrated movement patterns (crawling, climbing, pulling, punching, kicking) instead of training isolated muscle groups (biceps, triceps, glutes, chest, back). "Train movements not muscles" is perhaps the single clearest principle uniting functional training in all its varieties [Collins, 2012; Myers, 2020]. In contrast with traditional exercise programs, functional training programs are focused on functional movement patterns, are multiplanar and multidimensional (involving movements in sagittal, frontal or coronal, and transverse planes), and use the entire muscle-contraction and contraction-velocity spectrums [Clark, Lucett, Kirkendall, 2010]. By training a variety of practical movement patterns (such as pulling and pushing) functional training programs are also thereby able to train the variety of muscles that are involved in those movement patterns, whereas traditional exercise programs that train isolated muscle groups do not also thereby train functional movement patterns with practical carryover to the activities of daily life. This means that traditional exercise programs and functional training programs are both capable of promoting increased muscle mass and strength, but that only functional training programs are uniquely capable of promoting increased functional performance [Clark, Lucett, Kirkendall, 2010]. In fact, by improving motor unit recruitment and muscular balance and efficiency, functional training programs can even contribute to greater strength and hypertrophy gains over traditional exercise programs. This point is explicitly discussed in the textbooks for the National Academy of Sports Medicine's Certified Personal Training Program (NASM-CPT) and Performance Enhancement Specialist Program (NASM-PES). For example, Clark, Lucett, and Kirkendall [2010] explain in *NASM Essentials of Sports Performance Training* that:

> (...) isolated training does little to improve overall athletic performance. The athlete who applies an integrated functional approach to training will develop high levels of dynamic flexibility, core strength, neuromuscular control, power, speed/agility/quickness, and functional strength. In addition, your athlete may develop similar, or even greater, levels of hypertrophy following improved motor unit recruitment. Training that exploits integrated, functional movement patterns targets synergistic muscles to regulate isometric, concentric, and eccentric force while dynamically stabilizing the entire HMS (human movement system) in all three planes of motion. This creates maximal motor unit recruitment and facilitates a greater overall training response (p. 4).

Due to the SAID (Specific Adaptations to Imposed Demands) principle or principle of specificity, the body will adapt to the specific demands that are placed on it [DeLorme, 1945; Clark, Lucett, Kirkendall, 2010]. In order to improve functional performance in activities of daily life, training programs must therefore involve functional movement patterns. Since traditional exercise programs train muscles and not movements, traditional exercise programs offer little in terms of functional performance benefits and can even lead to functional performance deficits, pain, and injury [Clark, Lucett, Kirkendall, 2010]. Given the growing interest in functional training programs over traditional exercise programs, fitness clubs have increasingly incorporated

more functional training tools (TRX suspension systems, ViPRs, medicine balls, battle ropes, kettlebells, and fitness playground setups), functional training classes (boxing, kickboxing, and obstacle courses), and more open space into their training environments to facilitate functional training among club members [Rubin, 2013; McCall, 2019]. In fact, between 2013 and 2018, nearly 4,000 boxing gyms opened in the United States and the boxing fitness industry made a total of $1.2 billion [Landsverk, 2019]. Numerous female models and celebrities – including Halle Berry, Adriana Lima, and Gigi Hadid – have helped to popularize boxing training across genders by crediting boxing training for building their celebrity-status physiques [Badkar, 2018; Landsverk, 2019], and a study in 2018 involving nearly 17,000 individuals found that kickboxing was the exercise program that 18- to 45-year-olds were most interested in trying next [Livestrong, 2019]. Given the popularity of MMA-style fitness programs among the general population, it is surprising that almost no research has been conducted on MMA-style fitness programs in the literature.

Shadowboxing is a common way to learn and cultivate skill in martial arts as well as a vehicle for physical fitness and self-development [Croom, 2022; Cynarski, 2022; Okade, Shibata, Jennings, 2020; Panczyk, Pedrini, Jennings, 2021; Holt, 2023]. In an early study on shadowboxing, Muharram *et al.* [2011] investigated the influence of shadowboxing on participants with chronic low back pain (n = 82). This study consisted of a 12-week shadowboxing program with a training frequency of 6 sessions per week. Each session included 1-hour of practicing a 24-step Chen-style Taijiquan movement sequence. Muharram *et al.* [2011] found that this program provided pain relief and improvement in health-related quality of life for the participants involved. This study is important because it is an early study that demonstrates that shadowboxing can be beneficial for individuals with chronic low back pain. Limitations of this study include that it did not include nutrition or recovery information and that it did not examine the influence of this program on physiological or morphological variables, such as basal metabolic rate, muscle mass, fat mass, and body fat percentage. Also, it is important to point out that the style of shadowboxing investigated by Muharram *et al.* [2011] is very different from the style of shadowboxing involved in contemporary mixed martial arts, for example, Chen-style Taijiquan consists of a more structured 24-step sequence of fluid movements that are performed slowly and continuously, whereas shadowboxing as it is practiced in the context of MMA and modern fitness classes consists of a more open-ended sequence of movements that are performed explosively and in intervals. Given the difference in movement patterns, exercise intensity, and duration between these distinct styles of shadowboxing, it is not clear whether the results from Muharram *et al.*'s [2011] study on Taijiquan offers insight into the benefits that MMA-style shadowboxing may offer individuals. In another study, Zheng, Zhou, and Lai [2015] investigated the influence of shadowboxing on participants with type-2 diabetes (n = 60). This study consisted of a 24-week shadowboxing program with a training frequency of 3 to 5 days per week. Each day of training included two sessions lasting 40 minutes each (once in the morning and once in the evening) along with psychosomatic relaxation training. Zheng, Zhou, and Lai [2015] found that this program had a beneficial effect on depression, anxiety, and blood glucose levels for the participants involved. This study is important because it demonstrates that shadowboxing can be beneficial for individuals with type-2 diabetes. One limitation of this study is that it did not focus solely on shadowboxing, mixing in psychosomatic relaxation training also, so it is not clear whether the results from this study are due to shadowboxing, psychosomatic relaxation training, or some combination of these. Other limitations of this study include that it did not include nutrition or recovery information and that it did not examine the influence of this program on physiological and morphological variables such as aerobic capacity, resting heart rate, muscle mass, fat mass, and body fat percentage. Also, as was mentioned with the case of Muharram *et al.* [2011], Chen-style Taijiquan is very different from MMA-style shadowboxing in terms of movement patterns, exercise intensity, and duration, so it is not clear whether the results from Zheng, Zhou, and Lai's [2015] study on Taijiquan offers insight into the benefits that MMA-style shadowboxing may offer individuals.

Research by Combs *et al.* [2009] investigated the influence of boxing training on participants diagnosed with Parkinson's disease (n = 6). This study consisted of a 12-week boxing program with a training frequency of 2 to 3 sessions per week. Each session included 90 minutes of physical activity consisting of boxing exercises, calisthenics, and jump rope. Combs *et al.* [2009] found that this program resulted in improved balance, gait, and quality of life for the participants involved. This study is important because it demonstrates that boxing training can be beneficial

for participants diagnosed with Parkinson's disease. One limitation of this study is that it did not focus solely on shadowboxing, mixing in calisthenics and jump rope also, so it is not clear whether the results from this study are due to shadowboxing, calisthenics, jump rope, or some combination of these. Other limitations of this study include that it did not have information about goals, drills, or combinations to practice while training, it did not include nutrition or recovery information, and it did not examine the influence of this program on physiological and morphological variables such as aerobic capacity, resting heart rate, muscle mass, fat mass, and body fat percentage. In other work, Bosch *et al.* [2012] investigated the influence of playing a boxing video game on young adults in their twenties (n = 20). This study consisted of a 30-minute session of playing Nintendo Wii Sports boxing, where players simulate punches with the controller in a manner similar to shadowboxing. Bosch *et al.* [2012] found that this program provided a moderate to vigorous aerobic response in healthy young adults and can contribute to daily recommendations for physical activity [Thompson, Gordon, Pescatello, 2010]. This study is important because it demonstrates a practical way for young adults to maintain their own health and fitness at home, in a manner that is enjoyable and mentally engaging. This has been especially relevant recently due to the coronavirus pandemic, since social distancing regulations have made it useful for individuals to have more options for maintaining their health and fitness at home. Several limitations of this study include that it did not examine the response to training over time (e.g., over a 3-week or 3-month training period), it did not include nutrition or recovery information, and it did not examine the influence of this program on physiological and morphological variables such as resting heart rate, muscle mass, fat mass, and body fat percentage.

More recent work from Doherty *et al.* [2021] investigated the influence of shadowboxing on participants diagnosed with breast or ovarian cancer (n = 9). This study consisted of an 8-week shadowboxing program with a training frequency of 3 sessions per week. Each session included 8 blocks consisting of 3 minutes of work and 1 minute of rest. The movement patterns (n = 4) utilized in this program included the jab, cross, hook, and uppercut. Doherty *et al.* [2021] found that this program resulted in improved strength, endurance, and quality of life for the participants involved. This study is important because it demonstrates that shadowboxing can be beneficial for women with breast and ovarian cancer. Several limitations of this study include that it had a small sample size (n = 9), it utilized few movement patterns (n = 4), it did not include information about goals, drills, or combinations to practice while training, it did not include nutrition or recovery information, and it did not examine the influence of this program on physiological and morphological variables such as aerobic capacity, resting heart rate, muscle mass, fat mass, and body fat percentage. In other recent work, Brown *et al.* [2021] investigated the utility of shadowboxing for cardiac prehabilitation in a 56-year-old man with end-stage heart failure (n = 1). The 4-week program consisted of 4 sessions per week with each session including 10 minutes (week 1) to 25 minutes (week 4) of shadowboxing. Brown *et al.* [2021] found that the 4-week program helped this patient increase his sustained exercise tolerance from an estimated 3.5 METs (walking at a leisurely pace on a flat surface) to 6 METs (light-intensity boxing). This study is important because it demonstrates that shadowboxing can be beneficial for older men and patients in cardiac prehabilitation programs. Several limitations of this study include that it had a small sample size (n = 1), it did not specify the movement patterns used, it did not include information about goals, drills, or combinations to practice while training, it did not include nutrition or recovery information, and it did not examine the influence of this program on physiological and morphological variables such as aerobic capacity, resting heart rate, muscle mass, fat mass, and body fat percentage.

Finally, Jackson *et al.* [2012] investigated the influence of kickboxing training on participants diagnosed with multiple sclerosis (n = 11). This study consisted of a 5-week kickboxing program with a training frequency of 3 sessions per week. Each session was 1 hour in duration and focused on movements (n = 6) from boxing, kickboxing, and Muay Thai including the jab, cross, hook, front kick, side kick, and knee thrust. Jackson *et al.* [2012] found that this program resulted in improved balance and mobility for the participants involved. This study is important because it demonstrates that kickboxing training can be beneficial for participants diagnosed with multiple sclerosis. Other strengths of this study include that it discusses the training program in greater detail than in other work and that it incorporates a larger number of movement patterns (n = 6) from boxing, kickboxing, and Muay Thai, whereas other work focuses mostly on boxing or Taijiquan-style shadowboxing. Several limitations of this study include that it had a small

sample size (n = 11), it did not include nutrition or recovery information, and it did not examine the influence of this program on physiological and morphological variables such as aerobic capacity, resting heart rate, muscle mass, fat mass, and body fat percentage.

Although several studies have focused on shadowboxing in the literature and have made important contributions in their own right, many important questions remain, especially concerning shadowboxing as it is practiced in the context of MMA and modern fitness classes. Specifically, no study in the literature has focused on investigating the influence that MMA-style shadowboxing has on physiological and morphological variables such as aerobic capacity, resting heart rate, basal metabolic rate, muscle mass, bone mass, fat mass, body fat percentage, and visceral fat rating. Even preliminary results in the field are lacking. Given the vast number of individuals interested in MMA-style training for athletic and general fitness purposes, such an investigation would be an incredibly valuable contribution to the literature. Furthermore, our review of previous work on shadowboxing [Bosch *et al.*, 2012; Brown *et al.*, 2021; Combs *et al.*, 2009; Doherty *et al.*, 2021; Jackson *et al.*, 2012; Muharram *et al.*, 2011; Zheng, Zhou, Lai, 2015] has shown that (1) there is a lack of research on MMA-style shadowboxing, with previous research focusing on boxing and Taijiquan-style shadowboxing instead, (2) no existing research discusses goals, drills, movement patterns, or combinations to practice during shadowboxing training, leaving it unclear for researchers and individuals what to do during shadowboxing training, (3) no existing research provides information about nutrition or recovery procedures that were followed during the training program, which may be helpful in interpreting results (as poor nutrition and sleep habits can hinder results from training programs), (4) no existing research provides even preliminary data on the influence that a shadowboxing training program may have on physiological and morphological variables including aerobic capacity, muscle mass, bone mass, basal metabolic rate, resting heart rate, fat mass, and body fat percentage. This article contributes to the literature on shadowboxing by addressing all of the aforementioned shortcomings by (1) focusing on MMA-style shadowboxing, rather than pure boxing or Taijiquan-style shadowboxing, (2) providing goals, drills, movement patterns, and combinations to practice during shadowboxing training, making it clear for researchers and individuals what to do during shadowboxing training, (3) providing information about nutrition and recovery procedures that were followed during the training program, as supplementary information that may be useful in considering results and guiding behaviors, and (4) providing preliminary data on the influence that a 3-week shadowboxing training program has on physiological and morphological variables including aerobic capacity, muscle mass, bone mass, basal metabolic rate, resting heart rate, fat mass, and body fat percentage, which may help individuals decide on whether this kind of exercise program is best for their individual fitness goals. Toward this end, the present article also (5) confirms the test-retest reliability of the Tanita BC-1500 for body composition analysis.

2. Materials and Methods

2.1 Study Design

This article presents an original hypothesis and includes a case study to provide a preliminary test of this hypothesis. The original hypothesis presented is that consistent shadowboxing training (e.g., over a 3-week period) will increase aerobic capacity, muscle mass, bone mass, and basal metabolic rate, and decrease resting heart rate, fat mass, body fat percentage, and visceral fat rating.

2.2 Participant

The participant in this case study (male, age = 38 years) was a Lecturer in Cognitive Science at the University of California, Merced, that holds a Ph.D. as well as Certified Personal Trainer (NASM-CPT) and Performance Enhancement Specialist (NASM-PES) qualifications with the National Academy of Sports Medicine (NASM) and Certified Personal Trainer (ACE-CPT) and Certified Health Coach (ACE-HC) qualifications with the American Council on Exercise (ACE). He was a qualified referee for the World Boxing Council (WBC), a Master Instructor for the Everlast Striking Specialist Level 1 course, and a former Group Fitness Instructor for the Real Deal Boxing class at Equinox South Bay. He has over 30 years of martial arts experience and specializes in boxing, kickboxing, and Muay Thai. Since this individual was already familiar with shadowboxing technique, the heart-rate data and results from the training sessions are free of any learning curve effects, whereas a complete novice would devote large portions of time in low-activity states learning fundamentals (how to hold the hands while defending or throwing a jab, how not to cross the feet while moving laterally, etc.). Using an

experienced participant rather than a novice thereby allows the results to more accurately reflect the actual work-to-rest guidelines of the shadowboxing training program, whereas complete novices may spend different amounts of time learning fundamentals. Although the participant in this study was experienced in martial arts and exercised regularly before the coronavirus pandemic, he was completely inactive during the last 12 months due to COVID lockdown measures. Due to the pandemic and social distancing regulations, this participant discontinued training altogether, while focusing on teaching university courses online from home. This sedentary lifestyle over the last 12 months provided an optimal opportunity to determine how the adoption of a new exercise program based exclusively on shadowboxing would impact key health and fitness variables. Since the participant was single with no pets and worked from home, he remained at home throughout the 3-week study duration and discontinued all other physical activities. Specific food for the nutritional program was purchased ahead of time and stored at home to prevent extraneous physical activity, while shadowboxing was done at home in a large ring-size area. A warm-up, cool-down, sleep, and nutrition program was also followed throughout the program duration (see the supplementary materials for details).

2.3 Shadowboxing Program

Shadowboxing is a form of martial arts practice and exercise where one rehearses martial arts techniques with an imaginary rather than a real partner or opponent, or with other training goals in mind such as improving technical mastery, muscular endurance, balance and power, and sports-relevant strategies (takedown defense, evasive footwork, etc.) [Croom, 2023]. For example, the basic strikes within the striking system of boxing ("the sweet science") include the jab (#1), cross (#2), lead and rear hooks (#3 and #4, respectively), and lead and rear uppercuts (#5 and #6, respectively), so a martial artist or fitness enthusiast may use a shadowboxing session to practice improving the fluidity of these strikes (neuromuscular efficiency) or to increase the volume that can be thrown during the session overall (muscular endurance) (there are also variations from these basic strikes, such as the gazelle hook and overhand rear punch, but the 6 basic strikes numbered 1-6 will suffice for the present article). Kickboxing includes the same strikes as boxing, but further includes kicks and knee strikes. Muay Thai ("the art of eight limbs") includes the same strikes as boxing and kickboxing, but further includes elbow strikes and clinch work. MMA utilizes the strikes from all the martial arts, including punches, kicks, and elbow and knee strikes (for artwork depicting 4 different strikes in MMA see Figure 1; for a numbering system for striking see Everlast [2017]). In addition to single strikes (**1**, **2**, **3**), there are also combinations of strikes (*1-2-**3***), defensive maneuvers, footwork, and other movement patterns that provide the martial artist and fitness enthusiast with a rich system of full-body functionally integrated movement patterns to practice during training sessions [Croom, 2023; Feleke, 2022; Ryan, 2014]. In this article, I have included an original shadowboxing program that covers 13 goals to focus on, 6 drills, 58 movement patterns covering basic positioning, footwork, defense maneuvers, and offensive strikes, as well as 70 striking combinations (see the supplementary materials for details). The training procedures used in this study were primarily based on general training principles outlined in the official Everlast Striking Specialist and Master Instructor course material [Everlast, 2017]. Training procedures were also based on experience and knowledge gained through practical boxing, kickboxing, and Muay Thai training, as well as professional certification with the National Academy of Sports Medicine (NASM), American Council on Exercise (ACE), and EXOS. Since training should be done in both orthodox (right-handed) and southpaw (left-handed) stances to maintain muscle symmetry on both sides of the body [Clark, Lucett, Sutton, 2013], and to further provide one with a wider repertoire of martial arts skills [Evolve MMA, 2018], the shadowboxing program below in fact provides over 100 basic movement patterns and 140 combinations to practice while shadowboxing. This demonstrates the rich variety of full-body, functionally integrated movement patterns that are available for practice during shadowboxing training, and it further provides the reader with the guidelines and resources to begin a shadowboxing training program of their own. Remember to always consult your physician before beginning any new fitness program and that inclusion of additional rest periods may be required depending on individual abilities. It is also advisable to receive introductory training in proper striking technique from a qualified and experienced instructor.

- **Total program duration:** 21 days
- **Training frequency:** 1 session per day
- **Duration of training session:** 60 minutes

- **Training session split:** 10 blocks with each block consisting of 5 minutes of work and 1 minute of rest
    - Block 1a: Round 1 consists of 5 minutes of work at low to medium intensity for a warm-up
    - Block 1b: Rest 1 consists of 1 minute of rest
    - Block 2a: Round 2 consists of 5 minutes of work at any intensity (see the supplementary materials for an introductory list of goals, techniques, and combinations to work on during this block)
    - Block 2b: Rest 2 consists of 1 minute of rest
    - Blocks 3 through 9 are similar to block 2 (see the supplementary materials for an introductory list of goals, techniques, and combinations to work on during these blocks)
    - Block 10 is similar to block 1 with a focus on cooldown
- **Functional warm up and cool down:** The first and last rounds are done without weight at low to moderate intensity to gradually transition the body between resting and exercise states
- **Focus for each round:** Details regarding objectives and guidelines are provided in the program (see the supplementary materials)
- **Training schedule:** Every day in the evening between 6 and 8 pm (for this case study)
- **Assessment schedule:** Initial assessments were conducted (on an empty stomach wearing only boxers and a t-shirt) one day before beginning the training program, then an assessment was conducted every week for 3 weeks to track weekly progress as well as overall progress
- **Sleep schedule:** 8 to 9 hours of uninterrupted sleep every night from 1 am to 10 am
- **Pre-training meal:** 1 to 2 bananas 45 minutes before training
- **Post-training meal:** 1 Muscle Milk protein drink and 3 to 4 handfuls of almonds after training
- **Meal frequency:** Every 2 to 4 hours (whenever hungry)
- **Meal composition:** Every meal consists of one serving of protein (palm size at 20-30 grams), one serving of vegetables (fist size at 75 grams), one serving of carbohydrates (cupped hand size at 20-30 grams), and one serving of fat (thumb size at 7-12 grams) (see the supplementary materials)

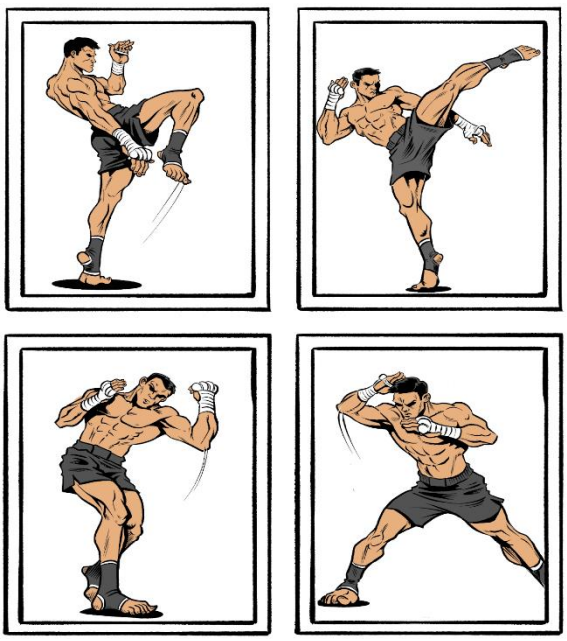


Figure 1: This figure provides examples of shadowboxing techniques. Artwork depicts a striker in the southpaw (left-handed) stance. Top left: Lead knee. Top right: Rear roundhouse kick. Bottom Left: Rear uppercut. Bottom Right: Lead upward elbow. Original artwork courtesy of Sonny Chargualaf @heroesandheadkicks.

This shadowboxing program consisted of an hour-long shadowboxing session each day for 21 consecutive days (April 26 through May 16 2021). Each hour-long session was organized into temporal blocks of work and rest. In boxing, rounds are typically 3 minutes long followed by 1 minute of rest ["Unified Rules of Boxing," Association of Boxing Commissions and Combative Sports, 2016]. In kickboxing and Muay Thai, rounds are typically 3 minutes long followed by 2 minutes of rest ["Unified Rules of Professional Kickboxing," Association of Boxing Commissions and Combative Sports, 2017; "Rules and Regulations for Muay Thai Competitions," WBC Muay Thai, 2021]. In MMA, rounds are typically 5 minutes long followed by 1 minute of rest ["Unified Rules of Mixed Martial Arts," Association of Boxing Commissions and Combative Sports, 2019]. The shadowboxing program in this study was based on the structure of MMA and utilized a high work-to-rest ratio with 10 rounds consisting of 5 minutes of work followed by 1 minute of rest (10 x 6 minutes). 50% of the time a 4 pound "Knockout" set of Egg Weights (2 pounds each egg) was used while shadowboxing, the other 50% of the time shadowboxing was done without any weights. The first and last round of each shadowboxing session was done without weights and at a reduced intensity for the purpose of gradually transitioning between resting and exercise states (for warming-up and cooling-down, respectively). The participant did not engage in any other form of exercise or physical activity during the 21-day program since he worked remotely from home during the coronavirus pandemic and did not have to commute or engage in any other physical activities.

2.4 Exercise Equipment

A 4 lbs "Knockout" set of Egg Weights (2 lbs each egg) was used during shadowboxing sessions about 50% of the time (Egg Weights, Newbury Park, CA.). By training with the Egg Weights 50% of the time, the participant was able to focus on strength and power. By training without the Egg Weights 50% of the time, the participant was able to focus on striking speed. No other equipment was used during this shadowboxing program.

2.5 Tanita BC-1500 Segmental Body Composition Monitor

The Tanita BC-1500 8-electrode segmental body composition monitor (Tanita Inc., Arlington Heights, IL) was used to collect body composition data including (i) the date of the assessment; (ii) total body weight; (iii) body mass index (BMI); (iv) body fat percentage; (v) total fat mass; (vi) body fat range; (vii) fat free mass; (viii) visceral fat rating (VFR); (ix) body water percentage; (x) body water mass; (xi) total muscle mass; (xii) bone mass; (xiii) physique rating; (xiv) left leg muscle mass; (xv) left leg body fat percentage; (xvi) right leg muscle mass; (xvii) right leg body fat percentage; (xviii) left arm muscle mass; (xix) left arm body fat percentage; (xx) right arm muscle mass; (xxi) right arm body fat percentage; (xxii) trunk muscle mass; (xxiii) trunk body fat percentage; (xxiv) metabolic age; (xxv) basal metabolic rate (BMR); and (xxvi) daily calorie intake (DCI). The Tanita BC-1500 uses bioelectrical impedance analysis (BIA) to measure body composition based on the rate at which electrical current travels through the body. Results from the measurements are based on the preset equations for this device [Tanita, 2013]. Previous work has compared results from BIA against the results from dual-energy x-ray absorptiometry or DEXA [Bracco *et al.*, 1996; de Abreu, Wilvert, Wazlawik, 2020; Kabri, Hernandez, Mitchell, 2015; Pietrobelli *et al.*, 2004], air displacement plethysmography or ADP [Vasold *et al.*, 2019], and magnetic resonance imaging or MRI [Janssen *et al.*, 2000] as reference methods and repeatedly demonstrated that BIA is a valid (accurate) and reliable (consistent) method for the estimation of human body composition. Duz, Kocak, and Korkusuz [2009] compared results from skinfold techniques, ultrasound techniques, and BIA against results from DEXA as a reference method and found that BIA provided the closest results to DEXA for males. Since BIA provides the closest results to (the reference method) DEXA for males, and the participant in this study is male, it made sense to select BIA for measuring his body composition throughout the training program. In one previous study examining the validity and reliability of the Tanita BF-689 (a lower-end model compared to the BC-1500), Kabri, Hernandez, and Mitchell [2015] compared results from the Tanita BF-689 against results from DEXA as a reference method and found that the Tanita BF-689 had moderately strong absolute agreement with DEXA and excellent test-retest reliability. To confirm the reliability of the particular Tanita BC-1500 used in this study, a test-retest reliability procedure was conducted on the same subject 200 consecutive times over a continuous 6-hour period. Test-retest reliability was assessed by the coefficients of variation of repeated BIA tests [Chertow *et al.*, 1995]. The coefficient of variation is a measure of relative variability and is defined as the standard deviation divided by the mean,

with the result reported as a percentage [Reed, Lynn, Meade, 2002]. The coefficient of variation can be used as a measure of reliability because it assesses the stability of a measurement across repeated trials. A small coefficient of variation value indicates a more reliable (consistent) measurement and a large coefficient of variation value indicates a less reliable (consistent) measurement [Shechtman, 2013]. Since the coefficient of variation indicates the degree of variability in repeated tests conducted on a specific person, it may be used to determine if the same person has undergone true change when two results are separated by an intervention, such as a medical treatment or shadowboxing training program. An intervention effect would be indicated when the two results differ by more than expected from the inherent variability of the measuring tool [Shechtman, 2013]. An advantage of this measure is that it allows one to make a direct comparison between the reliability (consistency) of measurements across instruments, irrespective of the scale or calibration [Shechtman, 2013]. The coefficient of variation cut-off value for acceptable variability ranges from 7.5% to 20% in the literature, with the most common cut-off value being 15% [Shechtman, 2013]. As evidenced in the data provided in the supplementary materials for this article, measurements for all variables are highly reliable for the Tanita BC-1500 based on established standards in the field, falling below 7.5% for all measures ([Shechtman, 2013]; see the supplementary materials for details).

2.6 Polar OH1 Optical Heart Rate Sensor

The Polar OH1 optical heart rate sensor (Polar Electro Ltd., Finland) was used to collect (xxvii) the date of the assessment or training; (xxviii) resting heart rate (RHR); (xxix) aerobic capacity score; (xxx) cardiovascular fitness rating; and training data from the shadowboxing sessions including (xxxi) training duration; (xxxii) calorie expenditure; (xxxiii) heart rate max (HRmax); (xxxiv) heart rate average (HRaverage); (xxxv) duration in Zone 1; (xxxvi) duration in Zone 2; (xxxvii) duration in Zone 3; (xxxviii) duration in Zone 4; and (xxxvix) duration in Zone 5. Previous studies have demonstrated that the Polar OH1 is a valid (accurate) and reliable (consistent) tool for measuring instantaneous heart rate and training load during exercise [Hermand *et al.*, 2019; Hettiarachchi *et al.*, 2019; Schubert, Clark, De La Rosa, 2018]. The Polar OH1 is a photoplethysmographic sensor [Polar, 2019b] that tracks heart rate, places heart rate in a range between 50% and 100% of the individual's maximum heart rate, and divides this range of heart rates into five distinct training zones: *Very Light*, *Light*, *Moderate*, *Hard*, and *Maximum*. Training in each of the five heart rate zones carries its own main benefits [Polar, 2021]. *Zone 1* is *Very Light* at 50-60% of heart rate max, and training in this zone improves overall health and aids in recovery from more demanding training. *Zone 2* is *Light* at 60-70% of heart rate max, and training in this zone develops general endurance and improves the body's ability to utilize fat as an energy source. *Zone 3* is *Moderate* at 70-80% of heart rate max, and training in this zone improves aerobic fitness. *Zone 4* is *Hard* at 80-90% of heart rate max, and training in this zone improves speed, endurance, and the body's ability to utilize carbohydrates for energy. *Zone 5* is *Maximum* at 90-100% of heart rate max, and training in this zone improves maximum performance. The Polar Fitness Test (PFT) uses built-in equations to calculate an individual's aerobic fitness from resting heart rate, heart rate variability, gender, age, height, body weight, and level of physical activity. An individual taking the test rests for 3 to 5 minutes while the Polar OH1 measures their heart rate and heart rate variability from a sample of at least 240 heart beats. The PFT was developed in the 1990s using artificial neural networks and is used to calculate maximal oxygen uptake (VO_2max), a widely accepted standard for aerobic capacity and cardiovascular fitness. Previous studies comparing results from the PFT to laboratory measurements of VO_2max as a reference method have demonstrated that the PFT is a valid (accurate) and reliable (consistent) method for assessing aerobic capacity in human subjects [Vainamo *et al.*, 1998; Vainamo *et al.*, 1996; Polar, 2019a]. Further, the PFT is commonly used in the exercise physiology literature for the assessment of aerobic capacity [Mileski *et al.*, 2018; Brum *et al.*, 2013; Tumiati *et al.*, 2008; Borodulin *et al.*, 2006; Borodulin *et al.*, 2005; Borodulin *et al.*, 2004].

3. Results

Results from the 3-week shadowboxing training program are provided below. Figure 2 provides results of pre-training and post-training body composition evaluations using the Tanita BC-1500.

Figure 2: This figure provides the results of pre-training and post-training body composition evaluations using the Tanita BC-1500. The pre-training evaluation was conducted on April 26th and the post-training evaluation was conducted on March 18th.

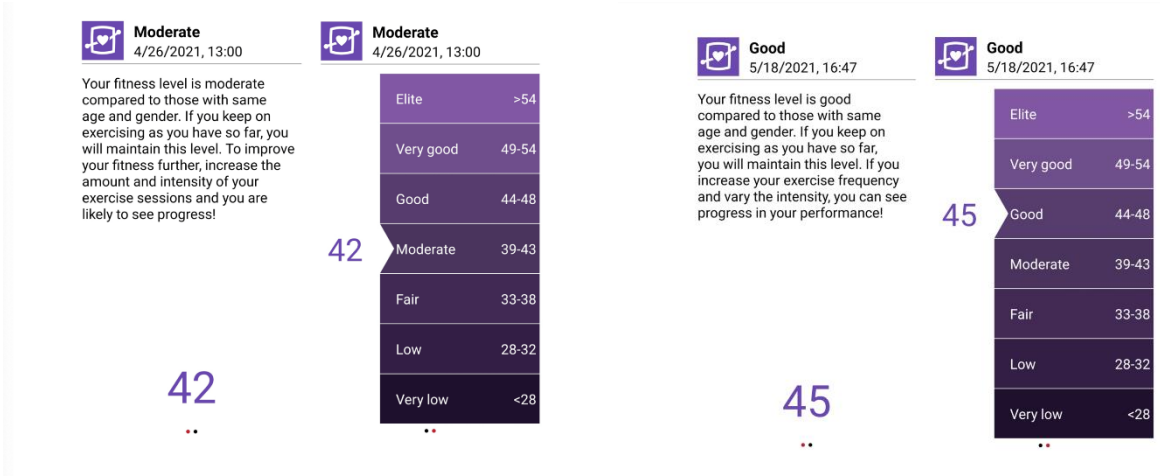


Figure 3: This figure provides the results of pre-training and post-training cardiovascular fitness evaluations using the Polar OH1. The pre-training evaluation was conducted on April 26th and the post-training evaluation was conducted on March 18th.

Figure 3 provides results of pre-training and post-training cardiovascular fitness evaluations using the Polar OH1. Figure 4 provides data about heart rate (HR average and HR max) and calories burned for each shadowboxing session using the Polar OH1. Figure 5 provides training data from each shadowboxing session using the Polar OH1. Statistics regarding the test-retest reliability of the Tanita BC-1500 are provided in the supplementary materials for this article. The coefficients of variation on all measures show that the Tanita BC-1500 has excellent test-retest reliability by accepted standards in the literature, confirming that the changes in measurements of the same individual over time are not due to the inherent variability of the measuring device but are rather due to the intervention or shadowboxing training program [Buchholz, Bartok, Schoeller, 2004].

- **Calories burned during the program:** 13,698 kcals
- **Calories burned per session:** 652.29 ± 71.77 kcals

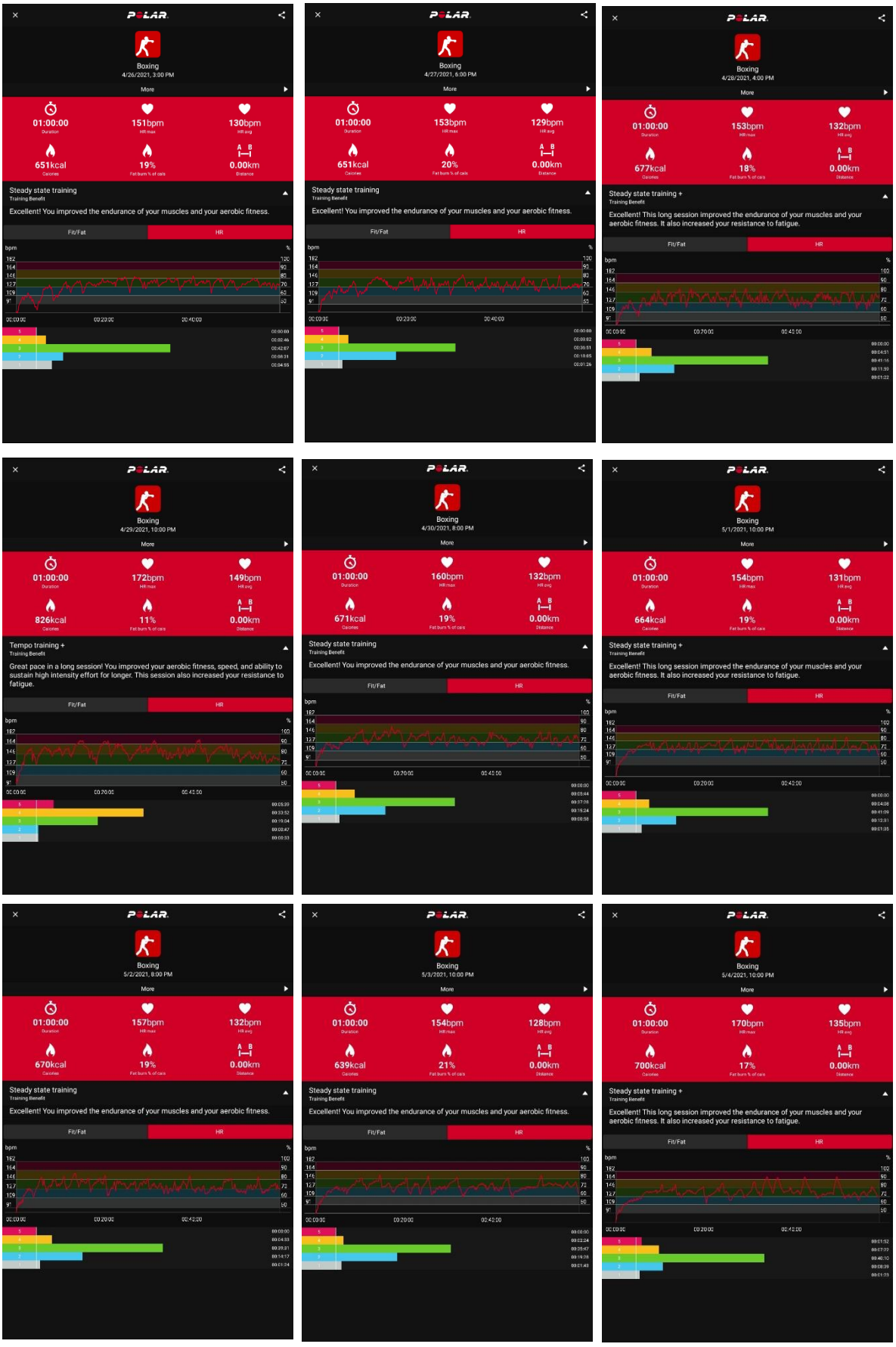
- **Heart rate average per session:** 129.71 ± 7.93 bpm
- **Heart rate max per session:** 159.71 ± 8.50 bpm
- **Maximum heart rate during the program:** 172 bpm
- **Total duration spent in HR Zone 1 during the program:** 1 hr 15 min 40 sec
- **Total duration spent in HR Zone 2 during the program:** 6 hr 17 min 44 sec
- **Total duration spent in HR Zone 3 during the program:** 10 hr 11 min 27 sec
- **Total duration spent in HR Zone 4 during the program:** 2 hr 35 min 1 sec
- **Total duration spent in HR Zone 5 during the program:** 0 hr 19 min 11 sec
- **Aerobic capacity score:** Increased by a total of 3 (from 42 to 45); the post-training aerobic capacity score was increased by 7.1% compared to the pre-training aerobic capacity score, suggesting that shadowboxing training can increase aerobic capacity scores
- **Aerobic capacity rating:** Increased by a total of 1 aerobic capacity rating level from MODERATE to GOOD, suggesting that shadowboxing training can increase aerobic capacity ratings
- **Resting heart rate:** Decreased by a total of 30 bpm (from 78 bpm to 48 bpm); the post-training resting heart rate was decreased by 38.5% compared to the pre-training resting heart rate, suggesting that shadowboxing training can decrease resting heart rate
- **Basal metabolic rate:** Increased by a total of 67 kcals (from 2021 kcals to 2088 kcals); the post-training basal metabolic rate was increased by 3.3% compared to the pre-training basal metabolic rate, suggesting that shadowboxing training can increase basal metabolic rate
- **Daily calorie intake:** Increased by a total of 136 kcals (from 3581 kcals to 3717 kcals); the post-training daily calorie intake increased by 3.8% compared to the pre-training daily calorie intake, suggesting that shadowboxing training can increase daily calorie intake
- **Total body weight:** No change at 177.4 lbs (from 177.4 lbs to 177.4 lbs); the post-training total body weight demonstrated a 0% change compared to the pre-training total body weight, suggesting that shadowboxing training does not necessarily increase or decrease total body weight
- **Body mass index:** No change at 24.8 (from 24.8 to 24.8); the post-training body mass index demonstrated a 0% change compared to the pre-training body mass index, suggesting that shadowboxing training does not necessarily increase or decrease body mass index
- **Body fat percentage:** Decreased by a total of 3.6% (from 13.3% to 9.7%); the post-training body fat percentage decreased by 2.7% compared to the pre-training body fat percentage, suggesting that shadowboxing training can decrease body fat percentage
- **Total muscle mass:** Increased by a total of 6 lbs (from 146.4 lbs to 152.4 lbs); the post-training total muscle mass increased by 4.1% compared to the pre-training total muscle mass, suggesting that shadowboxing training can increase total muscle mass
- **Total bone mass:** Increased by a total of 0.2 lbs (from 7.8 lbs to 8.0 lbs); the post-training total bone mass increased by 2.6% compared to the pre-training total bone mass, suggesting that shadowboxing training can increase total bone mass
- **Total fat mass:** Decreased by a total of 6.4 lbs (from 23.6 lbs to 17.2 lbs); the post-training total fat mass decreased by 27.1% compared to the pre-training total fat mass, suggesting that shadowboxing training can decrease total fat mass
- **Fat free mass:** Increased by a total of 6.4 lbs (from 153.8 lbs to 160.2 lbs); the post-training fat free mass increased by 4.2% compared to the pre-training fat free mass, suggesting that shadowboxing training can increase fat free mass
- **Visceral fat rating:** Decreased by a total of 2 (from 5 to 3), suggesting that shadowboxing training can decrease visceral fat ratings
- **Left leg muscle mass:** Increased by a total of 0.8 lbs (from 23.4 lbs to 24.2 lbs); the post-training left leg muscle mass increased by 3.4% compared to the pre-training left leg muscle mass, suggesting that shadowboxing training can increase left leg muscle mass
- **Right leg muscle mass:** Increased by a total of 0.8 lbs (from 24.6 lbs to 25.4 lbs); the post-training right leg muscle mass increased by 3.3% compared to the pre-training right leg

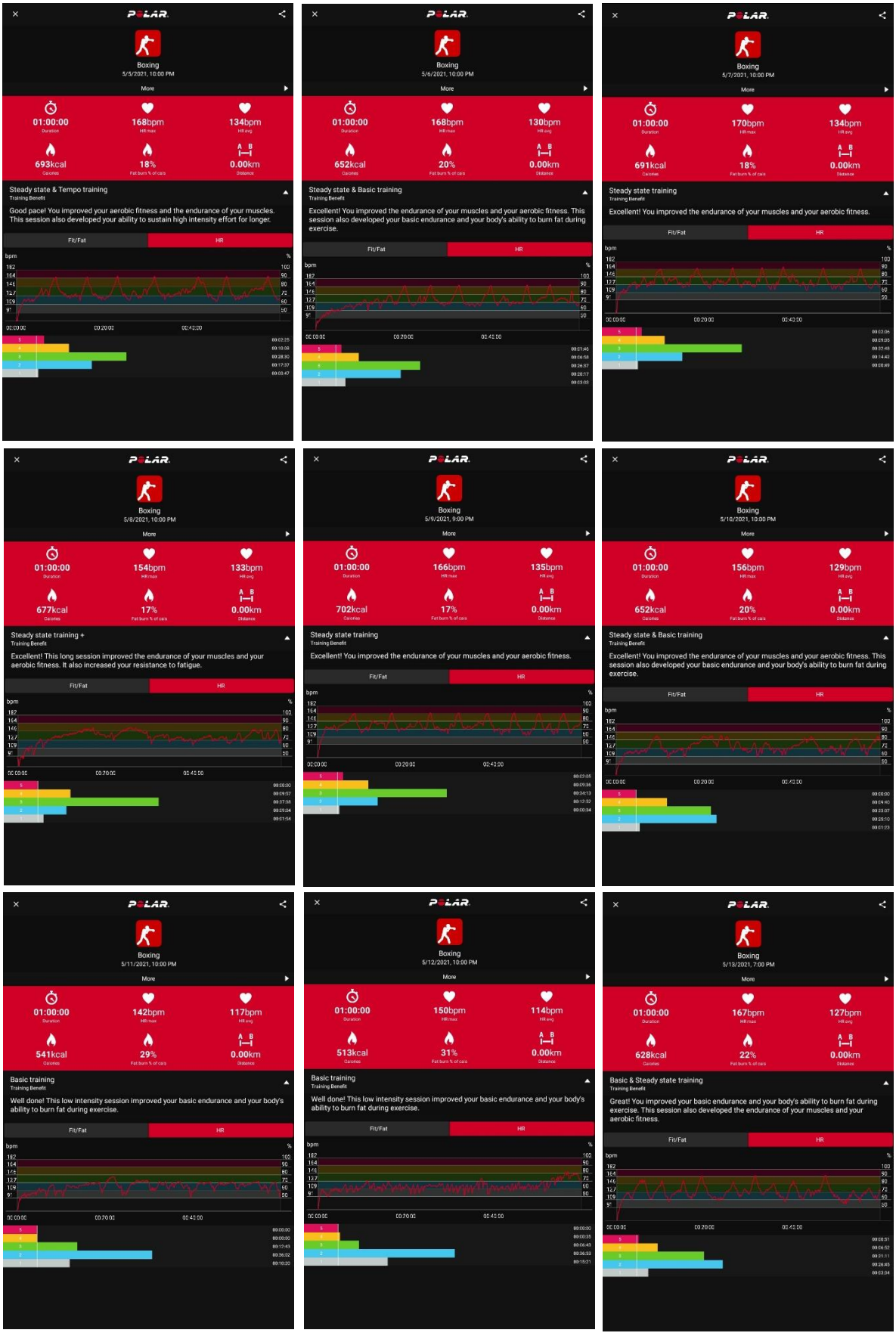
muscle mass, suggesting that shadowboxing training can increase right leg muscle mass

- **Left arm muscle mass:** Increased by a total of 0.2 lbs (from 8.8 lbs to 9.0 lbs); the post-training left arm muscle mass increased by 2.3% compared to the pre-training left arm muscle mass, suggesting that shadowboxing training can increase left arm muscle mass
- **Right arm muscle mass:** No change at 8.6 lbs (from 8.6 lbs to 8.6 lbs); the post-training right arm muscle mass demonstrated a 0% change compared to the pre-training right arm muscle mass, suggesting that shadowboxing training does not necessarily increase or decrease right arm muscle mass
- **Trunk muscle mass:** Increased by a total of 3.6 lbs (from 81.2 lbs to 84.8 lbs); the post-training trunk muscle mass increased by 4.4% compared to the pre-training trunk muscle mass, suggesting that shadowboxing training can increase trunk muscle mass
- **Left leg fat percentage:** Decreased by a total of 2.4% (from 14.4% to 12.0%); the post-training left leg fat percentage decreased by 16.7% compared to the pre-training left leg fat percentage, suggesting that shadowboxing training can decrease left leg fat percentage
- **Right leg fat percentage:** Decreased by a total of 1.7% (from 12.5% to 10.8%); the post-training right leg fat percentage decreased by 13.6% compared to the pre-training right leg fat percentage, suggesting that shadowboxing training can decrease right leg fat percentage
- **Left arm fat percentage:** Decreased by a total of 0.9% (from 13.9% to 13.0%); the post-training left arm fat percentage decreased by 6.5% compared to the pre-training left arm fat percentage, suggesting that shadowboxing training can decrease left arm fat percentage
- **Right arm fat percentage:** Decreased by a total of 0.9% (from 14.2% to 13.3%); the post-training right arm fat percentage decreased by 6.3% compared to the pre-training right arm fat percentage, suggesting that shadowboxing training can decrease right arm fat percentage
- **Trunk fat percentage:** Decreased by a total of 5.1% (from 13.1% to 8.0%); the post-training trunk fat percentage decreased by 38.9% compared to the pre-training trunk fat percentage, suggesting that shadowboxing training can decrease trunk fat percentage

Date	Duration	Calories	HR max	HR average
April 26 2021	1:00:00	651 kcal	151 bpm	130 bpm
April 27 2021	1:00:00	651 kcal	153 bpm	129 bpm
April 28 2021	1:00:00	677 kcal	153 bpm	132 bpm
April 29 2021	1:00:00	826 kcal	172 bpm	149 bpm
April 30 2021	1:00:00	671 kcal	160 bpm	132 bpm
May 1 2021	1:00:00	664 kcal	154 bpm	131 bpm
May 2 2021	1:00:00	670 kcal	157 bpm	132 bpm
May 3 2021	1:00:00	639 kcal	154 bpm	128 bpm
May 4 2021	1:00:00	700 kcal	170 bpm	135 bpm
May 5 2021	1:00:00	693 kcal	168 bpm	134 bpm
May 6 2021	1:00:00	652 kcal	168 bpm	130 bpm
May 7 2021	1:00:00	691 kcal	170 bpm	134 bpm
May 8 2021	1:00:00	677 kcal	154 bpm	133 bpm
May 9 2021	1:00:00	702 kcal	166 bpm	135 bpm
May 10 2021	1:00:00	652 kcal	156 bpm	129 bpm
May 11 2021	1:00:00	541 kcal	142 bpm	117 bpm
May 12 2021	1:00:00	513 kcal	150 bpm	114 bpm
May 13 2021	1:00:00	628 kcal	167 bpm	127 bpm
May 14 2021	1:00:00	570 kcal	166 bpm	121 bpm
May 15 2021	1:00:00	513 kcal	154 bpm	115 bpm
May 16 2021	1:00:00	717 kcal	169 bpm	137 bpm

Figure 4: This figure provides training data including heart rate (HR average and HR max) and calories burned for each shadowboxing session using the Polar OH1. Shadowboxing training occurred every day for one hour from April 26th through March 18th.


POLAR
Boxing
4/26/2021, 3:00 PM
More
01:00:00
151bpm
130bpm
651kcal
19%
0.00km
Steady state training
Training Benefit
Excellent! You improved the endurance of your muscles and your aerobic fitness.
Fit/Fat
HR
Boxing
4/27/2021, 6:00 PM
More
01:00:00
153bpm
129bpm
651kcal
20%
0.00km
Steady state training
Training Benefit
Excellent! You improved the endurance of your muscles and your aerobic fitness.
Fit/Fat
HR
Boxing
4/28/2021, 4:00 PM
More
01:00:00
153bpm
132bpm
677kcal
18%
0.00km
Steady state training +
Training Benefit
Excellent! This long session improved the endurance of your muscles and your aerobic fitness. It also increased your resistance to fatigue.
Fit/Fat
HR
Boxing
4/29/2021, 10:00 PM
More
01:00:00
172bpm
149bpm
826kcal
11%
0.00km
Tempo training +
Training Benefit
Great pace in a long session! You improved your aerobic fitness, speed, and ability to sustain high intensity effort for longer. This session also increased your resistance to fatigue.
Fit/Fat
HR
Boxing
4/30/2021, 8:00 PM
More
01:00:00
160bpm
132bpm
671kcal
19%
0.00km
Steady state training
Training Benefit
Excellent! You improved the endurance of your muscles and your aerobic fitness.
Fit/Fat
HR
Boxing
5/1/2021, 10:00 PM
More
01:00:00
154bpm
131bpm
664kcal
19%
0.00km
Steady state training +
Training Benefit
Excellent! This long session improved the endurance of your muscles and your aerobic fitness. It also increased your resistance to fatigue.
Fit/Fat
HR
Boxing
5/2/2021, 8:00 PM
More
01:00:00
157bpm
132bpm
670kcal
19%
0.00km
Steady state training
Training Benefit
Excellent! You improved the endurance of your muscles and your aerobic fitness.
Fit/Fat
HR
Boxing
5/3/2021, 10:00 PM
More
01:00:00
154bpm
128bpm
639kcal
21%
0.00km
Steady state training
Training Benefit
Excellent! You improved the endurance of your muscles and your aerobic fitness.
Fit/Fat
HR
Boxing
5/4/2021, 10:00 PM
More
01:00:00
170bpm
135bpm
700kcal
17%
0.00km
Steady state training +
Training Benefit
Excellent! This long session improved the endurance of your muscles and your aerobic fitness. It also increased your resistance to fatigue.
Fit/Fat
HR


POLAR
Boxing
5/5/2021, 10:00 PM
More
01:00:00
168bpm
134bpm
693kcal
18%
0.00km
Steady state & Tempo training
Training Benefit
Good pace! You improved your aerobic fitness and the endurance of your muscles. This session also developed your ability to sustain high intensity effort for longer.
Fit/Fat
HR
Boxing
5/6/2021, 10:00 PM
More
01:00:00
168bpm
130bpm
652kcal
20%
0.00km
Steady state & Basic training
Training Benefit
Excellent! You improved the endurance of your muscles and your aerobic fitness. This session also developed your basic endurance and your body's ability to burn fat during exercise.
Fit/Fat
HR
Boxing
5/7/2021, 10:00 PM
More
01:00:00
170bpm
134bpm
691kcal
18%
0.00km
Steady state training
Training Benefit
Excellent! You improved the endurance of your muscles and your aerobic fitness.
Fit/Fat
HR
Boxing
5/8/2021, 10:00 PM
More
01:00:00
154bpm
133bpm
677kcal
17%
0.00km
Steady state training +
Training Benefit
Excellent! This long session improved the endurance of your muscles and your aerobic fitness. It also increased your resistance to fatigue.
Fit/Fat
HR
Boxing
5/9/2021, 9:00 PM
More
01:00:00
166bpm
135bpm
702kcal
17%
0.00km
Steady state training
Training Benefit
Excellent! You improved the endurance of your muscles and your aerobic fitness.
Fit/Fat
HR
Boxing
5/10/2021, 10:00 PM
More
01:00:00
156bpm
129bpm
652kcal
20%
0.00km
Steady state & Basic training
Training Benefit
Excellent! You improved the endurance of your muscles and your aerobic fitness. This session also developed your basic endurance and your body's ability to burn fat during exercise.
Fit/Fat
HR
Boxing
5/11/2021, 10:00 PM
More
01:00:00
142bpm
117bpm
541kcal
29%
0.00km
Basic training
Training Benefit
Well done! This low intensity session improved your basic endurance and your body's ability to burn fat during exercise.
Fit/Fat
HR
Boxing
5/12/2021, 10:00 PM
More
01:00:00
150bpm
114bpm
513kcal
31%
0.00km
Basic training
Training Benefit
Well done! This low intensity session improved your basic endurance and your body's ability to burn fat during exercise.
Fit/Fat
HR
Boxing
5/13/2021, 7:00 PM
More
01:00:00
167bpm
127bpm
628kcal
22%
0.00km
Basic & Steady state training
Training Benefit
Great! You improved your basic endurance and your body's ability to burn fat during exercise. This session also developed the endurance of your muscles and your aerobic fitness.
Fit/Fat
HR

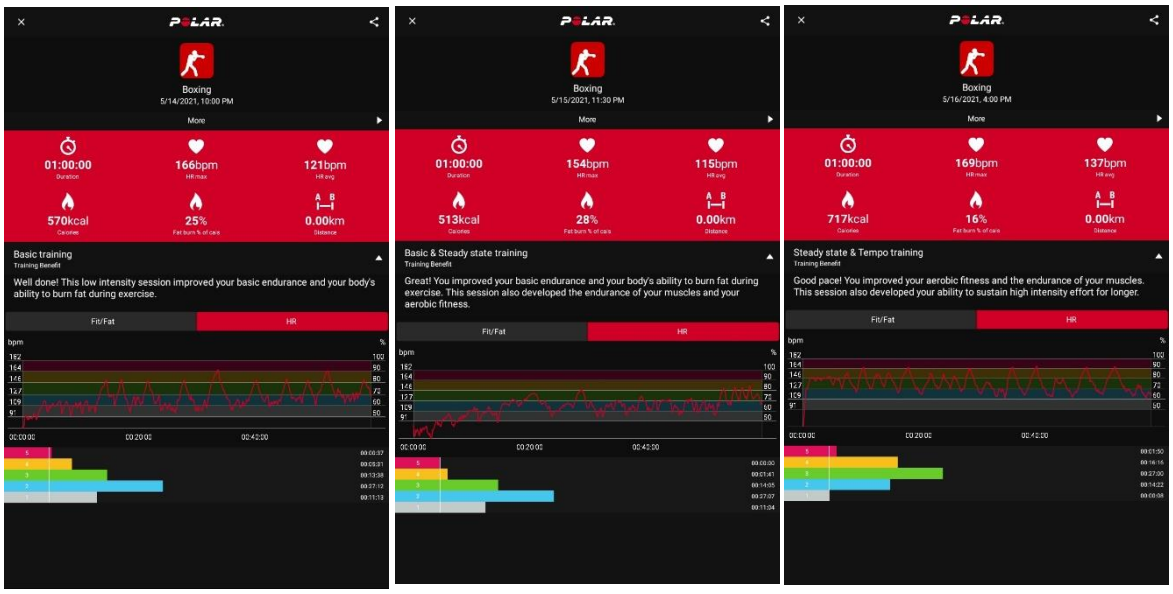


Figure 5: This figure provides training data from shadowboxing sessions using the Polar OH1. Shadowboxing training occurred every day for one hour from April 26th through March 18th.

4. Discussion

This research makes several important contributions to the literature on shadowboxing. The first contribution that this article makes is that it provides a review of the literature on shadowboxing, highlighting specific strengths and weaknesses of existing work [Bosch *et al.*, 2012; Brown *et al.*, 2021; Combs *et al.*, 2009; Doherty *et al.*, 2021; Jackson *et al.*, 2012; Muharram *et al.*, 2011; Zheng, Zhou, Lai, 2015]. This kind of review of the literature is important to assess the progress that has been made in the field thus far as well as areas for improvement moving forward. Given that existing research on shadowboxing (1) has not focused on MMA-style shadowboxing, (2) has not provided goals, drills, movement patterns, or combinations to practice during shadowboxing training, (3) has not provided information about nutrition or recovery procedures that were followed during the training program, (4) has not provided even preliminary data on the influence that a shadowboxing training program may have on physiological and morphological variables, it became clear that there were many gaps in the literature for this research to address. By highlighting weaknesses or gaps in existing work, the original contributions of this article become more evident.

The second contribution that this article makes to the literature is that it provides confirmation of the test-retest reliability of the Tanita BC-1500 8-electrode segmental body composition monitor. 200 consecutive tests on the same subject over a continuous 6-hour period provided coefficients of variation that were all well within the accepted standards in the literature, demonstrating that this tool is reliable for individuals to use in tracking their health and fitness progress at home ([Shechtman, 2013; Buchholz, Bartok, Schoeller, 2004]; see the supplementary materials for details). This is an important contribution to the literature since no previous work has conducted a test-retest reliability procedure on the Tanita BC-1500 specifically. Previous work has demonstrated the reliability of lower-end Tanita models (e.g., the Tanita BF-689 was examined by Kabri, Hernandez, and Mitchell [2015]), so the results about the reliability of the Tanita BC-1500 presented here are to be anticipated yet are nonetheless still important to be validated. The use of an 8-electrode system for bioelectrical impedance analysis enables the Tanita BC-1500 to reliably measure a variety of important health and fitness variables for individuals at home including total weight, muscle mass, bone mass, fat mass, body fat percentage, body water mass, body water percentage, basal metabolic rate, daily calorie intake, left leg muscle mass and fat mass, right leg muscle mass and fat mass, and trunk muscle mass and fat mass. This detailed information is important because total weight alone, which is provided by a traditional scale, does not discern between fat mass and fat free mass (e.g., between two individuals that have 9% and 39% body fat, but both weighing 180 lbs) so monitoring total weight alone is not a very informative method for individuals to assess what kind of progress they are making with their health and fitness programs. On a

traditional scale, 5 lbs of additional fat mass and 5 lbs of additional fat-free mass both appear as an additional 5 lbs, although these reflect opposing outcomes to a training goal (reducing body fat percentage). Without the ability to track more fine-grain details about their body weight (e.g., whether they are gaining lean muscle mass or fat mass), traditional scales can lead individuals to become frustrated since they are unable to see changes from their hard work. Traditional scales also do not provide other information - such as bone mass, water mass, and basal metabolic rate - that may be relevant for individual training and nutrition goals (e.g., elderly individuals may want to focus on increasing bone mass, but are unable to track this with a traditional scale). The reliability of this BIA method allows individuals to track their progress on specific measures over time [Buchholz, Bartok, Schoeller, 2004], such as whether muscle mass is increasing and fat mass is decreasing over a 3-week period, and a recent review by Ward [2019] found that the magnitude of errors associated with BIA methods are not dissimilar to those observed for so-called gold standard reference methods like DEXA [Ward, 2019]. This is one reason why BIA methods are now widely used at elite fitness clubs around the world including Equinox, TMPL, and many others [Bell, 2017; Gaddy, 2016; Jensen, 2019; Lappe, Powell, 2019; Rushbury, Cooper, 2022]. It is important to note here that for exact and valid measurements for clinical, medical, and contest purposes, measurements should always be done by a trained professional in accordance with established methods and guidelines for the specific situation at hand. Even though DEXA may be considered the gold standard for many purposes, it is important to keep in mind that even DEXA is measured against other gold standards such as magnetic resonance imaging (MRI), multislice computerized tomography (CT), and whole body phantoms with known values [Bilsborough *et al.*, 2014; Glickman *et al.*, 2004; Mohammad *et al.*, 2017; Ward, 2019]. There is no single, universally accepted gold standard for measuring body composition for all people and for all purposes, and many gold standard methods are prohibitively expensive for the average health and fitness enthusiast, costing hundreds to thousands of dollars per assessment. The Tanita BC-1500 therefore provides individuals with a practical, portable, cost-effective, and reliable tool for conveniently tracking their health and fitness progress at home.

The third contribution that this article makes to the literature is that it provides the first detailed shadowboxing program for mixed martial arts. Although earlier work on shadowboxing has made important contributions to the field, none of this earlier work included a detailed program that covered specific goals, drills, movement patterns, and combinations to practice while shadowboxing [Bosch *et al.*, 2012; Brown *et al.*, 2021; Combs *et al.*, 2009; Doherty *et al.*, 2021; Jackson *et al.*, 2012; Muharram *et al.*, 2011; Zheng, Zhou, Lai, 2015]. However, without knowledge of goals, drills, movement patterns, and combinations to practice while shadowboxing, the practice of shadowboxing is reduced to a mentally empty activity of randomly swinging limbs in the air without any point or purpose. This is not a charitable or accurate portrayal of what "boxing" consists of, just as it is not charitable or accurate to say that "soccer" ("football") simply consists of kicking a ball on the grass [Croom, 2022]. To genuinely engage in boxing and soccer training, the training must be relevant to the goals, drills, movement patterns, movement sequences, and scenarios that are utilized in these specific sports [Croom, 2023]. Accordingly, for future systematic research on mixed martial arts to take place, the literature needs a clear set of vocabulary, guidelines, goals, drills, movement patterns, and combinations to practice that are drawn from mixed martial arts as a professional sport. By providing an original shadowboxing program for mixed martial arts that includes 13 goals, 6 drills, over 50 movements, and 70 combinations, as well as a breakdown of the overall training program into individual sessions, blocks, and rounds, this article helps those unfamiliar with shadowboxing understand what it consists of, and helps to ensure the improved quality and consistency of future shadowboxing training programs. Since the shadowboxing program presented here has been created by a Certified Personal Trainer with the National Academy of Sports Medicine (NASM) and the American Council on Exercise (ACE), a qualified referee with the World Boxing Council (WBC), a Master Instructor for the Everlast Striking Specialist Level 1 course, and a former Group Fitness Instructor for the Real Deal Boxing class at Equinox South Bay, the reader is offered a practical martial arts based fitness program developed by an experienced professional in martial arts, exercise physiology, and coaching.

The fourth contribution that this article makes to the literature is that it provides preliminary data on the kind of physiological and morphological progress that can result from engaging in a 3-week shadowboxing program. Although earlier work on shadowboxing has made unique contributions in their

own right, none of this earlier work has offered any data suggesting how shadowboxing may influence a variety of physiological and morphological variables that are of interest to researchers and health and fitness enthusiasts alike. The hypothesis proposed in this article is that consistent shadowboxing training (e.g., over a 3-week, 3-month, or 3-year period) will increase aerobic capacity, muscle mass, bone mass, and basal metabolic rate, and decrease resting heart rate, fat mass, body fat percentage, and visceral fat rating, as assessed by the Polar OH1 and Tanita BC-1500. This is a hypothesis that any individual or researcher with a Polar OH1, Tanita BC-1500, and 21 days for training can replicate at home. Preliminary support for this hypothesis was evidenced through the pre-training and post-training results provided by the Polar OH1 and Tanita BC-1500 (see Figures 2 and 3). Results from this study demonstrated that a 3-week exercise program based exclusively on shadowboxing increased aerobic capacity (+3 PFT score), total muscle mass (+6 lbs), bone mass (+0.2 lbs), basal metabolic rate (+67 kcals), and daily calorie intake (+136 kcals), and decreased resting heart rate (-30 bpm), total fat mass (-6.4 lbs), body fat percentage (-3.6%), and visceral fat rating (-2 VFR score). Given the established reliability of the Polar OH1 and Tanita BC-1500, we now have preliminary evidence that supports the hypothesis proposed in this article that shadowboxing can positively impact morphological and physiological health variables (such as fat loss and increased aerobic capacity). Of course, individual results for any training program will vary, so future research should build upon and extend beyond this particular case study by drawing upon the hypotheses, tools, and procedures provided in this article for application with a larger number and wider variety of participants.

The main limitation in this particular case of research is the small sample size involved. However, this is a general limitation in the field as Brown *et al.* [2021] utilized the same sample size in their case study. Given the methodological importance of clear case studies and the fact that scientific research on shadowboxing is still in its earliest stages, this current limitation is not necessarily a shortcoming of the present research but rather a call to action for future research. Every well-developed area of research must first begin with more exploratory investigations, and despite the limitations of earlier research that we reviewed in the Introduction, the earlier work by Bosch *et al.* [2012], Brown *et al.* [2021], Combs *et al.* [2009], Doherty *et al.* [2021], Jackson *et al.* [2012], Muharram *et al.* [2011], and Zheng, Zhou, and Lai [2015] have been important in establishing that there is general interest and scientific legitimacy for further research on shadowboxing. The present case study extends this line of research by providing (1) an updated review of the literature, (2) the first confirmation of the reliability of the Tanita BC-1500 for the assessment of physiological and morphological variables, (3) the first detailed shadowboxing training program based on mixed martial arts, (4) an original hypothesis about the possible benefits of shadowboxing training, and (5) preliminary data that confirms the proposed hypothesis. Future studies are encouraged to utilize the methods and procedures presented in this article to further confirm or disconfirm the proposed hypothesis for specific populations of interest, such as children, adults, the elderly, patients with MS and PD, professional martial artists, and still others. Future work is also encouraged to utilize the program presented in this article to explore the potential benefits that shadowboxing may have on the mood and cognitive functioning of individuals [Harvard Health, 2015; Croom, 2023; Croom, 2022; Croom, 2014; Moore, Dudley, Woodcock, 2023]. Finally, individual health and fitness enthusiasts looking for a cost-effective way to maintain their health and fitness goals are encouraged to replicate the included shadowboxing program at home, but first, make sure to always discuss new training and nutrition programs with your physician and registered dietitian.

5. Conclusion

Mixed martial arts (MMA) is the fastest growing sport in the world and MMA-style fitness programs are among the most popular in gyms and fitness clubs worldwide, however, little research in the literature has focused on the potential physiological and morphological benefits that MMA-style training programs may have on individuals. For example, there is no data in the literature on whether shadowboxing programs are effective for decreasing fat mass or increasing muscle mass, reducing body fat percentage, and improving aerobic capacity and resting heart rate. In existing work there are also no explicit hypotheses about the possible benefits of shadowboxing, no guidelines for what participants should be doing while shadowboxing, no details for how programs should be structured, and no information about the recovery and nutrition procedures included as part of the overall training programs. This makes it unclear how future researchers should replicate and extend these studies and it makes it unclear for health and fitness

enthusiasts how to try out these shadowboxing training programs for themselves at home. The few studies on shadowboxing that do exist in the literature have focused on boxing and Chen-style Taijiquan, rather than MMA-style shadowboxing (with rounds consisting of 5 minute of work and 1 minute of rest, utilizing the full repertoire of strikes available in MMA), leaving research on MMA-style training programs almost non-existent in the scientific literature. The movement patterns involved in previous work also remain highly limited, for example, to only 4 movements in boxing programs [Doherty *et al.*, 2021], 6 movements in kickboxing programs [Jackson *et al.*, 2012], and 24 movements in Chen-style Taijiquan programs [Muharram *et al.*, 2011; Zheng, Zhou, Lai, 2015]. The present work therefore provides a clear contribution to the literature by providing a detailed nutrition and recovery program as well as a detailed shadowboxing program that covers 13 goals to focus on while training, 6 drills, 58 movement patterns covering basic positioning, footwork, defense maneuvers, and offensive strikes, as well as 70 striking combinations. Information including total program duration (21 days), training frequency (1 session per day), duration of training sessions (60 minutes), training session split (10 blocks of 5 minutes of work and 1 minute of rest), as well as details about the tools for assessing and tracking progress (Polar OH1 and Tanita BC-1500) are provided so that any individual or researcher with a Polar OH1, Tanita BC-1500, and 21 days for training can replicate this program at home on their own. Finding safe and cost-effective ways to exercise during the coronavirus pandemic was challenging for many individuals around the world, so an important goal of this article was to suggest shadowboxing as an accessible solution to the general public and provide data on its potential effectiveness. Since shadowboxing is an effective form of functional exercise that can build muscle and burn fat, since it requires no gym membership and no equipment, and since it is scalable to any intensity level that is comfortable for the individual, this article presented the case that shadowboxing may be an excellent and flexible form of functional exercise for individuals aiming to reduce their body fat percentage and improve their aerobic fitness.

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The present research had ethics approval and participants provided informed consent. All procedures performed in this study were in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Data Availability
The datasets generated and analyzed during the current study are available from the corresponding author upon approval of the request.

Supplementary Information
Supplementary information is provided regarding the test-retest reliability of the Tanita BC-1500, goals to focus on during shadowboxing sessions (+13), drills (+6), techniques covering basic positioning, movement, defense, and offense (+58), combinations (+70), and guidelines for nutrition and recovery.

Informed Consent
Informed consent was obtained from the participants.

Conflict of interest
The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Electronic Supplementary Information

The Physiological and Morphological Benefits of Shadowboxing

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Test-retest reliability of the Tanita BC-1500
This section provides results from the test-retest reliability procedure conducted on 15 December 2021. This procedure was carried out 200 consecutive times on the same subject over a continuous 6-hour period. Results show that measurements for all variables are highly reliable for the Tanita BC-1500 based on established standards in the field [Shechtman, 2013]. Note that coefficients of variation are not used as an index of measurement reliability for metabolic age, physique rating, and visceral fat rating, since these ratings are not recorded on ratio scales [Shechtman, 2013]. SD = standard deviation, CI = confidence interval, CV = coefficient of variation.

- **Basal metabolic rate**: 2101.50 kcals, SD ± 7.56 kcals, 95% CI 2100.45-2102.55, CV = 0.35974304%
- **Daily calorie intake**: 3740.70 kcals, SD ± 13.49 kcals, 95% CI 3716.19-3748.87, CV = 0.36062769%
- **Total body weight:** 177.47 lbs, SD ± 0.42 lbs, 95% CI 177.41-177.53, CV = 0.236659717%
- **Body mass index**: 24.76, SD ± 0.06, 95% CI 24.75-24.77, CV = 0.242326332%
- **Body fat percentage**: 8.99%, SD ± 0.34%, 95% CI 8.95-9.04, CV = 3.781979977%
- **Total muscle mass:** 153.57 lbs, SD ± 0.60 lbs, 95% CI 153.48-153.65, CV = 0.390701308%
- **Total bone mass:** 8.00 lbs, SD ± 0.00 lbs, 95% CI 8.00-8.00, CV = 0%
- **Total fat mass**: 15.94 lbs, SD ± 0.64 lbs, 95% CI 15.85-16.03, CV = 4.015056461%
- **Fat free mass:** 161.54 lbs, SD ± 0.61 lbs, 95% CI 161.46-161.63, CV = 0.377615451%
- **Visceral fat rating:** 3.02 VFR, SD ± 0.14 VFR, 95% CI 3.00-3.04
- **Body water mass:** 116.09 lbs, SD ± 0.47 lbs, 95% CI 116.03-116.16, CV = 0.404858299%
- **Body water percentage:** 65.39%, SD ± 0.27%, 95% CI 65.35-65.43, CV = 0.412907172%
- **Left leg muscle mass:** 24.77 lbs, SD ± 0.20 lbs, 95% CI 24.74-24.80, CV = 0.80742834%
- **Right leg muscle mass:** 25.96 lbs, SD ± 0.11 lbs, 95% CI 25.94-25.97, CV = 0.423728813%
- **Left arm muscle mass:** 8.96 lbs, SD ± 0.08 lbs, 95% CI 8.95-8.97, CV = 0.892857142%
- **Right arm muscle mass:** 8.72 lbs, SD ± 0.10 lbs, 95% CI 8.70-8.73, CV = 1.14678899%
- **Trunk muscle mass**: 85.15 lbs, SD ± 0.45 lbs, 95% CI 85.09-85.21, CV = 0.528479154%
- **Left leg fat percentage:** 10.75%, SD ± 0.15%, 95% CI 10.73-10.77, CV = 1.395348837%
- **Right leg fat percentage:** 9.65%, SD ± 0.18%, 95% CI 9.63-9.68, CV = 1.865284974%
- **Left arm fat percentage:** 13.30%, SD ± 0.24%, 95% CI 13.27-13.33, CV = 1.804511278%
- **Right arm fat percentage:** 13.27%, SD ± 0.21%, 95% CI 13.24-13.29, CV = 1.582516955%
- **Trunk fat percentage**: 7.29%, SD ± 0.54%, 95% CI 7.22-7.37, CV = 7.407407407%

Goals to focus on during shadowboxing sessions (+13)

- **Train movements, not muscles.** "Train movements not muscles" represents a fundamental principle in functional training [Collins, 2012, pp. 19; McCall, 2012] so shadowboxing sessions should focus on movements (punches, kicks, elbows, and knee strikes) rather than muscles (biceps, triceps, chest, back). In the section below I have provided introductory drills (+6), techniques covering basic positioning, movement, defense, and offense (+58), and a variety of different striking combinations (+70). For visual demonstrations of these drills, techniques, and combinations, the reader can refer to video demonstrations available online by quality instructors from Boxing Works, Bang Muay Thai, Evolve MMA, Heritage Muay Thai, Warrior Collective, and elsewhere.
- **Last for the full 3-to-5-minute round before resting for 1 minute**. Due to the SAID (Specific Adaptations to Imposed Demands) principle or principle of specificity, the body will adapt to the specific demands that are placed on it [DeLorme, 1945; Clark, Lucett, Corn, 2007; Clark, Lucett, Kirkendall, 2010;

Clark, Lucett, Sutton, 2013; Collins, 2012] so training programs should be designed to reflect the demands of practical tasks or sports-relevant goals [Croom, 2023]. Since rounds in boxing consist of 3 minutes of activity followed by 1 minute of rest, one may follow this temporal structure as part of their boxing-based shadowboxing program. Since rounds in MMA consist of 5 minutes of activity followed by 1 minute of rest, one may follow this temporal structure as part of their MMA-based shadowboxing program. This will contribute to energy systems development (ESD) that is optimal for your practical tasks or sports-relevant goals [Clark, Lucett, Corn, 2007; Clark, Lucett, Kirkendall, 2010; Clark, Lucett, Sutton, 2013; Collins, 2012]. If you start to fatigue before the round has ended, slow down or stop striking and focus on footwork, head movement, feints, and simply enduring until you have recovered and can continue striking, or until the round has ended. Practice managing your energy throughout each round and over the training session overall, so you become better at not gassing out prematurely. Imagine that you are engaged in a real combat situation, where stopping to sit down in the middle of a bout is not an option. By keeping your training realistic, your adaptations from training will be more sport-specific and have the most carry over to the functional activities in your specific sport [Clark, Lucett, Corn, 2007; Clark, Lucett, Kirkendall, 2010; Clark, Lucett, Sutton, 2013; Collins, 2019]. This at least provides you with an initial reference point from which you can modify, if necessary, since training programs should always be customized to your individual training abilities and goals.

- **Last the full 30-to-60-minute session before stopping for the day**. The spirit of this goal is similar to the spirit of the previous goal. You want to last not only through individual rounds, but also throughout the entire bout or training session. Work on managing your energy over a 30-to-60-minute training period. Many fighters purposely wait until the later rounds to start advancing heavy attacks, since novices will tire themselves out in early rounds and not have enough energy reserve in their tank to keep up in the later rounds. With this in mind, work on managing your energy throughout the entire bout or training session. You want to remain cardiovascularly strong in the championship rounds.
- **Increase striking volume**. This will contribute to improving muscular endurance and energy systems development [Clark, Lucett, Corn, 2007; Clark, Lucett, Kirkendall, 2010; Clark, Lucett, Sutton, 2013; Collins, 2012]. In combat sports like boxing, kickboxing, Muay Thai, and MMA, you earn more points by landing more clean strikes on your target. To land more clean strikes, however, you need to be able to throw more strikes in general, so by focusing on increasing your striking volume in training you will thereby work to develop the specific adaptations required to increase your scoring in combat sports contexts. Throwing a high volume of strikes will also keep your partner or opponent busy defending rather than attacking ("offense is the best defense"), so being able to maintain a high output of strikes is defensively as well as offensively valuable.
- **Increase striking variety**. This will add more tools to your striking toolkit. In combat sports like boxing, kickboxing, Muay Thai, and MMA, you remain less predictable and earn more points by making greater use of all the strikes available in the sport. By focusing on increasing striking variety in training, you will thereby work to develop the specific adaptations required to increase your scoring in combat sports contexts. A well-rounded repertoire of striking-based movement patterns will also help to reduce the risk of overuse or injury from a more restrictive set of repetitive movement patterns [Clark, Lucett, Corn, 2007; Clark, Lucett, Kirkendall, 2010; Clark, Lucett, Sutton, 2013; Collins, 2012].
- **Improve single strikes**. This will contribute to improving neuromuscular efficiency, speed, power, balance, and overall striking technique [Clark, Lucett, Corn, 2007; Clark, Lucett, Kirkendall, 2010; Clark, Lucett, Sutton, 2013; Collins, 2012]. Having excellent technique makes your striking more effective while also requiring less energy (due to increased neuromuscular efficiency) and reducing the risk of injury (due to increased precision and consistency of movement patterns).
- **Improve specific combinations**. This will contribute to improving neuromuscular efficiency, speed, power, balance, and overall striking technique [Clark, Lucett, Corn, 2007; Clark, Lucett, Kirkendall, 2010; Clark, Lucett, Sutton, 2013; Collins, 2012]. A combination is more than the sum of its parts, so even if you have single strikes down you must still practice how those strikes go together into specific combinations. For example, a triple jab is fundamentally distinct from three single jabs both in rhythmic timing and power. Whereas three single jabs will have three jabs of equal timing and power (**1**, **1**, **1**), the triple jab will have two shorter and less powerful jabs followed by a third longer and more powerful jab all tied together as one uninterrupted movement sequence (*1-1-**1***). By focusing on improving specific combinations in training, you make these combinations more readily available and more fluidly executable in your sport. Croom [2022] calls this process of motor learning and refinement the "cultivation of combat-relevant affordances".
- **Increase defensive maneuvers**. The purpose of this is to incorporate defense as well as offense into your shadowboxing training and to improve neuromuscular efficiency, speed, balance, and overall defensive technique [Clark, Lucett, Corn, 2007; Clark, Lucett, Kirkendall, 2010; Clark, Lucett, Sutton, 2013; Collins, 2012]. Floyd Mayweather, an undefeated champion and one of the greatest boxers of all time, states that boxing or "the sweet science is [about] hitting and not getting hit". At first it may be natural to focus on striking but reflect on how much defense you're incorporating into your shadowboxing sessions and work to improve the amount of defensive techniques you incorporate. For example, if you threw 300 strikes but only executed one defensive maneuver (such as a pullback or rollunder) in your last

shadowboxing session, work to increase the number of defensive maneuvers in your next session (for example, at least 5-10 pullbacks and 5-10 rollunders).

- **Increase fakes and feints**. Fakes and feints are often used in combat sports to disrupt an opponent or to make your own strikes less predictable. Work on incorporating fakes and feints into your shadowboxing to disrupt your opponent and to set up your next strikes. If you get tired you can also use more fakes and feints to stay active, rather than just standing in one place like a sitting target.
- **Increase setups and traps**. The legendary boxer Mike Tyson said, "Everybody thinks this is a tough man's sport. This is a thinking man's sport. A tough man is going to get hurt real bad in this sport" [2020]. If you come straight out the gate trying to throw a cross at your opponent's chin with all the power that you have, your partner or opponent will likely see this coming and move. If your moves are so carelessly obvious, one will not likely be successful in combat sports. Instead, use setups and traps to land your strikes. For example, instead of going directly for the chin first, start by throwing two or three shots to the body to pull your opponent's guard down, then go for the chin after you have created that opening.
- **Improve striking in both orthodox and southpaw stances**. It is generally recommended to practice all of your techniques and drills in both stances - orthodox (right-handed stance angled with the left foot and left shoulder in front of the right foot and right shoulder) and southpaw (left-handed stance angled with the right foot and right shoulder in front of the left foot and left shoulder) - to maintain muscular symmetry on both sides of your body and to develop a more comprehensive skill set in mixed martial arts [Evolve MMA, 2018].
- **Keep your head off the line of attack by maintaining head movement**. Developing good defensive responsibility involves maintaining head movement so that your head stays off the line of attack. If you maintain head movement, this will also disrupt your partner or opponent's ability to focus and land clean strikes. In addition to fakes and feints, good head movement can be used to take the punching volume away from your partner or opponent while you recover and prepare your next attack.
- **Visualize and mentally simulate scenarios from training, sparring, and exemplary fights**. Use your shadowboxing session to visualize or mentally simulate scenarios from previous training sessions with a coach, sparring matches with a partner, martial arts classes you have taken, or highlights from exemplary fights [Croom, 2023]. You can get more from your training and combat sports experience by practicing what you watch, and by watching with a careful eye for techniques to incorporate into your own practice. By drawing upon real world scenarios - martial arts classes, sparring matches, one-on-one sessions with coaches, and highlights from exemplary fights - one is able to keep their training novel and realistic. Many people quit their exercise programs because traditional exercise programs are boring, however, the variety in shadowboxing may make it easier to maintain adherence and see results.

Drills (+6)

- Alternating straight punches (jab-cross, jab-cross)
- Alternating uppercuts (lead uppercut, rear uppercut)
- Alternating or skip knees (alternating rear knees; rear knee thrust lands in forward position)
- Alternating push kicks or teeps (alternating lead teeps; lead teep lands in backward position)
- Alternating roundhouse kicks (alternating rear roundhouse kicks; rear roundhouse kick lands in forward position)
- Footwork (moving forward, moving backward, moving left, moving right, pivoting on the lead foot turning inwards, pivoting on the lead foot turning outwards)

Basic positioning, movement, defense, and offense (+58)

- **Positioning and movement** (+11)
    - Stance (hip and foot positioning)
    - Guard (shoulder, arm, hand, and head positioning)
    - Lead arm control (using the lead arm to establish distance or control)
    - Move forward (lead foot steps forward first, then the rear foot follows)
    - Move backward (rear foot steps backward first, then the lead foot follows)
    - Move left (left foot moves leftward first, then the right foot follows)
    - Move right (right foot moves rightward first, then the left foot follows)
    - Pivot inward or turn in (pivot on the ball of the lead foot, turning inwards; turning inwards is rotating clockwise for orthodox and counterclockwise for southpaw)
    - Pivot outward or turn out (pivot on the ball of the lead foot, turning outwards; turning outwards is rotating counterclockwise for orthodox and clockwise for southpaw)
    - Turn (use your lead arm to turn your opponent on an angle)
    - Switching stances (swing the lead foot back so it is now the rear foot in the opposite stance)
- **Defense** (+14)
    - Pullback (moving the shoulders and head back from the punching range of your opponent; in one variation your feet do not move, in another variation your rear foot moves back-then-forward as your shoulder and head pull back-then-forward)

    - Slip towards the lead side (for orthodox, slip towards the left to evade a straight punch; for southpaw, slip towards the right to evade a straight punch)
    - Slip towards the rear side (for orthodox, slip towards the right to evade a straight punch; for southpaw, slip towards the left to evade a straight punch)
    - Roll under towards the lead side (for orthodox, roll under towards the left to evade a hook; for southpaw, roll under towards the right to evade a hook)
    - Roll under towards the rear side (for orthodox, roll under towards the right to evade a hook; for southpaw, roll under towards the left to evade a hook)
    - Catching punches to the head (use your hands to catch or cushion straight punches)
    - Catching punches to the body (use your elbows and lower arms to catch or cushion punches to the body)
    - Parry kicks towards the lead side (use your hands to parry push kicks or teeps away towards the lead side of your body)
    - Parry kicks towards the rear side (use your hands to parry push kicks or teeps away towards the rear side of your body)
    - Dutch block kicks towards the lead side (use your arms to block kicks towards the lead side)
    - Dutch block kicks towards the rear side (use your arms to block kicks towards the rear side)
    - Checking kicks with the lead leg (use your legs and shins to block kicks towards the lead side)
    - Checking kicks with the rear leg (use your legs and shins to block kicks towards the rear side)
    - Fakes and feints (pretend or partially initiate one maneuver then stop or change maneuvers, which will prevent your opponent from being able to time and predict your attacks)
- **Punches** (+14)
    - Jab (straight punch to the head with the lead arm; straight left punch for orthodox, straight right punch for southpaw)
    - Jab to the body (straight punch to the body with the lead arm, bend your knees and bring your body down instead of standing up and punching downwards; straight left punch for orthodox, straight right punch for southpaw)
    - Cross (straight punch to the head with the rear arm; straight right punch for orthodox, straight left punch for southpaw)
    - Cross to the body (straight punch to the body with the rear arm, bend your knees and bring your body down instead of standing up and punching downwards; straight right punch for orthodox, straight left punch for southpaw)
    - Lead hook (lead arm is curved instead of straight and punches horizontally around the guard of your opponent towards their head; use hip rotation to generate power)
    - Lead hook to the body (lead arm is curved instead of straight and punches horizontally around the guard of your opponent towards their body; bend your knees and use hip rotation to generate power)
    - Rear hook (rear arm is curved instead of straight and punches horizontally around the guard of your opponent towards their head; use hip rotation to generate power)
    - Rear hook to the body (rear arm is curved instead of straight and punches horizontally around the guard of your opponent towards their body; bend your knees and use hip rotation to generate power)
    - Lead uppercut (lead arm is curved instead of straight and punches vertically up through the middle of the guard of your opponent towards their chin; use hip rotation to generate power)
    - Rear uppercut (rear arm is curved instead of straight and punches vertically up through the middle of the guard of your opponent towards their chin; use hip rotation to generate power)
    - Rear overhand punch (rear arm is curved instead of straight and angles over the guard of your opponent and downwards towards their head)
    - Gazelle hook or jumping lead hook (use hip rotation to generate sufficient power so that you can lunge forward as you throw your lead hook; a jumping lead hook)
    - Superman jab (jump forward and throw the jab while in midair)
    - Superman cross (jump forward and throw the cross while in midair)
- **Elbows** (+7)
    - Lead horizontal elbow (step or skip forward as you strike horizontally with the lead elbow)
    - Rear horizontal elbow (step or skip forward as you strike horizontally with the rear elbow)
    - Lead upward elbow (step or skip forward as you strike vertically with the lead elbow)
    - Rear upward elbow (step or skip forward as you strike vertically with the rear elbow)
    - Reverse upward elbow (step or skip forward as you strike with a reverse elbow; the hand is positioned below the elbow and facing downward in a reverse elbow whereas the hand is positioned above the elbow and facing upward in a traditional upward elbow)
    - Spinning back elbow (step or skip forward turning your lead shoulder inward and rotating your rear elbow outward in a clockwise direction for orthodox or counterclockwise direction for southpaw so that you hit your opponent with the rear elbow during rotation)
    - Flying rear elbow (jump forward and throw the rear elbow)

- **Kicks** (+11)
    - Lead teep or push kick (straight kick with the lead leg connecting with the ball of the foot)
    - Rear teep or push kick (straight kick with the rear leg connecting with the ball of the foot)
    - Lead roundhouse kick (rotational kick with the lead leg connecting with the shin; use hip rotation to generate power)
    - Rear roundhouse kick (rotational kick with the rear leg connecting with the shin; use hip rotation to generate power)
    - Lead inside leg kick (low kick with your lead leg towards the inside of the lead leg of your opponent)
    - Rear low kick (low kick with your rear leg towards the outside of the lead leg of your opponent)
    - Lead side teep or push kick (straight kick with the lead leg but angled right before contact)
    - Rear question mark kick (rear kick that starts as a low kick then circles around over the top in a question mark motion towards the head of your opponent)
    - Sliding lead push kick (lunge or slide forward while delivering the lead push kick)
    - Jumping rear roundhouse kick (jump forward while delivering a rear roundhouse kick)
    - Jumping switch teep or push kick (jump forward while delivering a switch teep or push kick)
- **Knees** (+3)
    - Lead knee (knee thrust with the lead knee)
    - Rear knee (knee thrust with the rear knee)
    - Flying rear knee (jump forward then throw the rear knee in midair)

Combinations with an alternating pattern: LRLR and RLRL (+45)

- Cross, lead hook, rear roundhouse kick
- Cross, lead hook, rear upward elbow
- Cross, lead knee, rear horizontal elbow
- Cross, lead roundhouse kick
- Cross, lead roundhouse kick, rear horizontal elbow
- Cross, slip towards the rear side, rear uppercut, lead hook, rear overhand punch
- Dutch block kick towards the lead side, lead hook, cross, lead hook, rear roundhouse kick
- Dutch block kick towards the rear side, cross, lead hook, cross, lead roundhouse kick
- Jab, cross
- Jab, cross, jab, cross, lead hook, rear horizontal elbow, lead push kick
- Jab, cross, lead hook
- Jab, cross, lead hook, rear low kick
- Jab, cross, lead hook, Superman cross
- Jab, cross, lead hook to the body
- Jab, cross, lead knee, rear horizontal elbow
- Jab, cross, lead roundhouse kick
- Jab, cross, pullback, cross
- Jab, cross, slip towards the rear side, cross
- Jab, cross, turn, rear roundhouse kick
- Jab, cross to the body
- Jab, cross to the body, lead hook, rear hook
- Jab, cross to the body, lead hook, rear low kick
- Jab, rear hook to the body
- Jab, rear low kick
- Jab, rear roundhouse kick
- Jab, rear uppercut, lead hook, rear overhand punch
- Jab, rear upward elbow, lead horizontal elbow, rear horizontal elbow
- Lead hook, cross, lead hook, rear roundhouse kick
- Lead hook, rear hook, lead knee
- Lead hook, rear hook, lead roundhouse kick
- Lead hook, rear hook to the body
- Lead hook, rear low kick, lead hook, cross, lead roundhouse kick
- Lead hook, rear roundhouse kick
- Lead hook to the body, rear uppercut, lead hook, cross
- Lead roundhouse kick, spinning back elbow
- Lead uppercut, cross, lead hook, rear low kick
- Parry kick towards the lead side, rear low kick, lead roundhouse kick
- Rear hook, lead hook, rear knee
- Rear hook, slip towards the rear side, rear uppercut
- Rear hook to the body, lead uppercut, cross, lead hook
- Rear roundhouse kick, check kick with the lead leg, spinning back elbow
- Rear roundhouse kick, lead hook

- Rear roundhouse kick, lead hook, rear question mark kick
- Rear uppercut, lead hook, cross
- Superman jab, rear low kick

Combinations with a doubled-up pattern: LRRL and RLLR (+25)

- Check kick with the rear leg, cross, lead hook, rear roundhouse kick
- Cross, lead hook, lead push kick, Superman cross
- Jab, cross, lead hook, lead hook to the body, rear uppercut
- Jab, cross, lead hook, lead uppercut
- Jab, cross, lead uppercut, cross, lead hook, cross, rear roundhouse kick, rear push kick
- Jab, cross, rear knee
- Jab, cross, rear push kick
- Jab, cross, rear roundhouse kick
- Jab, cross to the body, rear low kick
- Jab, jab, check kick with lead leg, rear knee, rear horizontal elbow
- Jab, jab, cross
- Jab, jab, cross, lead hook to the body, lead hook, cross
- Jab, jab, cross, lead horizontal elbow, flying rear elbow
- Jab, jab, cross, lead push kick, sliding lead push kick
- Jab, jab, lead knee, rear horizontal elbow, rear roundhouse kick
- Jab, jab, lead knee, rear upward elbow
- Jab, jab, rear push kick, rear question mark kick
- Jab, jab, rear roundhouse kick, cross
- Jab, jab, rear upward elbow, rear horizontal elbow
- Jab, lead push kick, fake, rear horizontal elbow
- Jab, lead uppercut, cross, jumping rear roundhouse kick
- Jab, lead uppercut, rear overhand punch
- Jab, rear hook to the body, rear uppercut
- Lead hook to the body, lead hook, cross, rear knee
- Rear uppercut, lead hook, rear push kick, flying rear knee

Nutrition and recovery program

The participant in this case study followed a consistent nutrition program based on nutritional principles developed by registered dieticians and leading sports performance specialists [Athletes' Performance, 2014; Berardi, Andrews, 2017]. EXOS (formerly Athletes' Performance) has developed clear and effective nutritional principles for their professional athletes that focuses on four key requirements: *Fuel*, *Build*, *Protect*, and *Prevent* [Athletes' Performance, 2014]. *Fuel* refers to carbohydrates, which are the primary fuel source for the brain and physical activity. Examples of food sources for *fuel* include oatmeal, brown rice, high fiber cereal, quinoa, and whole grain bread. *Build* refers to protein, which builds muscle tissue and maintains the immune system. Examples of food sources for *build* include salmon, tuna, chicken, turkey, lean red meat, low fat dairy, and eggs. *Protect* refers to fats, which contain powerful antioxidants for cellular repair (of joints, organs, skin, and hair), aid in nutrient absorption (vitamins A, D, E, and K), and release energy slowly to stabilize energy levels, blood sugar, and keep individuals satiated. Examples of food sources for *protect* include avocado, almonds, walnuts, pecans, and seeds. *Prevent* refers to vegetables and fruits, which provide natural vitamins, minerals, and antioxidants that contribute to the repair of the body. Examples of food sources for *prevent* include beets and tomatoes (red food sources generally support heart and lung health), blueberries and plums (deep blue and purple food sources generally support brain, heart, and cellular health), carrots and sweet potatoes (orange food sources generally support skin health and DNA protection), broccoli and spinach (green food sources generally support eye and bone health), and garlic and onions (white food sources generally support the immune system). For the duration of this 3-week shadowboxing study, the food sources for the participant included salmon nigiri, tuna nigiri, Barbacoa Sabor pork jerky, Blue Diamond almonds, bananas, blueberries, strawberries, Chobani complete yogurt shakes, Muscle Milk protein shakes, Gatorade G series thirst quenchers, Red Bull energy drinks, and Suja Organic cold pressed juices: Sweet Beets (apple, carrot, beet, banana, orange) and Mighty Dozen (apple, celery, cucumber, kale, collard greens). Recovery, or the process of adapting to and overcoming the stresses imposed by the training environment, is essential to any general health and fitness or sports performance program [Athletes' Performance, 2014]. As coaches Mark Verstegen and Pete Williams [2004] write in *Core Performance*, "Work + Rest = Success." The participant in this case study therefore followed a consistent recovery program to optimize recovery from exercise, which consisted of 8 to 9 hours of uninterrupted sleep per night.

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