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Strength and Conditioning for Professional Boxing: Recommendations for Physical Preparation

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ABSTRACT

PROFESSIONAL BOXING IS A POPULAR PAN-GLOBAL SPORT THAT ATTRACTS CONSIDERABLE INTEREST AND REVENUE. IT IS A HIGH-INTENSITY SPORT THAT REQUIRES A RANGE OF WELL-ADAPTED PHYSIOLOGICAL CHARACTERISTICS AS LIKELY PREREQUISITES FOR SUCCESSFUL PERFORMANCE. SERIOUS CONSIDERATION HAS BEEN GIVEN TO MEDICAL ASPECTS AND POTENTIAL HEALTH RISKS FROM PARTAKING IN TRAINING AND COMPETITION. HOWEVER, THERE ARE NO COMPREHENSIVE SOURCES OF APPLIED SPORT SCIENCE RESEARCH IN THE PREPARATION OF PROFESSIONAL BOXERS FOR COMPETITION. IN THIS REVIEW, WE PRESENT RESEARCH FROM PHYSIOLOGY AND STRENGTH AND CONDITIONING TO FORM A KNOWLEDGE BASE FOR THOSE INVOLVED IN PREPARING

PROFESSIONAL BOXERS FOR COMPETITION.

INTRODUCTION

Professional boxing is regarded as one of the most physically and mentally demanding sports in the world, yet despite this recognition and popularity, professional boxing has received little attention within the scientific literature. A PubMed search (July 23, 2015), for “Professional Boxing” returned 44 results, the majority of which had a specific focus on brain injury. In contrast to this low volume of academic interest, professional boxing contests have the potential to generate considerable interest and local and international revenue. Indeed, in an article in *The Guardian* on May 12, 2015, unverified reports estimated revenue in excess of \$500 million for a single professional boxing event. To date, however, there are no comprehensive scientific reviews or practical recommendations for the preparation of professional boxers for training and competition. The reasons for the lack of applied sport science research are likely diverse and beyond the scope of this article, but it is surprising,

given the growing body of scientific research in sports with similar worldwide interest.

A professional boxer’s preparation is complicated by the requirement to include conditioning, strength, and boxing-specific training within a short time frame before a contest, usually 8–12 weeks (Figure 1). Given the complexity of the training process and time demands, professional boxers and their trainers would benefit from evidence-based guidance to supplement existing training practices. The preparation of a boxer should be considered in context, with a clear understanding of the determinants of successful performance. Therefore, this article will provide an overview of the rules governing professional boxing competition, highlight a variety of theory and research relevant to the demands of professional boxing, and provide practical recommendations for testing, and developing strength and conditioning programs.

KEY WORDS:

boxing; physiology; strength; combat; force; physical preparation

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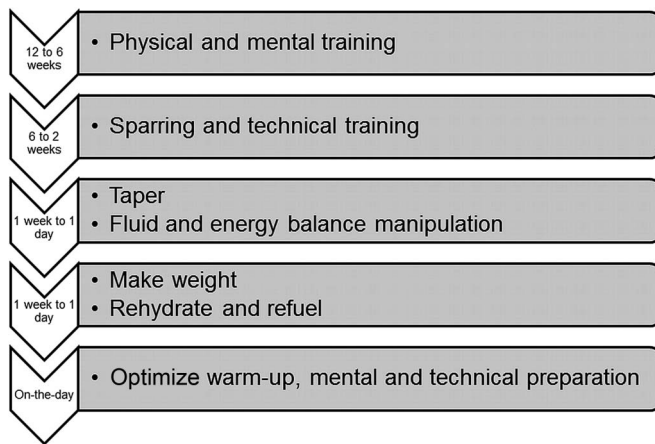


Figure 1. Overview of a typical 12-week preparatory phase for professional boxing.

BOXING COMPETITION AND SUCCESSFUL PERFORMANCE

Similar to most body mass restricted combat sports, professional boxers are required to weigh-in and meet their contest body mass 36 to 24 hours before competition. Lower standard contests might comprise of 4×2 minutes with a 1-minute interval between rounds, but an elite professional boxing contest can last up to 12×3 minute rounds. During the 1-minute interval between rounds, a trainer is allowed

in the ring to offer coaching instructions; they might also wish to provide ice, iced towels, and water, but stimulants (which include carbohydrate-electrolyte beverages) are prohibited. Perhaps the most well-known way to win a boxing match is by knockout. A knockout is usually caused by a single blow, but is often preceded by repeated high force legitimate blows. In the case of a head strike, a knockout is caused by acute neurological trauma, due to large magnitudes of internal torque

applied to the cerebellum and brain stem (14). A second way to win a contest is by technical knockout. This occurs when the referee has decided that the opponent is in no position to defend their self or is being outclassed. This is most likely preceded by demonstration of attacking skills and accompanying high force blows; in this circumstance, it is common for the corner to “throw the towel in” if they are concerned for their boxer. However, a professional boxer’s primary aim is not to knockout their opponent, but to demonstrate superior physical, technical, and tactical skills; these are paramount in the third way to win a boxing contest, by a points decision. Points are awarded using subjective criteria, but are based on the boxer’s attacking and defensive skills; the relative importance and content of these broad categories are both judge- and contest-specific. In this circumstance, preparation of the professional boxer is crucial to improve their chance of winning a round and the whole contest, because poor physical fitness would limit performance capacity.

PHYSIOLOGICAL DEMANDS

Data regarding physiological demands, and exercise to rest ratios in professional boxing are not available in scientific literature, however, based on our experience it is reasonable to assume, along with data relating to punch volume and intensity (33), force-velocity (30), and impulse-momentum relationships (28), that professional boxing comprises repeated high-intensity actions interspersed with brief periods of low-intensity actions or recovery. These high-intensity actions are derived from electrical, chemical, and mechanical physiological processes, most of which require rapid hydrolysis and phosphorylation of adenosine triphosphate through nonoxidative energy pathways. However, because of the repeated high-intensity demands, these needs cannot be met in full by nonoxidative sources. Hence, energy derived primarily through oxidation of muscle glycogen supports a large proportion of adenosine triphosphate hydrolysis and phosphorylation

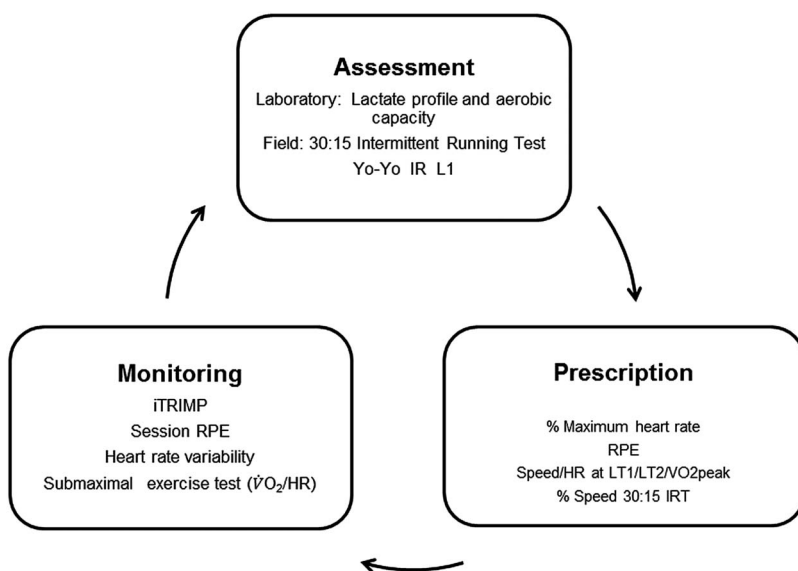


Figure 2. Assessment, prescription and monitoring recommendations for conditioning. HR = heart rate; LT = lactate threshold; RPE = rating of perceived exertion; iTRIMP = training impulse.

to meet systemic demand, the magnitude of which is likely a determinant of professional boxing performance. The assertion that performance demands a large contribution from oxidative energy pathways is supported by peak oxygen uptake values (derived from incremental exercise tests) of $58 \pm 7 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ in Italian middleweight amateur boxers (13) and up to $64 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ in senior international amateur boxers (32). The author's data indicates values of $>60 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ in our observations of elite professional boxers. Simulated amateur boxing has been reported to elicit large energy demands (4,31) (approximately 80–90% peak oxygen uptake) with 77%, 19%, and 4% of energy derived from aerobic, phosphocreatine, and anaerobic glycolysis energy pathways, respectively (9), which suggests a reliance on muscle glycogen as a primary fuel source.

IMPACT OF PHYSIOLOGICAL DEMANDS ON TECHNICAL ABILITY

Professional boxing is primarily a technical and tactical sport; external demands such as the requirement to attack or evade determines physiological strain. A boxer must perform appropriate attacking or defensive actions at an intensity that does not exceed their ability to control the ring using footwork skills and the precision of their attacking or controlling punches. If a boxer can perform at an intensity that induces low physiological strain, then they might have the potential to control the contest and avoid fatigue. However, if the external demands imposed on a boxer induce physiological strain, or when successive high-intensity actions compromise rates of recovery, fatigue will probably limit subsequent performance (5).

In professional boxing, fatigue might manifest as a transient decline in

punch impulsiveness, frequency or precision, poor decision making and limited defensive actions. Repeated high-intensity actions are associated with a decrease in phosphocreatine (10), reduced activity or inhibition of glycolysis (11), increased cellular hydrogen ions (31), altered calcium sensitivity (2), impaired sodium-potassium pump function (2), and skeletal muscle damage (15). However, performance is suggested to be an integrative multifactorial process (29) and it is likely that a combination of mechanisms determine short-term recovery (26). When boxers are required to perform above their critical intensity (8) or with limited recovery, physiological perturbations in skeletal muscle, cardiovascular functioning, metabolic strain, and pain sensation (22) integrate to alter perceived exertion and voluntary activation of the neuromuscular system, and manifest as fatigue (26). Skillful boxers can control the pace of the contest

Table 1
Conditioning recommendations for professional boxing

Weeks before competition	Training phase	Example session	Frequency	Intended physiological adaptations
12 to 9	Oxygen extraction and utilization	30-s all-out maximum effort sprints, 3 min 30 s passive recovery, 4–6 repetitions	2–4 sessions per training wk	Increase maximal activity and content of oxidative and nonoxidative enzymes
				Provide stimuli for improvements in rate of force development
8 to 3	Oxygen delivery	4–8 min at 85–90% maximum heart rate, 2–4 min passive recovery, 4–6 repetitions	2–4 sessions per training wk from 9–6 weeks	Improve cardiovascular capacity (stroke volume, cardiac output, muscle capillarization, and systemic vascular resistance), delivery of O_2 , and enhance venous return
			1–2 sessions per wk from 6–3 weeks	
2 to 0	Taper	20 s all-out maximum effort, 10 s passive recovery, 4–8 repetitions, 1–2 sets, 5 min recovery between sets	1–2 sessions per wk	Transfer adaptations induced from previous training blocks to boxing-specific activity profiles (fight/tactical dependent) while maintaining cardiovascular and neuromuscular strain
		Reduce training volume exponentially while maintaining high external intensity		

and, if required, limit the attack of an opponent by using footwork to control the ring and direction of activity, defensive tactics such as holding, and the 1-minute interval between rounds to recover. These tactics allow at least partial restoration of homeostasis, achieved by speeding recovery (e.g., repaying an oxygen debt) or limiting physiological strain in the first instance.

PRACTICAL APPLICATIONS: CONDITIONING TRAINING RECOMMENDATIONS

Of primary importance for many professional boxers is the development of aerobic capability. Athletes with well-developed aerobic energy systems are likely to recover from high-intensity activity faster (4), or perform at intensities that do not exceed their critical intensity (17). Precise quantification of aerobic capacity and an understanding of physiological characteristics of a professional boxer are important to monitor changes and program individual training intensities.

Data derived from assessments (Figure 2) might assist in identifying strengths and areas for improvement relating to energy system dominance, running economy, substrate utilization, and provide heart rate and rating of perceived exertion data required to prescribe and monitor training intensities. It is important that conditioners understand the physiological characteristics of their athletes, develop methods to assess characteristics, and use information derived from these tests to design specific training programs to develop these qualities. We recommend preparing professional boxers by developing aerobic capability in a sport-specific manner, based upon their strengths and areas for improvement. Using information derived from valid and reproducible tests, it is possible to tailor training programs in an appropriate way to develop physiological capabilities, whereas boxing training (bag work, pads, and sparring) might develop these more specifically.

There is compelling evidence that high-intensity interval training (HIIT) improves aerobic capacity (7,20,25,27).

The mechanisms by which adaptations occur are complex and it is unclear as to what type of stimulus and interventions provide optimal benefits for a particular physiological characteristic. Three possible sites for the main effects of HIIT are the active myocytes (utilization and cellular buffering), capillary structures (extraction), and myocardium (delivery). It is likely that HIIT induces central, peripheral, and neuromuscular adaptations with training demands being influenced by 9 variables (7). Despite this complexity, HIIT's strength is in its variety of application and it is clear that the choice of HIIT should be dictated by a boxer's individual strengths and areas for improvement, training and competitive schedule, and additional environmental/lifestyle constraints.

Table 1 provides an overview of conditioning recommendations for a typical 12-week preparatory period. Sprint interval training demands the recruitment of high-threshold motor units and is a potent stimulus for rapid improvements in skeletal muscle oxidative capacity (12), making this type of training ideal for improvements in force production and aerobic capability, early in

the training phase. These peripheral adaptations should be progressed by using high-intensity interval training for around 6 weeks to stimulate myocardial adaptations and muscle capillarization, which contribute to improvements in aerobic capacity (27). Finally, a taper phase of 2 weeks before competition, which also includes a reduction in boxing-specific technical training volume is recommended. This reduction should be athlete-specific but a volume decrease of around 40–60% of total training load is recommended (6). It should be noted that the aim of this training structure is not intended to replicate the potential time-motion demands of boxing. Rather, evidence-based interventions are used as stimuli for improvements in aerobic capacity and to a lesser extent, mechanical force production. Adaptations in these areas can be used to facilitate increases in boxing-specific technical training volume, and more specifically used as a base for high quality open sparring, which requires an adequate standard of aerobic fitness. To this extent, conditioning training is usually constrained by the coaches' decision to increase the volume of open sparring, however, a period of

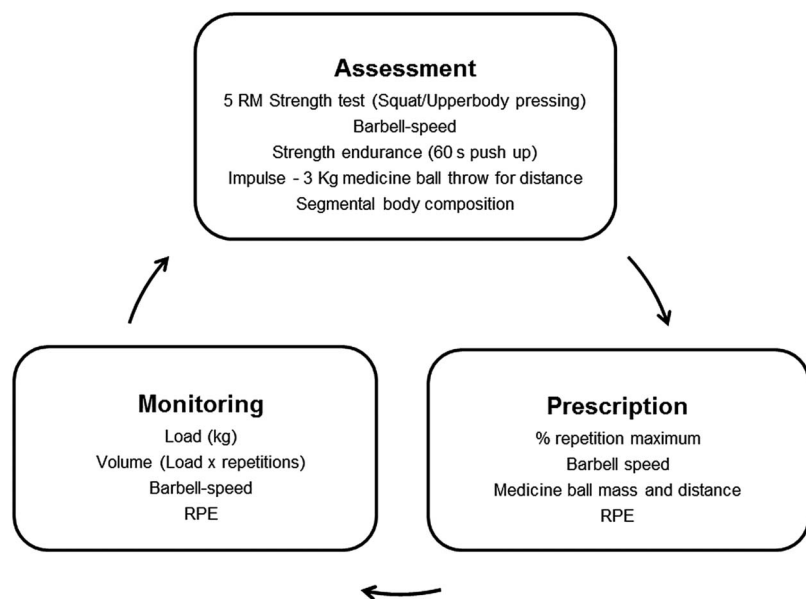


Figure 3. Assessment, prescription, and monitoring recommendations for strength training. RM = repetition maximum; RPE = rating of perceived exertion.

Table 2
General strength training exercise recommendations

Weeks until fight	8–12 wk	4–8 wk	3 wk
Focus	Strength	Strength and strength-speed	Speed and specific
Mobility/trunk	Eagles	Eagles	Eagles
	Spiderman and twist	Spiderman and twist	Lunge and DB sweep
	Lunge and twist	Lunge and MB rotation	Lunge and MB woodchop
	Glute bridge	Glute bridge with overhead reach suitcase deadlift variations	
	Pallof press	Rotational plank	
	Overhead squat		
Rate of force development	CMJ	Drop jump	MB woodchop Wall throws
	Broad jumps	Ice skaters	MB punch
	Lateral hop and hold	MB rotational throws	Band punch
Key lifts	Squat variation	Squat variation	Speed squats
	Loaded hip thrust	Hang snatch or KB variation	Hang power snatch or KB variation
	Bench press	DB floor press	Landmine punch
Volumes and intensity	70–80% 1RM	80–90% 1RM	50–65% 1RM
	5–8 repetitions	3–5 repetitions	2–5 repetitions
	3–5 sets	4–6 sets	2–8 sets
Assistance exercises	Suspension trainer row	KB row and rotate, DB step-ups	Suspension trainer row and rotate
	Pull-ups	Weighted pull-ups—dips	MB twist and slam
	DB push press	Goblet squat to press	Band press ups
	Goblet squat		KB swing
	Bulgarian split squat		

CMJ = countermovement jump; DB = dumbbell; KB = kettlebell; MB = medicine ball; 1RM = 1 repetition maximum.

around 6 weeks of focused conditioning is typical. Thus, optimizing training stimuli and adaptation using evidence-based training prescription is paramount in the preparation of a professional boxer.

EFFECTIVE PUNCHING

Striking an opponent with a clean “hit” irrespective of force will gain favor with judges and potentially disrupt an opponent’s acute strategy. More forceful single punches or repeated high-force punches are intended to position an opponent for a sustained attack (leading to contest termination) or display skill, technical ability, and dominance

during the contest. Forceful punches are also used as a defensive tactic to limit the advance of an opponent and their attacking strategy.

In principle, 3 factors contribute to the effectiveness of a single punch. Firstly, movements in sprint running, karate, or boxing typically involve fast skeletal muscle actions, highlighting the importance of developing large magnitudes of force in short periods of time (1). Secondly, the momentum of the punching arm is important and has been demonstrated to be a key variable contributing to the impulsiveness of a punch (28). Finally, a second pulse in muscle

activation is required on impact and has been defined as “stiffening” to create “effective mass” (23). These factors (rate of force development [RFD], momentum, and second pulse) are determined by effectiveness of a boxer’s ability to generate force through hip, knee and ankle extension, rotation of the trunk, and arm extension (21).

It is likely that the impulse generating capacity of a boxer is important and is intrinsically linked to segmental momentum during force generation and, at impact. Indeed, reductions in momentum of the punching arm before impact are suggested to explain around 95% of

Table 3
Specific strength training program for professional boxers

Exercise type	Day 1	Reps × Sets		Day 2	Reps × Sets	
		Week 1-6	Week 7-12		Week 1-6	Week 7-12
		Lower body	Goblet squat/box squat		8-12 reps × 3-4 sets	6-8 reps × 3-4 sets
Upper body push	DB floor press/tempo push-up	8-12 reps × 3-4 sets	6-8 reps × 3-4 sets	Kneeling shoulder press/landmine shoulder press	8-12 reps × 3-4 sets	6-8 reps × 3-4 sets
Upper body pull	Pull-ups	8-12 reps × 3-4 sets	6-8 reps × 3-4 sets	Hanging row/Suspension row	8-12 reps × 3-4 sets	6-8 reps × 3-4 sets
Unilateral	Goblet split squat	15-20 reps × 3 sets	20-24 reps × 3 sets	DB step up	15-20 reps × 3 sets	20-24 reps × 3 sets
Trunk	Isometric trunk holds, plank rows	15-20 reps or 20-30 s × 3 sets	20-24 reps or 30-40 s × 3 sets	Landmine rotations, MB woodchop	8-12 reps × 3-4 sets	8-12 reps × 3-4 sets
Punch specific	Landmine punch	12-16 reps × 3-4 sets	8-12 reps × 4-5 sets	Landmine punch throws	10-12 reps × 3-4 sets	6-8 reps × 4-5 sets

DB = dumbbell; MB = medicine ball; reps = repetitions.

the variance in peak impulse at impact during rear-hand straight punches (28). The main contributor to the impulsiveness of a punch might be hand speed, because it explains around 40% of the variance in hook and straight punching force. Therefore, a goal of strength training should be to increase the momentum of the punching arm, resulting in greater impulse on the target.

PRACTICAL APPLICATIONS: STRENGTH TRAINING RECOMMENDATIONS

An obvious way to increase the momentum of the punching arm is to increase mass (from Newtonian physics). It is common across most sports for practitioners to target muscular hypertrophy in the off-season or early mesocycles to stimulate increases in physiological cross-sectional area, building a foundation for strength development. However, body mass classifications make hypertrophy training difficult to implement, and can complicate dietary practices; therefore, improving the RFD should be a priority for the practitioner.

The rate at which force is developed is likely to be influenced more by the capacity to produce force irrespective of the phenotypical myosin heavy chain content of muscle fibers alone (3), suggesting that neuromuscular factors are integral to the RFD. The development of hand speed by inducing favorable adaptations in series-elastic components and the neuromuscular system is therefore a key variable in the prescription of strength training for professional boxers. Therefore, we recommend the selection of appropriate assessment methods, some of which are presented in Figure 3, to program multi-planar exercises, with carefully structured external loads that enable the boxer to train with attention, appropriately focused on strengths and areas for improvement.

Table 2 provides examples of general strength and movement training for professional boxers. Development of the hip extensors, in particular, function of the gluteal musculature, is important and is recognized for its role in athletic ability. These can be trained



Figure 4. (A) Medicine ball lunge woodchop, (B) medicine ball punch, and (C) landmine punch.

using key lifts such as squats, deadlifts, and Olympic-style lifts where there is a focus on developing forceful hip extension. In addition, assistance exercises such as dumbbell floor press, pull-ups, plank rows, and others detailed in Tables 2 and 3, are also recommended for their role in developing the force generating capability of a professional boxer, as well as improving robustness, and facilitating increases in boxing-specific technical training load.

In conjunction with strength and movement training, we also recommend that professional boxers incorporate exercises that require rapid rates of force development. Jump height depends on impulse (18), and as such the rate and magnitude of external-mechanical force development (24). Strength training designed to improve peak force combined with low-external load jump training to improve the RFD (24), should have positive transfer to force production during punching. Table 2 provides examples of jump training that might be used by trainers.

PRACTICAL APPLICATIONS: MOBILITY AND TRUNK TRAINING

Effective force transmission is derived from optimal force-coupling and length-tension relationships of active musculature, however, boxers are at risk of ineffective performance and injury because of dysfunctional movements and poor force production. Frequent physical impacts caused by blows to the body, collisions, structural imbalances, and overuse can result in microtrauma. The resulting inflammatory response might lead to fascia scar tissue over time and subsequent muscular dysfunctions. Physical impacts and collisions are unavoidable in professional boxing. However, our observations suggest that structural imbalances are common and are likely a greater cause of ineffective force transmission.

Synergistic force transmission occurs across myo-tendinous junctions (16), and summation, or “force transmission” is essential to create effective musculo-skeletal sequencing and punching force. Malalignment within the kinetic chain

might contribute to suboptimal length-tension relationships, constraining peak force and causing it to occur at a more acute joint angle. This is an obvious concern when force is generated in the upper body, because a limited reach caused by insufficient range of motion and reduced force at near full elbow extension might impair the effectiveness of a jab or rear hand punch. It is important to recognize that these limitations might restrict the ability to summate force, causing reduction in momentum and decreasing the subsequent impulse applied to the target.

It is likely that pelvic and trunk speed and stability contribute to increased hand speed during a punch. During rotation, a stretch of the trunk allows for a more forceful rotation through utilization of the stretch-shortening cycle (19), generating torque at the shoulder joint, and enhancing force transmission through the elbow extensor musculotendinous unit. Indeed, punches require multiple angular displacements through sagittal, frontal, and transverse planes throughout the full range of punch variations, with the punch type determining segmental force contribution and a countermovement before initiation of a punch, thereby increasing the capability to produce an impulsive punch (30). Exercises that are designed to improve the capability of the trunk to provide stability and contribute to the effectiveness of punching are detailed in general in Table 2, depicted in Figure 4, and presented as part of a 12-week training program in Table 3.

PRACTICAL APPLICATIONS: EFFECTIVE MASS

A double “peak” in muscle activity is evident during striking actions. Stiffening of the body at impact through isometric activity is postulated to create “effective mass” and reduce energy loss (23). Stiffening can be developed using pad and heavy bag training in technical training as well as using effective cues such as “popping” of the hips and “stiffen up” at the end range during strength exercises which might induce double activations and stiffening. Moreover,

isometric contractions paired with rapid relaxation can be beneficial in improving end range stiffening. Trunk training can also be used as means to facilitate improvements in the generation of “effective mass” by increasing isometric force production (bracing) at impact.

CONCLUSION

Research regarding the physical preparation of professional boxers for competition is limited. Professional boxing comprises repeated high-intensity actions interspersed with brief periods of low intensity activity or recovery. These demands require large contributions from both oxidative and nonoxidative energy pathways. As such, a range of physiological characteristics should be assessed using valid and reproducible tests. Variations in carefully prescribed high-intensity interval training tailored to the strengths, and areas of improvement elucidated from physiological assessments can be used to develop aerobic capacity. Punches are intended as both offensive and defensive actions, and a combination of rapid whole body RFD, resulting momentum of the arm, and isometric muscle activity at impact contributes to forceful punches. The use of multi-planar exercises with the aim of improving rotational range of movement, RFD, and segmental sequencing is recommended to develop an effective punch. A boxer who receives individualized and evidenced-based recommendations at all stages of preparation for a contest is an athlete who enters the ring with less risk of incurring serious medical conditions in the short- and long-term. A limitation of this review is that it generalizes across body mass categories, gender, ethnicity, and performance standards. As such, scientific support and research for professional boxing should be encouraged, particularly by governing bodies in the interests of athletes’ health, international audiences, media, and medical and scientific communities.

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