

Strength and Conditioning for Muay Thai Athletes

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SUMMARY

MUAY THAI WAS DEVELOPED IN THAILAND AND IS A COMBAT SPORT IN WHICH CONTESTANTS CAN KICK, PUNCH, KNEE, ELBOW, AND GRAPPLE WITH THEIR OPPONENTS. LIKE MOST MARTIAL ARTS, MUAY THAI ATHLETES TEND TO PLAY THEMSELVES FIT, OFTEN BECAUSE THIS HAS LONG BEEN THE TRADITIONAL APPROACH BUT ALSO BECAUSE OF THE MANY MYTHS THAT SURROUND GYM-BASED TRAINING EXERCISES. THIS PAPER THEREFORE AIMS TO JUSTIFY THE INCLUSION OF STRENGTH AND CONDITIONING WITHIN MUAY THAI AS AN INTERVENTION TO FURTHER ENHANCE ATHLETIC PERFORMANCE. IN ADDITION, AN EVIDENCE-BASED PROGRAM IS SUGGESTED.

INTRODUCTION

Muay Thai, literally Thai boxing, was developed in Thailand and is known as the art of 8 limbs. Athletes can kick, punch, knee, elbow, and grapple with their opponents. A Muay Thai match lasts up to 5 rounds of 3 minutes but is often manipulated depending on the skill of the athletes. As in most martial arts, contestants are weight matched.

In Muay Thai and more than likely boxing and most martial arts, fitness

appears to be gained through a traditional combination of running, pad work, and sparring. Most athletes are reluctant to undergo strength training because of fears of a loss in flexibility and a gain in body mass. The latter point is especially important and provides for a significant barrier, as athletes will often aim to compete at their lowest possible weight to fight opponents of lower mass.

The aim of this paper therefore was to rationalize the use of strength and conditioning (S&C) within Muay Thai and dispel any myths that prevent this form of intervention. The paper further aims to describe and rationalize “gym-based” methods to further enhance athletic performance and finally present the reader with an evidence-based S&C program.

PERFORMANCE ANALYSIS

As with any sport to which S&C interventions are to be implemented, the S&C coach must first undergo a performance analysis (also referred to as a needs analysis) to identify the biomechanical and physiological requirements of the sport. Following this, the S&C coach must construct an appropriate test battery to measure the strengths and weaknesses of the athlete against these variables. In addition, it is fundamental to identify mechanisms of injury and prehabilitative strategies. Finally, through consultation with the athlete and sports coach, individual goals must be identified.

BIOMECHANICAL ANALYSIS OF MUAY THAI

STRIKING

The straight, hook, and uppercut (Figures 1–3, respectively) are the 3 principle punches used in Muay Thai and are identical to those used in boxing. Each punch involves triple extension whereby the ankle, knee, and hip extend to generate force from the ground. Using the additional links of the kinetic chain, the trunk, shoulder, and arm, they then apply this force to the opponent. The need for this synchronization can be evidenced from studies conducted by Filimonov et al. (33) and Verkhoshansky (101). Filimonov et al. (33) analyzed the straight punch of 120 boxers, ranging from elite to junior ranks. All boxers were instructed to perform a straight right to the head, “maximally fast and powerful.” The results of this study are illustrated in Table 1 where it can be noted that elite level boxers predominantly generate force from the leg musculature, whereas lower ranked boxers generate the majority of force from the trunk and arms. This finding is corroborated by data acquired by Verkhoshansky (101) who showed that with mastery in the shot put, which may be considered biomechanically similar to a straight punch, the emphasis gradually shifts from the

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Muay Thai; boxing; martial arts; combat; power; strength; ballistic; plyometrics; testing



Figure 1. Straight.

shoulder to the leg musculature. This investigation revealed that for beginners, the correlation between athletic achievements and strength of the arm

muscles is 0.83 and with leg strength is 0.37. For highly qualified athletes, however, the correlations were 0.73 and 0.87, respectively.

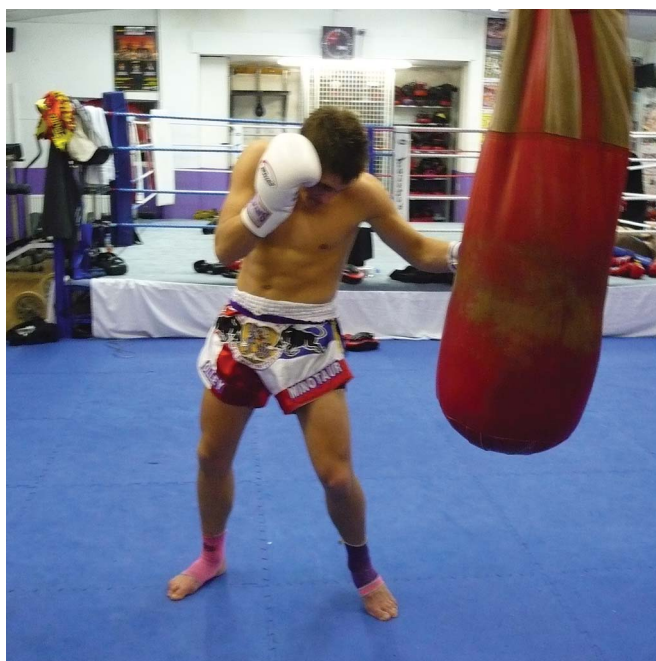


Figure 2. Hook.

As illustrated in Figures 4-7, Triple extensions movements are also required for kicking, kneeing, and elbowing. The development of this synchronization and use of triple extension-based exercises may therefore be considered essential to the generation of force within Muay Thai. Weightlifting and the associated lifts are often hypothesized to provide an appropriate stimulus for motor skills requiring triple extension (52,59,61,93). Moreover, the second pull position (Figure 8) provides a biomechanical comparison with the punching start position; therefore, sport specificity can be further gained by commencing lifts from this position.

To further facilitate the development of optimal synchronization patterns within the kinetic chain, and assist in the carryover of triple extension-based exercises to Muay Thai techniques, a derivative of complex training, termed “carry-over training,” is recommended (see 25,27 for a review of complex training). In this context, however, the objective is not the potentiation of force (although this may be an outcome) but rather the carryover of neuromuscular stimulus/firing sequence. For example, an athlete may perform a set of power snatches (often from the second pull/hang), followed by performing straight punches to the bag during the rest period. The athlete is encouraged to visualize the carryover and draw comparisons with the 2 forms of triple extension and in effect, regard the punch as synonymous with the power snatch. It is important to only perform a few punches (usually 3 per arm) and ensure the emphasis lies with power generation with enough rest between reps to minimize fatigue. It is hypothesized that this will assist in neural development and carryover, ultimately facilitating an increase in force production when striking. This form of carryover training is currently being tested within our laboratory to provide an objective assessment of its validity.

REACTIVE STRENGTH

Reactive strength, which describes the stretch-shortening cycle (SSC)



Figure 3. Uppercut.

capabilities of an athlete, may also be considered fundamental to force generation within Muay Thai. It is well documented that efficient SSC mechanics result in enhanced propulsive forces (11,14,15) and conservation of energy (12,100,102), and this therefore suggests that within martial arts, this may translate into enhanced power and power endurance of striking. As an example, double kicks or consecutive knees to an opponent require that after

each strike, the leg is quickly driven back down into the ground and then quickly driven back up toward the opponent. In addition, when the athlete wants to deliver a powerful strike with the front leg, they must first switch stance (change from a left foot forward, right foot back stance, to a right foot forward, left foot back stance), thus allowing the kicking leg to develop sufficient power through the SSC mechanism (Figure 9–11).

Optimization of SSC mechanics dictates that these movements, which (in the opinion of the author) may be considered biomechanically similar to sprint running (whereby the knee is “punched” forward and then the leg is quickly driven back down into the ground), require that ground contact be made via a forefoot landing only (51,69), thus minimizing ground contact time (GCT; 4,55,71), increasing energy return (and thus striking force; 51,69) and rate of force development (RFD; 13), and reducing the duration and metabolic cost of movement (11,12,24,100,102).

This SSC efficiency, however, is a learned ability gained through the generation of muscle stiffness, thereby optimally using the elastic recoil properties of the tendon (3,24,53,55,70,73). Muscle stiffness, however, is under the subconscious control of the nervous system, whereby the Golgi tendon organ (GTO) inhibits the generation of high forces (and muscle stiffness) as a protective mechanism against the risk of injury (88). Through observations made by this author, most athletes do not train SSC mechanics (enabling GTO disinhibition) beyond that gained from their sports practice. This is illustrated by the fact that the majority of athletes make heel contact, which is suggestive of a prolonged amortization phase and muscle compliance consequent to GTO inhibition (34).

It appears evident therefore that sports practices do not provide sufficient stimulus for this adaptation and that purposeful exercises such as plyometrics must be included

Category	Arm extension (%)	Trunk rotation (%)	Push off with extension of back leg (%)	Total (%)
Masters of sport and candidates for masters of sport	24.12	37.42	38.46	100
Class I	25.94	41.84	32.22	100
Classes II and III	37.99	45.50	16.51	100



Figure 4. Elbow.



Figure 5. Push kick.

(72,75,78,82,85,88,90). For example, Kyrolainen et al. (72) reported that 4 months of plyometric training, consisting of various jumping exercises such as drop jumps, hurdle jumps, and hopping, was required for the disinhibition of the GTO and the generation of muscle stiffness (concurrent with pre-activation tensioning and antagonistic cocontraction). Moreover, as well as takeoff velocity increasing by 8%, energy expenditure decreased by 24% suggesting that adaptations from this plyometrics protocol also resulted in a reduction in the metabolic cost of these movements (72). It appears apparent therefore that chronic plyometrics training is required to not only condition the Muay Thai athlete to increase striking forces of this nature but also facilitate them in employing these strikes with regularity (aid the development of power endurance). Finally, inherent to plyometric exercises is the powerful execution of triple extension (as previously described), so these exercises are also likely to have a carryover to kicking and punching mechanics and striking power.

Appropriate plyometric drills include drop lands (Figure 12; ensuring the athlete initiates the exercise by stepping from the box, Figure 13) whereby the body is hypothesized to adapt to high landing forces (eccentric loads) and disinhibition of the GTO is learned (105). This drill may then be progressed to drop jumps whereby the focus shifts to reducing the amortization phase and GCT and thus the loss of elastic energy (34). It may be prudent, however, to commence plyometric training with ankle/stiff leg hops (Caption 1), which enhance the stiffness of the ankle joint, as overall leg stiffness has been reported to largely depend on ankle stiffness (4,31,32). Of course, the S&C coach must determine safe and conducive plyometric intensities (e.g., drop height). It may be appropriate therefore to first practice landing drills by jumping up to a box (Figure 14) or simply jumping forward along the ground, as the intensity of each is less than when dropping from a box.



Figure 6. Roundhouse kick.

FORCE GENERATION CHARACTERISTICS

Boxing movements (i.e., punches) involve contraction times of 50–250 ms (1). As described earlier, GCT during double kicks and knees should (anecdotally) resemble that of sprint running where this has been reported to be 101 ms (77). Muay Thai motor skills therefore, like the vast majority of athletic movements, occur within 250–300 ms (93,104) and the opportunity to develop peak force, which may require up to 600–800 ms (29,68), is not a time luxury afforded to these athletes. This therefore suggests the need for these athletes to develop power.

It is hypothesized that if the time available for force development is less than 0.3 seconds (as is the case in Muay Thai), training should focus on improving RFD (80,87,105). Because RFD is a function of neuromuscular activation (86) and is representative of an individual's ability to accelerate objects (87), many authors recommend ballistic (explosive) training to improve this quality (10,43,45,46,103). It is

generally recognized that although heavy resistance training improves the final height of the force-time (F-T) curve, ballistic training improves the slope of the initial portion of the F-T curve, specifically within the first 200–300 ms (45,80) when striking is most likely to occur.

Ballistic exercises can best be described as explosive movements (rapid acceleration against resistance) whereby the body or object is explosively subjected to full acceleration. Reviews by Flanagan and Comyns (34) and Hori et al. (58) recommended the use of plyometric training and weightlifting, respectively, to train RFD, as in addition to their ability to be adapted to the specifics of the sport, they encourage full acceleration with zero velocity achieved only by the effects of gravity. In addition, weightlifting produces some of the highest power outputs of any exercise modality. For example, Garhammer (40) reported that the snatch and clean and jerk exhibit much greater power outputs compared with the squat and deadlift. For example, the relatively slow velocities involved in

powerlifting (i.e., back squat, deadlift, and bench press) produce approximately 12 W/kg of body weight (40). However, during the second pull phase of both the clean and the snatch, an average of 52 W/kg of body weight is produced (40).

It should be noted that a high and positive correlation exists between peak power and maximum strength ($r = 0.77-0.94$; 6), illustrating the significance of strength training as a prerequisite to power development. With this in mind and because strength levels may only be maintained for approximately 2 weeks (60), it is advisable to include strength sessions throughout the entirety of a periodized program so as to optimize and maintain high levels of power output. In further support of using a combined strength and power training approach, Cormie et al. (21), Harris et al. (50), and Toji et al. (96) concluded that when considering the improvement of a wide variety of athletic performance variables requiring strength, power, and speed, combination training produces superior results (compared with strength training only and power training only). The premise of this approach is thought to result from the additive improvements in both maximum force (through strength training) and maximum velocity (through power training), thus leading to a greater enhancement in power output across the entire force-velocity curve (96).

Finally, because most movements within Muay Thai are performed unilaterally, this should therefore be trained accordingly to increase the sport-performance carryover. This suggestion is corroborated by Coyle et al. (23) and Vandervoort et al. (99) who reported the existence of a bilateral deficit whereby when the limbs are working together, their net force is smaller than the combined total of when each limb is working independently. Ballistic movements therefore, such as plyometrics, should advance to incorporate unilateral movements and barbells should be progressed to dumbbells.



Figure 7. Knee.

REPS, SETS, INTENSITY, AND REST

Like most sports, developing an athlete's power output is considered a key component to successful sports performance (as most activities are force and time dependent). Because power production is largely a consequence of efficient neuromuscular processes, quality should be stressed at all times. Therefore, the effectiveness of a power program may be related to the quality of each repetition. It has been hypothesized that each repetition should achieve $\geq 90\%$ of maximum power output or velocity (36) and that this, anecdotally, is best achieved with the use of 3 reps per set, at least 3 minutes rest between sets (7,36) and a maximum of 5 sets (36). An additional method to

ensure quality of repetitions is through the use of cluster training (44). This form of training involves interrepetition rest intervals of between 10 and 30 seconds (interval length depends on exercise complexity) whereby the quality of performance is enhanced through decreases in repetition-induced fatigue. This method therefore should be used for both power/ballistic training and strength training.

As previously mentioned, strength is the prerequisite to power and therefore adequate strength training must be included. However, as Muay Thai is weight classed, S&C coaches should aim to increase athletic strength without concomitant increases in muscle cross-sectional area. For athlete

populations, maximal strength gains are elicited at a mean training intensity of 85% 1 repetition maximum (1 RM), ≤ 6 reps, 2 days training per week, and with a mean training volume of 8 sets per muscle group (81). In addition, a buildup of lactate and hydrogen ions should be avoided as these are a contributing factor to the release of anabolic hormones and subsequent muscle hypertrophy (and therefore body mass; 41,47). These metabolic by-products may be dissipated with long rest periods and/or alternating body parts in a set for set or exercise for exercise format. For example, an athlete can alternate between upper-body and lower-body exercises or between agonist and antagonist exercises.

PHYSIOLOGICAL DEMANDS OF MUAY THAI

Scientific data on Muay Thai are currently unavailable, therefore deductions must be based on empirically similar sports. In the opinions of the author, sports such as wrestling, fencing, boxing, and mixed martial arts (MMA) provide for a good comparison. In addition, Cordes (20) compares boxing with basketball, therefore this will also be considered. Table 2 illustrates the primary metabolic demands of these sports as described by Ratamess (84).

From the information presented above and through empirical observations, Muay Thai involves predominate anaerobic energy contribution and the speed and explosive nature of the sport further suggests phosphogen system dominance. In addition, rounds are fewer than boxing (5 versus 12) and shorter than both wrestling and MMA (3 versus 5 minutes). Therefore, aerobic energy system contribution may be minimal and be involved only in ring movement and recovery mechanisms.

These findings likely suggest that road running is detrimental to Muay Thai performance and unfavorably alters energy system adaptations. This is in agreement with Hoffman et al. (58) who analyzed basketball competitions over a 4-year period and reported that aerobic capacity had a significant



Figure 8. Second pull position.



Figure 9. Front leg knee starting position.

negative correlation to performance. This is further corroborated by authors who suggest that once an aerobic base is achieved, sport-specific team practices and games are sufficient to maintain aerobic fitness in anaerobic-dominant sports (17,56,57). Training programs therefore need to be directed toward high-intensity training such as interval and repetition training. Many athletes, however, use long distance running as a means to rapid weight loss (RWL). This, however, may be to the detriment of sports performance and perhaps more emphasis needs to be placed on nutritional interventions (but those based on scientific research). RWL is briefly discussed later in this text.

In summary of the above, therefore, interval training may be the optimal intervention to bring about efficacious adaptations within the metabolic system. Anecdotally, sparring provides the most specificity and optimally adapts the energy systems for the purposes of competition. However, it is not always reasonable to call on this intervention. Therefore, again anecdotally, it is suggested that coaches use a “5 s on 5 s off” protocol termed “Combat Intervals.” For this, athletes hit the pad for 5 seconds and then rest for 5 seconds throughout the entirety of a round. This time frame was chosen to represent the amount of time an athlete may attack for. The pad man can of course manipulate each interval by increasing or decreasing the time the athlete is attacking or resting (or both). Empirically, it is challenging for the pad man to continually use times less than 5 seconds. The pad man can also change the type of striking combinations between intervals and even attack during the rest period causing the athlete to defend and further increasing the intensity. Finally, it is recommended that the athlete uses 2-hit striking combinations only, for example, straight then hook, left up-percut then right roundhouse kick. This is to ensure a fast and continuing rhythm when attacking the pad. It should be noted that the S&C coach should not be considered responsible



Figure 10. Front leg knee—the athlete switches stance.

for delivering this aspect of training; however, it is important to note that these are suggestions that can be made to the sports coach.

RAPID WEIGHT LOSS

Research investigating the consequences of making weight in combat sports such as wrestling (42,54,56,65,67) and boxing (48) has shown that RWL is associated with concurrent decrements in performance. This may be because of dehydration (97), depleted glycogen

stores (19,94), reduced lean muscle mass (66), and negative mood (48,66,91). Significant to the latter factor, mood has been shown to be an effective predictor of performance in combat sport with 92% of winning and losing performances in karate correctly classified from precompetition mood (95). Losing karate performance was associated with high scores of confusion, depression, fatigue, and tension coupled with low vigor scores (95). There appears an evident paradox,



Figure 11. Front leg knee strike.

therefore, between the combat athletes' perception that RWL is associated with good performance, and the research that consistently demonstrates that athletes perform significantly below expectations. This perception may be explained by the fact that an athlete can win a contest despite performing below expectations (48). After all, both contestants likely underwent a RWL intervention.

PERFORMANCE TESTING

Testing enables coaches to identify the physical capabilities of their athletes. This further enables coaches to monitor the efficacy of the programs (allowing adjustments accordingly) and make predictions on competition performance. Based on the needs analysis conducted above, a suggested battery of tests has been identified and is illustrated in Table 3.

It is important to conduct the tests in the order described in Table 3 as this will reduce the negative effects of accumulated fatigue as the athlete progresses through the testing battery. This is in agreement with Harman (49) who suggests that for these reasons, tests should be conducted in the following order: nonfatiguing tests (e.g., anthropometry), agility, maximum power and strength, sprint tests, local muscular endurance, anaerobic, and then finally aerobic capacity tests.

RISK OF INJURY

Again deductions must be based on empirically similar sports. For example, within wrestling, injuries occur predominately at the knee, shoulder, and ankle (63). Within boxing, injury is more likely at the shoulder, elbow, wrist/hand, low back, and neck (30). This is corroborated by Cordes (20) who suggests that injury occurs primarily at the hand and wrist, followed by shoulder then elbow. However, the knee, ankle, leg, and foot are also at risk.

The author is of the assumption that many of the athletes from whom these data were gathered were not undertaking efficacious S&C programs. With this assumption in mind, strength training may have reduced the



Figure 12. Drop land.

incidence of these injuries through its positive adaptations on the structural integrity of all involved joints. For example, as well as an increase in muscle strength, tendon, ligament, and cartilage strength would also increase along with bone mineral density (35,37,92). Furthermore, boxers tend to use (and therefore develop) the anterior musculature more than the posterior (2), thereby leaving them exposed to muscle strains in the weaker muscles. S&C training can ensure the development and maintenance of proper ratios. Most significantly and pertinent to performance, increasing antagonist muscle strength may increase movement speed and accuracy

of movement (62). This has been hypothesized to occur because of alterations in neural firing patterns, leading to a decrease in the braking time and accuracy of the limbs in rapid ballistic movements (62). Therefore, strength balance is needed to break the agonists succinctly in rapid limb movements. When one muscle or movement action is stronger than its antagonist's, performance may be compromised. This is likely to provide the athlete with a greater source of motivation to develop the posterior musculature than that of reducing the risk of injury alone. In addition, strength training, unlike sports training (e.g., pad work, sparring), will train the eccentric phase of

movement skills. This enhanced eccentric strength may have defensive benefits through absorbing blows (20). For example, impact to brain depends on the acceleration and rapid turn of the head (20). A stronger neck, especially eccentrically, can help absorb forces. This is also likely to be true of the arms that are often up to guard the face. Specific to the former point, it may be concluded that Muay Thai athletes perform exercises specifically for the neck. As well as preventing injury, this may also prevent the occurrence of knockouts. Cordes (20) also suggests that knockouts resulting from blows to the thorax or abdomen may be less likely with the addition of strength training.

The S&C coach is also advised to check for movement dysfunctions within the kinetic chain. For example, much research has centered around gluteus medius dysfunctions (8,26,38,39,83,89,98). However, this, along with many other factors that are likely to contribute to the occurrence and reoccurrence of injury within this sport, is beyond the scope of this paper.

STRENGTH AND CONDITIONING PROGRAM

The following program (Tables 4 and 5) is based on 2 S&C sessions per week (as this anecdotally appears to be the mean training time allocated/available to S&C training for these athletes) and has been developed based on the reviewed research. Plyometrics (to develop the SSC mechanism) or carry-over training (see previous text) is performed during most rest intervals and the selected drills should be alternated to avoid neural monotony, thereby ensuring the neuromuscular system is continually challenged to develop. This “complex training” approach (performing ballistic exercises in the rest period) is a valuable tool to S&C coaches who are limited to 1 or 2 S&C sessions per week as it enables them to effectively use the rest period without detriment to performance (28). As previously described, plyometric drills should be logically progressed to ensure appropriate overload and an



Figure 13. Step from box (before drop land or drop jump).

ethos of quality over quantity should be enforced.

Strength exercises should be prescribed at intensity slightly below the maximum intensity for that prescription of repetitions. This point was concluded in a meta-analysis conducted by Peterson et al. (81) where it was revealed that training to failure does not elicit greater gains than not training to failure, and in addition, athletes are less likely to overtrain. Finally, for all power exercises, the load should be varied as this will also vary the velocity and further increase sport specificity. Although it is well understood that peak power output occurs at 80% 1RM in weightlifting (namely the power clean, 22) and using body mass only for squat jumps (22,76), it is likely that this is of greater theoretical relevance than practical significance.

Finally, it is important to address the issue of flexibility. The athlete and coach should be assured that providing weight training is performed using the full range of motion, flexibility will not be lost (9,64) and may even be increased (9,74). This can be further corroborated by data collected at one of the Olympic games whereby weightlifters were second only to gymnasts in a battery of flexibility tests (64). Moreover, in shoulder flexion, a movement specific to the snatch and jerk, their flexibility was significantly better than any other group. Therefore, the persistent myth that weight training negatively affects flexibility is unfounded and is most likely based on bodybuilding athletes who may have

Table 2
Energy system contribution to sports considered empirically similar to Muay Thai

Sport	Phosphagen system	Anaerobic glycolysis	Aerobic metabolism
Wrestling	High	Low	Low
Fencing	High	Moderate	—
Boxing	High	High	Moderate
Mixed martial arts	High	High	Moderate
Basketball	High	Moderate to high	—

Table adapted from Ratamess (84).

Table 3 Battery of fitness tests suitable for Muay Thai athletes
Performance tests and supporting comments (with reference literature where relevant)
Skinfold assessment: this identifies body fat percentage that has been reported to be from 10.9% in high school wrestlers (18), 6.5% in elite level freestyle wrestlers (16), and 9.5% in Olympic Kung-Fu athletes (5). This assessment is to enable the regulation of nonfunctional mass
Vertical jump: measure of lower-body power
Medicine ball throw: this should be conducted in the relevant stance and should mimic the action of the straight punch. The data can also be used as described by Verkhoshansky (101)
RSI (height jumped/GCT): as described by Flanagan and Comyns (34) and Newton and Dugan (79), this test can provide strength and conditioning coaches with a good indication of an athletes' SSC ability. The athlete is usually tested over the following drop heights: 30, 45, 60, and 75cm (79). Efficient SSC mechanics should result in greater jump heights from greater drop heights (also reflected by the RSI score). If equipment is not available to measure GCT, the coaches can simply monitor the drop height that produces the greatest vertical displacement
1RM power clean: this test evaluates the athlete's speed strength (power under heavy loading) but should only be included once the athlete's technique is of sufficient standard
1RM bench press and back squat: evaluation of maximum muscular strength, which as described, is significantly correlated with peak power output
Aerobic tests: not applicable because of the minimal contribution of the aerobic energy system
GCT = ground contact time; SSC = stretch-shortening cycle; 1RM = repetition maximum; RSI = reactive strength index.

bulk above a certain amount, thereby affecting the flexibility of that joint (9).

CONCLUSIONS

The vast majority of scientific literature supports the use of S&C training as

a means to enhance athletic performance. Programs can be manipulated to increase both strength and power and neither need be at the expense of an increase in body mass or a loss of flexibility. Moreover, athletes should be

critical of some traditional training methods such as long distance running and RWL interventions because of their detrimental effects on performance. In summary, a more scientific approach to performance training is

Table 4 Strength and conditioning program for Muay Thai athletes: 2 example strength suggestions and 2 example power sessions			
Strength session 1 (sets × reps)	Strength session 2 (sets × reps)	Power session 1 (sets × reps)	Power session 2 (sets × reps)
Squat snatch (4 × 2)	Squat clean and split jerk (4 × 2)	Squats (3 × 3)	Front squats (3 × 3)
Dumbbell chest press (*10° incline) (4 × 4)	Lat pull down or chins (4 × 6)	Power snatch from hang → power split snatch from hang (5 × 3)	Power clean from hang and split jerk (5 × 3)
Bent over row or seated row (4 × 6)	Dumbbell fly (*10° incline) (4 × 6)	Squat jumps (5 × 3)	Dumbbell chest press (*10° incline) (3 × 3)
Back squats (4 × 4)	Stiff leg dead lift or Nordics (4 × 6)		
→ = progress to.			
*10° represents the angle at the shoulder during punching.			



Figure 14. Jump up to box.

required for these athletes and more objective data are required within the sport of Muay Thai.



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Table 5
Example plyometric and carryover drills that can be performed in the rest interval

Plyometric (SSC) and carryover drills (sets × reps)
Lower-body SSC (1 × 3): anklng (1 repetition = anklng over 4 m; Caption 1) → jump up to box (gradually increase the height; Figure 12) → drop lands (gradually increase the height; Figure 13) → drop jumps (gradually increase the height; Figure 14) → progress to consecutive jumps (e.g., drop jump followed by jump over 3 × hurdles) → progress to lateral jumps → progress to single leg variants of above
Upper-body SSC (1 × 3): Smith machine bench press throws → medicine ball throws (in sports stance and mimicking punching techniques, i.e., straight, hook, and uppercut) → medicine ball drops (Caption 2) → push-up claps
Carryover training (1 × 3/per limb): kicks (roundhouses/push kicks), punches (straights/hooks/uppercuts), knees, elbows
SSC = stretch-shortening cycle; → = progress to.
Caption 1. Anklng: The knees should remain straight as the athlete hops from one foot to the other. Throughout the swing phase, the foot should be dorisflexed. At ground contact and the instant before, the plantar flexor muscles should forcefully contract. Only the ball of the foot should make contact.
Caption 2. Medicine ball drops: The strength and conditioning (S&C) coach stands on a box above the athlete who is lying supine on the ground (head is closest to the box). The S&C coach drops the medicine ball into the arms of the athlete who immediately throws it back up to the S&C coach. The athlete must aim to catch and throw the ball as quickly and as powerful as possible. Intensity may be increased by increasing the weight of the medicine ball or height of the box.

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