Strength and Conditioning Considerations for Speed Climbing

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Abstract

Climbing has developed into a professional sport with worldwide participation. Olympic climbing consists of lead climbing, speed climbing, and bouldering. The objective of speed climbing is to reach the top of the route in the fastest time. Speed climbing has not been subjected to the same level of investigation as other types of climbing. A strength and power base underpin performance in speed climbing. This physiological and mechanical basis provides the foundations for effective program design for the speed climber. Effective programming should incorporate a long-term planning approach that is based upon a needs analysis of the sport and the climber's physical qualities. The development of high performance will involve the sequential application of regional hypertrophy, maximal strength, explosive strength training, plyometrics, and climbing-specific training to a varying degree.

Key words Speed climbing, strength and conditioning, Olympic climbing, climbing

Introduction

Climbing has developed into a professional sport with worldwide participation. Today, it has grown in international standing and has recently become an Olympic sport (39). Olympic climbing consists of lead climbing, speed climbing, and bouldering. Although there are similarities between the climbing disciplines, (55) this review will focus specifically on the strength and conditioning requirements for optimal performance in speed climbing (17), which is the newest of the three disciplines (Figure 1). The objective of speed climbing is to reach the top of the route in the fastest time (39). A speed climbing wall is 15.5 meters in height with a 5° inclination. The athlete must ascend 20 hand holds and 11 foot holds (41,42). The duration of this event is short with elite male competitors ascending on average in ~6.0s and the female completion time ~8.05s (6). There is a paucity of literature on the needs of the athlete and the physiological requirements of the sport. Therefore, a detailed review is required with recommendations for strength and conditioning professionals.

Figure 1 A speed climbing wall

The Needs Analysis

Movement Analysis

As a movement skill, climbing involves the displacement of the climber's mass from one position to another as efficiently as possible (23). The culmination of movement often involves a 'reaching' movement when transitioning from one point to the next. Climbing can be operationalized into three distinct phases: stabilization, preparation, and displacement (55). The stabilization phase is necessary for the climber to maintain contact with the climbing surface and to establish postural stability. This requires isometric muscle actions from the forearm flexors, finger musculature, trunk muscles, and lower limbs (7). The preparation phase is a transition phase between stabilization and the next displacement phase. This phase requires a combination of isometric and concentric muscle activity. The forearm and finger muscles are used to maintain a static position on the climbing surface, while the trunk, shoulder, and lower quadrant are used dynamically to adjust body position ready for the next phase. The displacement phase is characterized by the displacement of the center of mass (COM) from one hold to the next hold. Muscle activity at this point is largely concentric requiring activity from the lower quadrant, trunk, shoulder, and the forearm and finger musculature (56).

Unlike other climbing disciplines, speed climbing appears to have a strong reliance on the lower limb and upper limb musculature for performance (34). In dynamic climbing movements, the lower limb has been reported to exhibit a similar proximal to distal pattern of movement and force time profile to the squat jump (31). Optimizing vertical ascent and reducing lateral whole-body displacement may be an important kinematic variable in speed climbing (72). This may influence climbing fluency, energy expenditure, and the mean velocity of the climber (72), (41). The reduction in whole body lateral displacement is a function of the climber's technical and skill related strategy for ascending the route. The choice of route selection will be influenced by the athlete's anthropometrics, physical capabilities and climbing style. Further, it has been shown that speed climbers display decreased velocity at various sections along the climbing route. This reduction in velocity means that the climber must possess the ability to re-accelerate their mass after each deceleration. The practical application of this for the strength and conditioning professional is that the athlete's route selection may influence the physical capabilities required for optimal performance.

Anthropometric and muscular profile

The anthropometric dimensions of an athlete can provide an important performance advantage in regard to competitive success. Body stature among male and female elite climbers is relatively consistent within genders. Male speed climbers tend to be taller than female climbers (Table1). Stature may be associated with a performance advantage with taller speed climbers performing fewer total movements, and consequently using less energy expenditure during the climb. Therefore, taller climbers may gain a performance advantage due to coverage of a lower relative distance compared to shorter climbers (73). However, this may not apply to female climbers. Some authors (31), have shown no relationship between stature and speed climbing time among female speed climbers. A comparison of average height between female and male speed climbers suggests that the average height of female climbers is similar to that observed in male speed climbers with the shortest stature (73). Consequently, in female speed climbers, stature may have less influence on performance. Body mass as a performance indicator has shown a high degree of variability in the literature with some studies finding correlations with climbing time (31), and other studies finding none (33).

Table 1. Anthropometric characteristics of male and female speed climbers.

Speed climbers have been shown to have significantly higher levels of thigh muscle circumference in comparison to climbers in lead climbing and bouldering (64). This suggests thigh circumference may be an indicator of high force capabilities. This conclusion corresponds with Krawczyk et al. (33) which noted a high correlation between climbing time and maximum power output of the lower limb expressed as a ratio of lean body mass. Additionally, evidence of muscle circumference and speed climbing performance has been previously established. In this study (90) forearm, upper arm, thigh, and calf muscle circumference of male and female climbers was measured. Significant correlations have been reported for thigh muscle circumference and climbing performance in male speed climbers but not in female climbers. These results suggest that specific muscle hypertrophy (particularly in lower limb muscles) may be an important factor in speed climbing performance in male speed climbers.

Electromyographic (EMG) analysis of upper limb performance has been examined during speed climbing. Guo et al. (19) reported high muscle activity in flexor digitorum superficialis, biceps brachii, and latissimus dorsi during speed climbing. In similar research Voronov et al. (90) noted climbing speed was influenced by activity of the gastrocnemius and biceps brachii muscles regardless of the climbers' skill level. However, in climbers with low-skill levels, muscle activity of the upper limb appeared greater compared to higher skilled speed climbers. The different muscle activity patterns may be related to greater skill development and movement efficiency in skilled speed climbers and better utilization of the lower limb for force and power generation.

Energy systems

Optimizing speed performance requires an interaction between mechanical and metabolic factors to maximize power output (96). Speed climbing time at the elite level is characterized by short all-out efforts requiring high force outputs. The predominant energy system utilized during these efforts is the anaerobic alactic system. This is an immediate energy system in which the splitting of creatine phosphate is used to resynthesize adenosine triphosphate (ATP) (11,17). In elite senior male speed climbers, race completion is often 6 seconds or less suggesting a high rate of energy production. In male, female youth, and sub-elite categories the duration for course completion ranges from 8.5 – 13 seconds (34). This divergence in course duration between gender and competition levels suggests some degree of specificity in relation to metabolic energy demands. This may have implications for the type of training activities selected to develop the climber's metabolism to sustain power outputs for optimal performance. In light of the above considerations, we proposed a speed climbing model including five factors that indicate the energetics involved in each subcategory (Table 2). This model is based upon a general physiological understanding of human metabolic energy pathways (53). The model infers the utilization of specific substrates, energetics and energy systems based upon empirical models of metabolic energy production used to produce high rates of mechanical work (16),(19). Speed climbing is typified by high rates of energy production (16), (34). The limiting factors and training objectives are based upon the physical qualities which might produce favorable adaptations in the central nervous system (82) and neuromuscular system (25).

Table 2. Speed climbing physiological model.

Strength and power

Kinetic analyses in speed climbing indicate that the rate of force development (RFD) and power output of upper and lower limbs is important for performance (Figure 2). (32, 57). Higher vertical jump heights have been shown in male speed climbers when compared to other climbing disciplines (e.g. bouldering, and lead climbing), suggesting greater lower limb maximal power output in speed climbers (28, 35). Some studies have shown higher levels of force and power output during upper limb tests in bouldering athletes (measured via pull-up tests) (38). However, other studies have reported no differences in upper body power output between bouldering athletes and speed climbers (measured via upper-limb Wingate tests). This is not surprising considering the crossover of metabolic energetics between speed climbing and bouldering. Speed climbing and bouldering are both highly anaerobic with high strength and power requirements associated with performance(32),(31). The lower limb's importance for speed climbing performance has been confirmed in related research, which has shown relationships between vertical jump tests (VJT) and performance outcome data (32,11,). These results suggest that power output of the lower limbs is an important factor in determining male speed climber performance. The evidence suggests that strength and conditioning professionals may be able to use VJT's as a part of a diagnostic battery of performance tests (34).

The importance of force production capabilities is further underscored by Fuss and Niegl (13) who noted faster performance times are associated with higher levels of finger reaction forces during contact with climbing hand holds. The ground contact times (GCTs) of the hand and feet are not uniform during speed climbing. Fuss and Niegl (13) reported GCTs for the hand holds ranging from 0.71 – 1.61 seconds (s) and (14) foot GCTs between 219 – 403 milliseconds (ms). The longer foot and hand holds GCTs may relate to the requirement to spend longer on the hold to generate a larger impulse for vertical propulsion and skill levels. Fuss and Niegl (13) found more experienced speed climbers had shorter GCTs. The role of the lower limb during dynamic climbing movements has been reported to be 1.8 times greater than the contribution of the upper limb. Propulsive force values in the range of 1000N have been reported for the lower limb and 600 N for the upper limb during jumping techniques used in climbing (14). These techniques are called two handed dyno problems and are used to explosively propel a climber from one hold to the next, similar to that exemplified in speed climbing (57).

Figure 2 Speed climber displaying explosive strength

Power endurance

Analysis of speed climbing velocity dynamics suggests a reduction in velocity at various points along the route (41), as well as power output (42). The reduction in velocity has been observed during three sections of the route. This includes the turn, the first dyno, and the second dyno. We postulate that this slowing of velocity is due to the route taken by the climber to complete the course. The climber with high levels of skill acquisition and route reading skills, in addition to superior strength and rate of force development, may confer a performance advantage. Contrastingly, the climber with low skill development after each phase will need to re-accelerate to maintain a high mean velocity for the entire course compared to the higher skilled climber (41,42).

Upper and lower limb muscle performance have been subject to physiological evaluation. Guo et al. (19) noted during speed climbing the reduction in upper limb muscle activity was faster than that of lower limb muscle activity. Moreover, climbing duration significantly influenced blood lactate concentrations, with longer assent times associated with higher concentrations. This may highlight the need to develop alactic capacity and fast glycolytic substrate utilization in sub elite climbers. These results suggest that power endurance training methods, particularly for the upper limb, may be beneficial for low-skill or youth speed climbers. In regard to fatigue management during training, Fuss et al. (15) and Shulko & Kravchuk (72), have analyzed heart rate (HR) behavior during speed climbing training. The results indicate maximum HR values after course completion of 176.43 ± 8.09 (15) and 172 (72). Fuss et al. (15) noted a mean HR recovery value below 100 bpm in 3 minutes and 57 seconds. Shulko & Kravchuk (72) reported the degree of HR recovery was dependent upon the type of climbing effort. For maximum, sub-maximal, and moderate intensity climbing, the time values from peak HR, were: 59, 44, and 39 seconds, respectively. These studies support the International Federation of Sport Climbing and its recovery recommendation of 5-minute rest phases between climbing runs for HR recovery at international competitions.

Injury risk profiles

Injury rates in speed climbing are not well established. However, injury rates in elite climbing populations (e.g., lead climbing and bouldering) have been reported. It is noteworthy that in Olympic climbing, athletes compete in lead, bouldering, and speed climbing. Therefore, injury rates and mechanisms in elite climbers may be reflective to some degree of speed climbing participation. In a cohort of 436 elite climbers (299 male /137 female), the prevalence of upper limb injuries was 77.1%, the lower limb 17.7%, and 5.2% attributed to other body regions (40). In the hand, the most frequently reported injuries were to the finger pulley ligaments (12.3%) followed by finger tenosynovitis (10.6%). Common shoulder injuries include superior labral lesion tears from anterior to posterior (SLAP) accounting for 29.8% of all shoulder injuries, which was closely followed by conditions associated with rotator cuff related shoulder pain (27.4%), dislocations, and Bankart lesions (17.7%). In the same cohort, 43.9% of reported injuries were acute (trauma) and 56.1% relate to persistent (overuse) conditions. In youth climbers, speed climbing has been associated with finger growth plate injuries (48). This may be related to the high contact forces associated with speed climbing. Lower limb injuries in speed climbing have not been well reported.

Strength and conditioning considerations:

Speed climbing in comparison to other climbing disciplines has a muscular strength and power development basis (38). It is, therefore, appropriate to suggest a rationale for programming that addresses both upper and lower limb development. Programming for the speed climber should develop the underpinning physical capacities to support performance. A periodization schedule can allow the sequential potentiation of physical qualities that may need to be developed with respect to the climber's needs analysis. This may include regional hypertrophy, maximal strength, and explosive strength qualities during a training year (24). This will facilitate the appropriate physical development at specific times during an athlete’s season to allow optimal physical preparedness while minimizing fatigue prior to important competitions.

Force development

It is well recognized that muscular strength is a foundational capacity for muscular power, rate of force development, starting strength, and acceleration strength (37). In a speed climber's training year muscular strength is an important capacity that lays the foundation for other physical qualities. Notable gains in lower limb force have been shown in 4-12 week blocks in several sports (38, 49).

Regional hypertrophy

Adaptations in morphology, neurophysiology, and the material properties of muscle have been reported with strength training interventions (68). Changes in muscle and connective tissue morphology are associated with submaximal strength training because of its ability to change tissue volume (70). The mechanisms responsible for hypertrophy are thought to involve muscle tension, metabolic changes, and muscle damage (77). Hypertrophy development of the climbing athlete should be used judicially. The climbing athlete needs to maintain an optimal strength to mass ratio to remain competitive for their sport. Therefore, muscular development is based upon regional hypertrophy of muscle and tendon cross sectional area at specific sites (28). This is influenced by the climber’s physical characteristics limiting performance. A haphazard approach has the potential to negatively influence climbing performance through non-functional muscular development.

Hypertrophy development should focus on muscle groups designed to achieve a specific performance outcome. For example, an increase in the physiological cross-sectional area (PCSA) of the gastrocnemius, soleus, and quadriceps muscles may be performance enhancing. Previous studies have noted differences in the forearm, quadriceps, and calf muscle circumference between elite and sub elite speed climbers (36) Further, higher thigh muscle circumference has been reported in speed climbers compared to rock climbers (64). An increase in their PSCA can increase the force generating capacity of muscle which can be advantageous for explosive strength development(51),(52). Correspondingly, functional hypertrophy may be beneficial from an injury prevention perspective due to an increase in connective tissue and muscle cross-sectional area (84). However, the relationship between muscle hypertrophy and performance must be closely monitored to elucidate its effect on the climber. Climbing is a bodyweight-based sport similar to other sports such as gymnastics, consequently, performance is optimized by an appropriate strength and power to weight ratio (56),(93). Therefore, regular monitoring during hypertrophy blocks should be undertaken to assess its impact on key outcome measures such as upper and lower limb power tests (jump height), muscle girth and 1RM testing (Table 3). Close monitoring of both lower and upper limb explosive strength and maximal strength can be used to ensure regional hypertrophy does not negatively affect performance.

Table 3 Muscle performance field assessments

Programming considerations

Regional hypertrophy exercise selection will be contingent upon the muscle groups needing greater strength or power development. The frequency of training will depend upon the athlete's tactical, technical, and other training commitments (41). However, hypertrophy-oriented sessions generally involve high volumes of work per muscle group. To optimize this strategy and gain an appropriate anabolic response, split routines may allow a high weekly volume and afford greater recovery between sessions (94). The load utilized is widely considered an important variable for the hypertrophic response to resistance training (69). Training in a medium repetition range is suggested to achieve an optimal amount of mechanical tension and metabolic stress for maximizing hypertrophic adaptations (94).

A repetition maximum (RM) range of 6 -12 repetitions is suggested to be an optimal range for hypertrophy. This should consist of multiple sets (3-6) at a moderate intensity of effort (60-80% of 1RM) (37). This type of loading regime theoretically provides resistances that are heavy enough to recruit high threshold motor units and is of sufficient duration to stimulate adequate metabolic stress (68). The muscle action chosen to stimulate functional hypertrophy will depend upon several factors including the athlete's S&C training age and phase of training. From a muscle damage and muscle tension perspective, eccentric muscle actions are a logical choice for producing a high anabolic response (60). The forces generated during eccentric training are approximately 45% higher than concentric training and almost double that of isometric training (25). This therefore allows heavier loading during eccentric exercise. Eccentric loading may also heighten adaptations related to muscle damage(89). Exercise induced muscle damage for eccentric loading is greater compared to isometric and concentric muscle actions (60). Mechanistically, early phase myofibrillar damage may drive greater satellite cell responsiveness and acute signalling responses that facilitate long term muscle growth (12). However, this must be reconciled with exercise induced muscle damage and soreness associated with eccentric muscle training which may affect the quality of skill related training. This consideration may well necessitate the use of concentric based hypertrophic development for which there is substantial evidence of effect (70).

The rest interval between sets is suggested to have distinct effects on hypertrophic responses. Short rest intervals < 30 seconds have been suggested to increase metabolic stress (61). This may lead to a decrease in the mechanical load that athletes are able to tolerate at the expense of optimal levels of mechanical tension. Long rest intervals > 5 minutes (mins) allow higher levels of mechanical tension to be sustained during each set. However, this may be at the expense of reduced metabolic stress with respect to metabolite accumulation (54). Moderate rest periods may therefore be the best compromise between mechanical tension and metabolic stress. Interset rest periods of 2-3 minutes may be preferable for hypertrophy-based training (29). This approach may help to maintain the volume load across multiple sets.

Maximal strength.

Maximal strength training has been shown to promote both morphological and neuromuscular adaptations necessary for high levels of force production (75). This classification of exercise improves both intra and intermuscular coordination (96). Maximal strength training utilizes high external loads to improve the relative strength of the speed climber. High force capabilities have been reported as performance enhancing in both the upper and lower limb of speed climbers. Force values in the region of 1000 N have been reported for dynamic jumping techniques used in speed climbing (14). Maximal strength training is designed to overload the following: the triple extension movement pattern seen during the ascent phase of speed climbing (34), the concentric pulling action of the shoulder adductors (78), and forearm flexor muscles responsible for gripping holds (90).

Lower limb exercises such as the back squat, front squat, deadlift, and unilateral exercises such as the Bulgarian split squat are effective for overloading the extension movement pattern. Ballistic exercises such as the clean, snatch, and pulling derivatives can also be utilized when programmed with high loads (74). These exercises are multi joint lifts that utilize the critical lower limb extensor muscles to develop high ground reaction forces (71). Maximal strength training to develop the high force capabilities of the shoulder adductors, forearm flexors, and synergistic musculature can be utilized. Training exercises such as the weighted pull-ups, the bench press, machine-based variations (78), and weighted hang board training for the finger and forearm muscles are appropriate to improve their function (43). These exercises, when prescribed appropriately share the common adaptation of increased neural drive and force production (1) (Table 4).

The loading scheme selected will depend upon the end outcome required from the training program. However, to improve maximal strength, a high degree of muscle tension is required. Loads between 70-90% of 1RM with explosive intent result in significant central nervous system adaptation (CNS) and improve coordination between muscle groups involved in the pattern of movement. The number of sets should range from 3-5 sets for each fundamental exercise. At the lower percentages of the 1RM load scheme (e.g. 70 -80 %) repetitions can range from 3- 6, at the higher range (80-90%.), 1-3 repetitions is appropriate (30). Lower repetition and high load ranges are better suited to the development of intramuscular coordination adaptations. This may be beneficial at the start of a speed climb. At the start of a speed climbing route, a climber is required to generate high forces to accelerate their body mass from a stationary start. Rest between sets should be prescribed to ensure adequate recovery of the alactic energy system and central nervous system. An inter-set recovery of 3-6 minutes is generally sufficient to resynthesize ATP (22). It may also be appropriate to allow an inter repetition recovery during the execution of higher 1RM loads or during periods of overreaching to maximize load attainment, motivation, and the quality of each repetition (86). The frequency of training will depend upon the training phase within the annual plan, the training goal, and other training units. Dedicated maximal strength sessions are likely to lead to the most improvement in this quality, and 2-3 sessions per week have been shown to be appropriate (75). However, because of the relationship between maximal strength and explosive strength, it may be prudent to include 1-2 key strength exercises all year round (25).

Table 4 weight training exercise for maximum strength and hypertrophy

Rate of force development and explosive strength.

Explosive strength is critical to speed development and has been positively correlated with high performance in several sports, (46, 30) In speed climbing this quality may be advantageous for improving the athlete's starting speed and average velocity. This has been supported by research suggesting that vertical jump performance is able to differentiate between speed climbers and other climbing disciplines (38). The development of explosive strength or rate of force development can be improved with ballistic exercise. Ballistic exercise involves the production of force in very short periods (47). In practice it either involves the acceleration of an athlete's body mass or an implement with maximal intent into free space. The acceleration of the object or athlete is typified by the absence of a deceleration phase before it reaches maximal velocity. Exercises that meet this criterion include loaded and unloaded jumping (47), medicine ball throwing (Figure 3) (81), Olympic weightlifting (Table 4), and its derivatives that utilize the second pull phase which can span large portions of the force velocity curve (74).

Figure 3 Ballistic Medicine ball slams

Rate of force development and explosive strength should be systematically periodized in regard to volume and intensity based upon the phase of the training year (49). However, if the aim is to increase strength speed for acceleration then moderate to heavy loads should be used. This from a performance perspective may be beneficial at the start of a race when the athlete's body mass must be accelerated from a stationary position. High vertical force application at a lower velocity of motion would mimic the start of a speed climb and the force side of the force velocity spectrum. However, this will depend upon the relative strengths and weaknesses of the athlete's force velocity profile. In contrast, the development of speed strength for maximal velocity development requires low to moderate loads (27). As the speed climber nears the completion of the acceleration phase, the need to maintain force application at a high velocity may become a limiting factor. Speed strength training modalities targeting force production at high velocities should be emphasized. The volume load recommendation will depend on the athlete's training age and training phase(20). Explosive strength training should consist of 1-5 sets per exercise using a light to moderate or a moderate to heavy loading scheme dependent upon the physical capacity trained (strength speed vs speed strength). Typical intensities for strength speed range from 60-80 % of 1RM and typical intensities for speed strength range from 30-60% of 1RM. All repetitions regardless of the capacity trained are performed with maximal intention to move at high velocities for 3-6 repetitions (58). The rest period will be dependent upon the sub-quality being developed during the specific training block. It is preferable to allow a rest period long enough to promote adequate resynthesis of the ATP- CP system. Therefore a 3 -5-minute rest period is often recommended (22). However, this can be manipulated to target sub qualities such as power endurance by progressively reducing the rest period between sets and minimizing the intra set rest period. An example of a sample 4- phase block periodization model for speed climbing is shown in (Table 5) (79). The development of physical capacities alongside speed climbing skill development should allow the optimal development of the athlete before important competitions.

Plyometric and stretch shortening cycle training

Plyometric exercise is a modality utilizing the stretch shortening cycle (SSC)(45). It has been shown to increase strength, power, RFD, and speed (62),(7) which are critical elements for improving speed climbing. Plyometrics can be incorporated into a speed climber's training program in two ways depending upon the athlete's needs. It can be included with resistance training workouts known as complex training or can be used as stand-alone training units. Complex training can be used by athletes with an extensive training history. It is a time efficient method to improve acute power performance using post activation potentiation by utilizing planned rest intervals (83). For example, the athlete might perform depth jumps followed by a set of Bulgarian split squats.

Plyometric exercise should be chosen based upon the specific outcome sought and the demands of the sport. Plyometric type activities can be selected to bias the acceleration phase of speed climbing which will tend to favour exercises with higher ground contact times (Table 7) (50). Climbers are stationary at the start of the speed climb and must overcome the inertia of their mass to begin the acceleration phase. Exercises with long ground contact times and higher angular displacements at the knee and hip may preferentially improve acceleration qualities. Deep countermovement jumps and squat jumps have been reported to improve both reactive and explosive strength qualities important for acceleration (26),(50).

Bounding, drop jumps and depth jumps have been shown to have variable ground contact times dependent upon the technique utilized (80),(92). However, bounding exercises may have correspondence to parts of the ascent phase because of the intermittent unilateral load profile of speed climbing. Additionally, mechanistic adaptations which enhance the material properties of the muscle tendon unit (MTU) may provide a potent stimulus for SSC potentiation. MTU stiffness may enhance concomitant force production by enhancing storage and release of elastic energy during the acceleration and maximal velocity phases of the climb. The upper limb as a functional unit can be trained to improve its explosiveness using exercises such as body weight clap push ups, bench press throws, ballistic pull ups and medicine ball throws (Table 7) (7),(87),(8). Climbing specific explosive training using campus boards and bouldering derivates are also important methods to develop the shoulder adductors and forearm and finger musculature (65),(23) (Figures 4, 5). This may provide a high degree of specificity in regard to the metabolic and mechanical profile of speed climbing (Table 6).

Figure 4 Climbing specific explosive training using campus boards

Figure 5 Climbing specific strength training using campus hyper gravity bouldering

Plyometric activities with short ground contact times are thought to increase maximum velocity in sprinting and may therefore be beneficial in a climber’s long-term plan. These exercises have been suggested to elicit fast stretch shortening cycles when the ground contact times are less than 0.25 m/s (44). This classification of exercises mechanistically may reduce tension deformation during ground contact by lowering collagen compliance. This improves energy return via elastic recoil and minimizes unnecessary muscular work. It has been shown that exposure to high eccentric forces increases stiffness and improves energy storage and return (9). The progressions in height and distance should be kept very small for athletes not used to this type of training or for athletes with a poor upper and /or lower limb strength base.

If the athlete’s strength base is insufficient the athlete is likely to have longer ground contact times as a compensation (91).

Table 5 Climbing specific power and strength training

The prescription for plyometric exercise is typically based upon the training age of the athlete, the specific capacity requiring improvement, and their phase of training. However, the inclusion of plyometrics for the speed climber should be incorporated in a periodized manner. We recommend a phased approach where low intensity plyometrics are incorporated into the athlete’s preparatory phases. During the functional hypertrophy phase, it can be used to familiarize the athlete with plyometrics. These exercises will have low movement and sports specificity. As the training year progresses towards competition, the focus will shift to higher load and higher intensity plyometrics with greater volumes of exercise. It has been shown that when plyometrics are proceeded by blocks of strength focused training (strength endurance, hypertrophy, and maximal strength), this optimizes performance (4).

The volume and intensity are determined by the amount of work performed during a training session. This is typically measured by the number of foot contacts for the lower limb or the number of repetitions performed for the upper limb. It is recommended that the prescription of repetitions or ground contacts be based upon the experience level of the athlete with the following considered appropriate for beginners 80-100, intermediate 100-120, and advanced athletes 120-140 per session (59). The intensity of the session will be determined by the speed of movement of each exercise, the points of contact (single vs double leg hopping), the amplitude of the movement, the body weight of the athlete, and the amount of added external system mass (6).

Table 7 Plyometric exercise

Conclusion

A strength and power base underpin performance in speed climbing. This physiological and mechanical basis provides the foundations for effective program design for the speed climber. Effective programming should incorporate a long-term planning approach that is based upon a needs analysis of the sport and the climber's physical qualities. The development of high performance will involve the sequential application of regional hypertrophy, maximal strength, and explosive strength training to a varying degree. However, this will require the blending of fundamental strength and conditioning principles with the athlete's technical and tactical speed climbing training.

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Table 1. Anthropometric characteristics of male and female speed climbers.

Reference	Sports level	Male climbers			Female climbers		
		BH mean ± SD	BW mean ± SD	FM% mean ± SD	BH mean ± SD	BW mean ± SD	FM% mean ± SD
(64)	International Level	179.1 ± 7.9	~ 68 (no exactly value was reported)	N/D	N/D		
(73)	World Games Participants	175.3 ± 9.57	N/D	N/D	N/D		
(35)	Polish National Team Members	174 ± 6	67.2 ± 3.4	13.4 ± 1.64	N/D		
(17)	International Level	177.5 ± 8.7	70.7 ± 9.5	N/D	N/D		
(18)	Polish National Team Members	N/D			167 ± 5.7	55.8 ± 6.8	N/D
(31)	Polish National Team Members	N/D			163.7 ± 2.7	52.7 ± 4.9	17.3 ± 2.9
(57)	International Level	179.3 ± 9.5	72.2 ± 7.31	N/D	N/D		
(19)	Chinese National Team Members	171.1 ± 2.4 BH and BW averaged for male and female	65.2 ± 7.8 BH and BW averaged for male and female	14.3+2.4	N/D		17.8 ± 2.1
(32)	Polish National Team Members	175.6 ± 4.5	67.5 ± 5.3	13.3 ± 1.2	164.1 ± 2.7	54.6 ± 5.1	17.4 ± 1.8
(33)	Polish National Team Members	177.6 ± 6.4	70.3 ± 6.2	7.4 ± 2	163 ± 2.5	54.9 ± 5.5	19.1 ± 4.2

(36)	International Level	178.5 ± 8.8	70.2 ± 12.2	8.4 ± 2.5	N/D

Note. BH – Body height, BW –Body weight, FM% - Percentage of fat mass, Mean – average results, SD – standard deviation, ND – No data

Table 2. Speed climbing physiological model (16, 17, 19, 20, 53, 85).

Climbing level	**Senior Male, Senior Female, Male Youth A (Under17)**	**Male Youth B (Under15), Female Youth A (Under 17), Female Youth B (Under15)**
Dominant energy system	anaerobic alactic (power, capacity for low-skill climbers)	anaerobic alactic (power, capacity), anaerobic lactic (power)
Energetics	90% alactic - 10% lactic	80% alactic - 20% lactic
Main Energy substrate (s)	ATP-CP	ATP-CP, glycogen
Limiting factors	Early rate of force development (RFD) , Late RFD	Early rate of force development (RFD, Late RFD, Power endurance
Training objectives	maximum strength, power	maximum strength, power, power endurance

Table 3 Muscle performance field assessments

Assessment		
Functional Hypertrophy	**Maximum strength**	**Explosive strength**
Measuring muscle cross sectional area (Girth)	1RM upper limb or lower limb key exercises	Counter movement jump (lower body explosive strength
Strength to mass ratio upper limb or lower limb key exercises	Strength to mass ratio upper limb or lower limb key exercises	Arm jump test (upper body explosive strength)
Counter movement jump (lower body explosive strength		Strength to mass ratio upper limb or lower limb key exercises
Squat jump		
Arm jump test (upper body explosive strength)		

Table 4 weight training exercise for maximum strength and hypertrophy

Weight training exercises		
Ballistic Olympic / power lifts	**Basic strength (Lower limb)**	**Basic strength (Upper limb)**
Power snatch	Back squat	Weighted Pull - ups
Power clean	Front squat	Bent over row
High pull clean	Overhead squat	Bench press
High pull snatch	Bulgarian Split squat	Shoulder press
Pull snatch	Leg press	Towel chin ups
Pull clean	Deadlift	Upright row
Bench throw	Romania deadlift	
Barbell punch	Single leg weighted calf raises	
Loaded squat jump		
Jump pull ups		

Table 5 Sample 12 week linear periodization model for speed climbing (79)

Sample 12-week linear periodization model for speed climbing			
Physical capacity	**Training block**	**Example session**	**Dosage**
Regional hypertrophy mesocycle	General preparatory phase	Back squat, Deadlift, Weighted pull ups, Calf raises, Bench press, shoulder press, Low Box drop jumps[c]	2-3 x per week 70-80% 1RM 3-6 Sets 6-12 Reps Rest 2-3 mins
Maximal strength mesocycle	Specific preparation phase	Back squat, High pull clean, Bent over row, weighted calf raise, Tuck jump[c]	2-3 x per week 70-90% 1RM 3-5 Sets 1-6 Reps Rest 3-6 mins
Maximal power mesocycle	Pre-competitive phase	Deadlift[a] , hurdle jumps, Weighted pull ups[a], Sprint bounding [c], Depth drop push up	2-3x per week 60-80% 1RM[b] 30-60% 1RM[b] 1-5 Sets 3-6 Reps Rest 3-5 mins
Power maintenance mesocycle	Main competitive phase	Power snatch, Back squat[a], Campus board laddering[a] , Hurdle rebound jumps[a]	2x per week 60-80% 1RM[b] 30-60% 1RM[b] 1-4 Sets 3-6 Reps Rest 3-5 mins
[a] Use a maximal strength dosage			
[b] Use a speed strength dosage (30-60% 1RM[b]) or a strength speed dosage (60-80% 1RM[b]) depending upon the athletes needs analysis			
[c] Plyometrics dosage is determined by the number of foot contacts for the lower limb or repetitions for the upper limb. The dosage should be low enough to not induce neuromuscular or metabolic fatigue			

Table 6 Climbing specific power and strength training

Climbing specific training	
Ballistic climbing specific	**Climbing specific Basic strength**
Campus board laddering	Hyper gravity bouldering
Campus board double dynos	Bouldering Hard moves (4 moves)
Big move bouldering	System board Hyper gravity
Boulder campusing	Finger board max strength holds

Table 7 Plyometric exercise

Plyometrics		
Lower body Acceleration	**Lower body Maximum velocity**	**Upper body Acceleration and Maximum velocity**
Medicine ball squat – push to dive	Assisted jumps	Med ball Scoop toss
Push off and dive	Ankle bounce Pogo	Med ball Lateral toss (low hold)
Sprint bounding	Low Box drop jumps	Med ball Lateral toss (high hold)
Single leg hop	Hurdle jumps	Med ball Over head throw
Single leg box explosion Depth jumps to high box Medium – high Box jump	Drop jump	Two handed wood chop throws
Squat jump	Hurdle rebound jump	Med ball explosive chest pass
Depth jumps		
Tuck jump		
Broad jump with even stance		Depth drop push up
Broad jump with uneven stance		