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Review Article

Enhancing Weightlifting Performance : A Narrative Review

Maria Anjali Baptist[1]*, Shrirang Tatte[2]
[1]Independent Researcher, Mangalore, Karnataka, India.
[2]Assistant Professor, DY Patil (Deemed to Be University), Navi Mumbai, Maharashtra.
*Email: mariabaptist03@gmail.com

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Maria Anjali Baptist


Shrirang Tatte

ABSTRACT
Weightlifting is an explosive power sport that demands superior neuromuscular coordination, strength, speed, and technical skill in two primary lifts: The snatch and the clean and jerk. This review provides a needs analysis of Olympic weightlifting, focusing on its physiological, biomechanical, and injury-prevention demands. A targeted needs analysis helps optimize training time, reduce injury risk, and support long-term athlete development. Understanding energy systems, movement mechanics, and common injury patterns enables support staff to implement effective training and recovery strategies. These strategies enhance lift efficiency, minimize injury risk, and improve competitive performance. This paper aims to serve as a practical guide for coaches and sports science professionals involved in the training and development of competitive weightlifters.
Keywords: Olympic weightlifting, strength training, needs analysis, biomechanics, injury prevention, athlete development, performance enhancement.

1. Introduction

Weightlifting is a sport whereby athletes compete against each other to lift the maximum amount of weight during the two major lifting events. They are the snatch and the clean and jerk.These two lifts are featured in the Olympic Games [12].It is also called as Olympic lifting, but this is not technically accurate unless referring to elite weightlifters participating in an Olympic weightlifting competition [12]. Furthermore, weightlifter is a term reserved for an individual that participates in the sport by training or competing in weightlifting [22].

The two primary lifts in weightlifting are the snatch and the clean and jerk, along with the variations of each lift such as the hang snatch, hang clean, and clean pull. In the snatch, the lifter lifts the barbell from the platform to an extended overhead position all at once. While the clean and jerk consists of a combined movement where the lifter brings the barbell from the platform to their shoulders during the clean phase of the lift and pressing overhead during the jerk phase of the lift. Both lifts exhibit a high demand for technical skill, and are performed at a rapid pace, which requires an elaborate amount of skill and coordination [6].

At the highest level of sport, it is well documented that small changes in performance can have a large impact on an athlete's chance to succeed. Therefore, continuing to improve is essential [19]. Since most weightlifting exercises are done in training on a frequent basis, practitioners and athletes should consider that small changes in technique or strength can yield a large improvement in performance outcome. With the current lack of reliable performance metrics related to competitive strength athletes, especially Olympic weightlifters, there is a call for further evidence to support the continued research of how to train and condition athletes [19]

The objective of this paper is to provide a needs analysis for weightlifting athletes, but more importantly, analyzing the need for continual improvement in training. As the majority of lifts performed by competitive weightlifters during their regular programs are critical, even small modifications to an existing training program can have a substantial effect on the results of performance. This paper aims to illustrate the role of support staff, including S&C Coaches and sports scientists, in all aspects of an athlete's program to assist them in refining their technique, to cultivate optimal training loads, and finally to minimize the risk of injury.

2. Needs Analysis of Weightlifting

2.1. Physiological Demands

Weightlifting uses the phosphagen system as its main energy source due to the short anaerobic, high-intensity lifts [12]. Movements such as the snatch and the clean and jerk, which last only a handful of seconds, rely on immediate availability of ATP, due to the short duration of the movements. While engaged in training, the body replenishes energy during the rest periods between sets using the fast glycolytic system. While weightlifting is referred as an anaerobic sport, the available research suggests that weightlifters possess vastly greater VO_2 max than sedentary individuals [12] which provides evidence to the internal adaptations of the cardiovascular system to satisfy training demands. It is also worthy to note, strength and power athletes can sustain greater workloads as compared to endurance-trained athletes, despite higher peak oxygen consumption VO_2 max by endurance-trained athletes.

Furthermore, metabolic stressors during both training and recovery contribute to elevated post-exercise oxygen consumption (EPOC), with aerobic metabolism remaining elevated for up to 90 minutes post-training. The complete restoration of the body's homeostasis could take up to 36 hours [12]

Olympic-style weightlifting relies not only on raw strength, but also on the application of power and speed [13]. Unlike traditional weight training, where force production protocols are relatively slow in nature, Olympic weightlifting requires explosive actions and the application of large forces immediately. Similarly, research shows that weightlifters create some of the highest peak power outputs recorded in the scientific literature of sport, and ultimately, weightlifting is considered one of the most power-dominant activities (Storey et al).

Power which is defined as the rate of work performed in unit time [12] is a critical component for successfully completing each lift. Hä̈kkinen and Komi discuss maximal power as the explosive property of force production, highlighting importance of the rapid rate of force development (RFD) on performance of lifts. Given the nature of weightlifting, where the lift action must be completed in milliseconds, an athlete's ability to develop force equally as fast is just as important as their overall strength and ability to maintain posture and control [13]. Combined, these components of strength, power, and speed make Olympic weightlifting a unique sport, and success in weightlifting is especially contingent upon the combination of muscular force and neuromuscular control to successfully execute a lift.

2.2. Biomechanical Demands

Effective weightlifting execution is a product of explosive power, proper movement biomechanics, and stability. While biology determines any athlete's energy capabilities, biomechanics will determine how effectively they can convert energy into powerful and efficient movements

Olympic weightlifting consists of two primary lifts: the snatch and the clean and jerk.

I. The snatch: The snatch is a one-phase lift where the barbell is pulled from the platform to the overhead position in one continuous motion. The bar must be high enough for the lifter to get below and into a deep squat position to receive the weight overhead and stand to an upright position with control in a safe position [4]. The skill requires speed, mobility, and stability. Any change in a lifter's trajectory of the barbell, or positioning of the body may result in the loss of stability and force production.

The lifter can drop under the bar but must not touch their knee to the floor or interrupt the bar's upward motion [10]. To complete the lift, they must stand upright with the barbell overhead for two seconds and wait for the referee's approval [10].

There are two styles of snatching: The split and the squat variation. In the split snatch, one leg moves forward with a bent knee, and in the squat snatch, the lifter drops into a deep knee-bend to catch the weight overhead. Finally, they must rise to a standing position to finish the lift [10]

II. The clean and jerk: A two-stage lift, allowing heavier weights to be moved than in the snatch.

- Clean phase: The lifter pulls the barbell from the floor and catches it in a front squat position before standing up.
- Jerk phase: The jerk portion of the lift is when the lifter explosively drives the bar overhead, while simultaneously dropping under it either into a split position or a squat, in order to stabilize the load [7]

To do this, the lifter has to produce maximal force in a very short amount of time

The weightlifting movement requires power generation from the lower body, especially the hips, knees, and ankles. Additionally, multi-joint muscles could contribute to the transfer of force from the generation of the lower body to the bar. However, the exact role that angles of the joints can add to maximize power output is still an area of study (Burdett, 1982).

A biomechanical advantage of highly skilled lifters is their ability to minimize the height required to pull the bar before transitioning under it. Therefore, this can help reduce the total amount of work and improve the efficiency of the lift. As well, highly skilled lifters can descend into the squat very possibly quicker than gravity would allow if being voluntary to dropping down under the bar, indicating that the lifter with the bar, incurs a positive upward force over and despite the active downward motion [4].

From a point of mechanical efficacy, the most optimal technique involves lifting the combined center of gravity (CoG) in a vertical orientation without unnecessary energy expenditure [28]. While the CoG of the barbell remains in the center of the bar, the lifter's CoG constantly changes based on their body position. As the weight of the barbell becomes greater, the combined CoG moves towards the barbell, creating a need for balance and stability. To maintain control, the line of action of the combined CoG must stay within the lifter's base of support, which is the feet once the barbell leaves the ground [28]. Losing this alignment will cause instability, inefficiency of the force application, and potentially lead to injury.

2.3. Injury Risk & Prevention

Injuries associated with weightlifting can often be classified as either acute (rapidly occurring traumatic event) or overuse injuries, otherwise known as repetitive strain injuries. Previous work has evaluated the types of injury suffered through weightlifting and have indicated that the most commonly injured sites are back, knees and shoulders, with strains and tendonitis being the most common types of injury [1, 5]. Overuse injuries like tendinitis and joint stress are more prevalent, especially due to high training volumes and repetitive movements.

Injury prevention extends beyond methodical reflection of proper ergonomic load bearing and stability and entails proper mobility and recovery methods too. Maintaining flexibility and strength, particularly in the shoulders and lower back, helps lifters avoid serious injuries [10]. Strengthening the paravertebral muscles and proper lifting techniques reduce the risk of lower back issues, while controlled squats and knee stability minimize knee injuries. Flexibility of the shoulders is also crucial when lifting as it allows for a safe range of motion in conditions where heavy weight is used.

Apart from technique, equipment can play a role in prevention of potential injury upon safe lifting protocol and behavior. A hook grip, wrist wraps and proper footwear can significantly improve grip, stability, and balance while weightlifting. Having said that, excessive Valsalva maneuvers should be avoided as these can cause an abrupt drop in blood pressure and blackouts when lifting heavy weight [10]. Additionally, young lifters in particular should in general be focusing on proper technique over lifting excessive loads in order to lessen early joint stress and injury.

3. Training Guidelines for Strength & Conditioning Coaches / Sports Science Support Staff

3.1. Strength & Power Development

Strength and power are the base of weightlifting performance. However, before an athlete can focus on strength and power, athletes should first develop adequate mobility and flexibility. Weightlifting requires deep squat positions, rapid force production, and coordinated and controlled movement patterns, therefore joint and muscle mobility is a critical component for safe and effective execution of lifts.

3.1.1. Mobility and Flexibility Training

It is important to obtain the full ranges of motion in the critical joints including the ankles, hips, shoulders, and thoracic spine. If an athlete is unable to achieve a deep squat with body weight alone, this will be even more difficult when starting to add loads. If mobility drills are included in every session, they will enhance flexibility while promoting joint position during lifts.

Studies have shown that flexibility training can significantly improve joint range of motion. One report showed that flexibility training increased joint range of motion by 33% in a healthy young adult population [23]. Also, combining resistance training and flexibility training do not inhibit flexibility gains when compared to flexibility training alone.

Furthermore, it is important to note that strength training does not significantly improve flexibility as was reported in the same study showing that resistance training improved muscle strength by 14-16% while having a negligible effect on flexibility. Therefore, flexibility training is important to improve mobility in weightlifting athletes.

3.1.2. Fundamental and Accessory Strength Lifts

Once mobility is addressed, strength development can be prioritized. The primary lifts for weightlifters include:

- Squats (Front and Back Squats) – Critical for leg strength and force production.

- Deadlifts (Snatch Grip and Clean Grip)– Essential for posterior chain development and pulling strength.
- Overhead Presses – Important for upper body stability and overhead strength.

Zecchin et al. (2023) analyzed the relationship between foundation strength lifts and weightlifting performance. The authors found significant correlations between 1RM for the overhead press and snatch (r=0.69), front squat and snatch (r=0.73), overhead press and clean and jerk (r=0.67), and the front squat and clean and jerk (r=0.72) [31]. This indicates that including foundation strength lifts like front squats and overhead press can positively correlate to weightlifting performance.

While these exercises form the foundation of strength training, S&C coaches should develop programs that extend beyond fundamental lifts. Since weightlifters already incorporate squats, deadlifts, cleans, and snatches in their training, additional methodologies can further enhance performance.

3.2. Advanced Training Strategies

S&C practitioners can incorporate specific training approaches to enhance strength, power, and movement efficiency. The following methods would be beneficial:

3.2.1 Unilateral Training

Utilizing unilaterally trained single-leg and single-arm movements can help to balance imbalances between limbs, improve stability, and improve coordination. Examples include Bulgarian split squats/Rear Foot Elevated Split Squats, single-leg Romanian deadlifts, unilateral overhead presses, DB Single Arm Snatches, and DB Split Snatches. Botton et al. (2016) [3] performed a study demonstrating unilateral training can improve neuromuscular efficiency using bilateral facilitation methods. This may help improve a weightlifter's performances indirectly.

3.2.2 Eccentric Overload Training

Most muscular failures in lifts will occur during the concentric effort rather than during the eccentric loading phase, as eccentric loads are generally higher than concentric efforts. By overloading the eccentric/loading phase in exercises such as squats and deadlifts, athletes can develop muscular control, desired strength features, or gains, and enhance hypertrophy, connective tissue strength and stiffness to decrease the risk of injury from a want's perspective. For example, a study conducted by Munger et al. (2017) demonstrated that applying eccentric overload in front squat exercises enhanced concentric velocity and power, suggesting that incorporating supramaximal loads during the eccentric phase can be beneficial for athletes [21].

Example of Eccentric Overload Training: If a weightlifter's 1RM Squat is 250 kg, they can lift this weight concentrically. In eccentric overload training, they can perform the lowering phase with 260-270 kg while lifting concentrically with 220-230 kg. Load adjustments should be made based on individual needs and training demands.

3.2.3. Offset Training

Offset loading is a method of training which utilizes higher load on one side of the body, contrasting the other side. This style of training requires more neuromuscular control, core stability, and overall coordination under external load. This type training can help improve control and posture during a heavy lift during sport activity.

Empirical evidence regarding the benefits of unilateral and offset loading strategies can be found in strength and conditioning literature. A study by Szafraniec et al. (2020) found that a four-week core stability program significantly improved dynamic balance and trunk muscle endurance in

weightlifters [29]. This finding suggests that offset training can play a critical role in optimizing postural control and lifting mechanics.

By integrating offset training into a weightlifting program, athletes can develop greater control and resilience under asymmetric loads, leading to improved performance and reduced injury risk.

3.2.4 Resistance Tempo Training

Changing the tempo of the different phases of a lift such as slowing down the eccentric phase and trying to accelerate the concentric phase helps improve motor control, strength, and power output. Resistance tempo training improves motor control, skill acquisition, and ultimately force production.

Tempo changes in the literature have been shown to change strength adaptations and training responses. For example, Wilk et al. (2019) altered the eccentric movement duration while monitoring power and velocity production in a bench press and concluded that controlled eccentric phases improved explosive strength during the concentric phase [30]. Wilk et al. (2020) found that altering the eccentric tempo during a lift affected one-repetition maximum (1RM) performance, as well. Longer eccentric phases reduced the 1RM in a bench press [20]. These results emphasize the importance of strategic tempo manipulation in strength training programs.

Hence, Incorporating resistance tempo training into a strength program can therefore be an effective strategy for athletes aiming to enhance motor control, refine movement patterns, and optimize force production during lifts.

Example: Performing squats with 3-3-1 tempo

3.2.5 Multiplanar Strength Training

Multiplanar strength training can be assimilated into weightlifting programs to satisfy the various components of athletic development. Most classical weightlifting, for example, the Olympic lifts, provides conditions for the sagittal plane movements. Implementing exercises that involve rotation (transverse plane) and lateral (frontal plane) movements create adaptations in the entire kinetic chain resulting in improved stability and coordination, while also reducing the chance of injury. An inclusive emphasis of these movements supports holistic functional fitness and trains to prepare for the unexpected physical demands of various physical activities [26].

For example, the performance of side lunges, lateral raises, or hip internal and external rotation will put athletes in a position in the frontal and transverse planes to load and adapt those muscles in a way to neutralise the risk of sustained injury in various regions. It will also create balanced strength and stabilization of the joints where the movement is occurring. Incorporating these movements ensures that the body can effectively perform tasks involving bending, twisting, and side-to-side actions, thereby reducing the risk of injuries and enhancing overall performance.

By adopting a training routine that includes multi-planar movements, support staff can facilitate more efficient and effective training programs for weightlifters, leading to improved athletic performance and reduced injury rate

3.2.6. Core Control Training

Developing core strength and stability through exercises like anti-rotation presses, dead bugs, and plank variations improves control in heavy lifts and reduces the risk of compensation-related injuries. For effective force transfer and injury prevention when lifting weights, a strong core is necessary.

Beyond conventional weightlifting programming, support staff can assist weightlifters in improving their technique, lowering their risk of injury, and maximizing their performance by combining these approaches.

3.3 Recovery and Regeneration Strategies

Effective recovery is essential for optimal weightlifting performance. The Recovery Pyramid, adapted from NSCA's Essentials of Sport Science, organizes recovery strategies based on their importance and scientific backing.

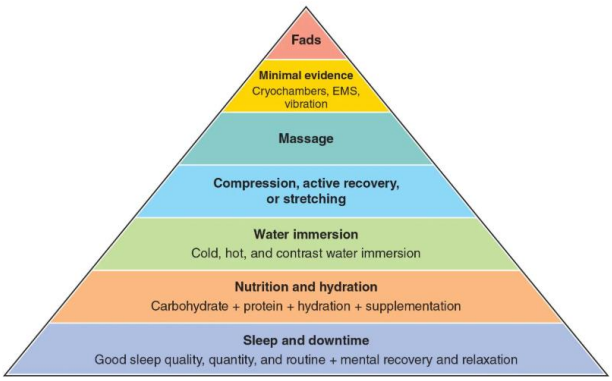

Image from NSCA's Essentials of Sports Science

First and foremost, sleep and rest are the most important components of recovery. Good sleep allows for recovery of muscle, hormonal regulation, and cognitive function. Weightlifters should be allowing 7–9 hours of sleep each night to achieve neuromuscular recovery while reducing the potential for injuries [27]. After sleep, nutrition and hydration are a large part of the equation. Adequate protein will allow for muscle recovery, carbohydrates will help with replenishing energy stores, and healthy fats can aid in hormonal balance. Hydration helps with strength, thermoregulation and also helps in tissue recovery [14].

The next tier of the recovery pyramid will include hypothermia based water immersion methods, cold-water immersion and contrast therapy. These may help to manage muscle soreness and inflammation. There are additional recovery modalities like compression garments, active recovery techniques, and stretching to support circulation, mobility, and relaxation of soft tissue.

On the next tier of the pyramid we have massage therapy although it is well supported as an effective modality to reduce muscle stiffness and fatigue [17], the last tier of the pyramid, are the less supported modalities such as some of the cryotherapy modalities and other emerging modalities that do not have as much scientific support [16]. While some athletes may find them beneficial, they should not replace foundational recovery strategies that are sleep, nutrition and hydration.

In order to properly manage recovery, monitoring training load is necessary. Training loads can be monitored through the use of monitoring tools such as session RPE and velocity-based training (VBT), which can help to identify fatigue levels and helps adjust the workload. Monitoring athletes' scores on biomarkers (e.g., HRV and cortisol levels) and incorporating deload periods can further enhance the management of recovery and provide further transparency on an athlete's state of recovery [25].

By prioritizing strategies according to the Recovery Pyramid, athletes can optimize performance while reducing the risk of overtraining.

3. 4 Effective Load Management

Load management is an important consideration in weightlifting to achieve desired performance outcomes while reducing the number and severity of injuries. By utilizing monitoring techniques like rate of perceived exertion (RPE), velocity, and heart-rate-variability (HRV) measures to assess load management, it becomes easier to objectively assess training load. RPE provides subjective

measurements of how hard an athlete perceives they are working while training, thus allowing an athlete to adjust their training intensity based on individual needs. Velocity during a lift indicates speed of movement and provides an instantaneous measure to assess speed-related intensity thus allowing the trainer/coach to control training intensity and volume. HRV can objectively and accurately measures an athlete's autonomic nervous system function and are associated with recovery and training readiness [25].

An effective load management systems needs to manage training intensity, volume and recovery. If a coach fails to monitor training intensity and volume, an athlete may overtrain or undertrain, subsequently losing the capacity for optimal adaptations and potentially increasing the outcomes related to overtraining. While in a competition period, it is essential to also modify training programs similar to how load management is modified to accommodate increased physical demands and recovery time. By modifying training variables (i.e., intensity and volume) during the competitive period, the athlete will subsequently be able to retain performance levels while avoiding situations that lead to overtraining [25].

Utilizing and implementing these monitoring approaches, and as well as modifying training programs accordingly, supports the load management in weightlifting which assists with athlete performance improvements and reduces injury risk.

3.5 Enhancing Psychological Resilience

Mental resilience is an essential aspect of being successful in weightlifting, as athletes are required to perform in high pressure situations. Mental training methods like visualization, meditation, and breathing have helped athletes focus, relieve anxiety, and improve motor control [8].

In order to address feelings of anxiety before competitions, S&C practitioners need to implement strategies like controlled breathing, self-talk, pre-performance routines that can improve weightlifting by allowing them to remain calm and carry out their lifts with confidence. Furthermore, training weightlifters in an environment that simulates competition environments has been shown to prepare athletes for the highly skilled, high-pressure contexts they would experience in competition.

Promoting a growth mindset helps weightlifters see challenges as opportunities for success, help the weightlifter to learn from failure, and stay motivated for a long time. Coaches must create a narrative that incorporates constructive feedback and recognizes improvement instead of expecting perfection. Lastly, it is crucial to promote athletes' self-efficacy and help them understand that resilience will require their dedication and patience.

4. Practical Recommendations for S&C and Sports Science Professionals

The application of individualized training programs for Olympic weightlifting involves a detailed approach in terms of strength assessments and exploring the athletes' ability to develop strengths and address weaknesses. Athletes will require tailored programs based on the assessment data available to correct weaknesses while optimizing strengths to ultimately improve performance. Utilizing a data-driven approach, strength and conditioning professionals can implement similar methods through standardized assessments to ensure reliable, comparable data across different environments, and the development of individualized programs [2].

A multi-disciplinary approach is critical when working with Olympic weightlifting in order to minimize injury, and enhance performance. Strength and conditioning professionals have an active role in working with physiotherapists, dieticians and psychologists, to enable athlete development. Physiotherapists will be the first to use assessments to explore restrictions to mobility with targeted interventions including joint mobilization, soft tissue treatment, stretching, or corrective movement. As exercise and particularly Olympic weightlifting demands substantial mobility, such as in the snatch

and clean & jerk, mobility in the ankles, hips and thoracic to ensure technique is sound and reduce the risk of injury is essential [9]. Our ability to combine injury prevention strategies alongside strength training including corrective exercises and movement screening, identifies potential injury risks, and minimizes injury in the long-term while improving potential for performance output. Integrating injury prevention strategies alongside strength training includes corrective exercises and movement screening can identify potential injury risks to reduce future injuries, while maximizing their potential for performance sustainably over time [15].

Nutritionists play an important role in balancing energy availability, recovery and muscle repair, making sure that weightlifters meet their macronutrients and micronutrients requirements. Protein is important for recovery and muscle hypertrophy, carbohydrates are important as they lead to glycogen reunion and training performance. Micronutrients such as calcium, vitamin D, and iron are necessary to support bone, neuromuscular function and oxygen transportation, especially in athletes who are engaged in high intensity exercise.

Sports psychologists help athletes focus, cope with stress, and stay motivated, which is critical in weightlifting as athletes perform under stress when they compete. Weightlifters can use a number of techniques to cope with stress like Visualization, Self-talk, and Mindfulness. These Training allow athletes to use positive emotions to absorb and cope with stress [8]. Athletes must also utilize strategies to manage pre-competition anxiety and improve motivational beliefs through a growth mindset that increases long-term psychological resilience in weightlifters to limit performance drops from fatigue.

Communication between coaches, athletes, and support personnel must be open in order to get the best out of training. Engaging with the athletes regularly through scheduled performance reviews, feedback sessions and individual goal meetings is expected to improve athlete accountability and belonging within a training group.

5. Conclusion

The evaluation of weightlifting's physiological and biomechanical requirements highlights the need for an appropriate training strategy to develop weightlifting performance with the aim to mitigate the risk of injury. Considering the weightlifter's reliance on producing explosive power, applying force rapidly and coordinating their neuromuscular system, the athlete's training should involve a mixture of strength, power, and mobility development to optimize performance. With the potential impact an average weightlifting training session has on a weightlifter's physiology, the use of recovery strategies should be a high priority to support adaptation and the sustainability of performance. Injury prevention strategies, such as working on technical development, mobility training, and using appropriate equipment to limit risk, will improve long term success. In doing so, strength and conditioning practitioners and sports science support staff may better support weightlifting performance through evidence-based training strategies, and in doing so support the longevity and safety of the athlete in the sport of weightlifting.

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