EFFECTS OF WEIGHTLIFTING ON THE NERVOUS SYSTEM

Weightlifting training can cause many physical adaptations. Body composition can change, muscles may increase in size and the lifter may become more flexible and mobile. However, some of the most significant developments to the physiology of a lifter occurs within the neuromuscular system. These neural changes are a big contributor to increased muscle force and power output. This power output is responsible for enabling the athlete to lift more weight in both the snatch and clean and jerk.

The fact that an athlete can get stronger and more powerful without changing physical size is particularly important in weightlifting as it is a weight-categorised sport. It is the nervous system that generates the signals to tell which muscles to activate and how much force to apply, so optimising neuromuscular function is often the priority of training.

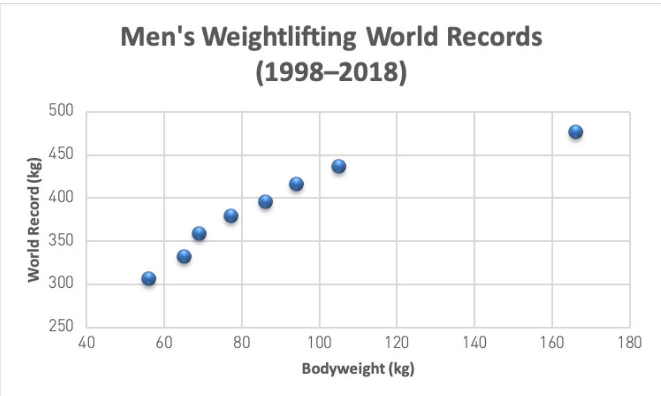
In this paper, we will introduce the anatomy of the nervous system, specific neural adaptations that occur when training in weightlifting, and how we train to optimise these adaptations. After reading this paper, you will have an increased understanding of the impact that weightlifting training has on the nervous system. You will better understand the role of the nervous system in its ability to help athletes lift more weight and how to program to optimise these adaptations.

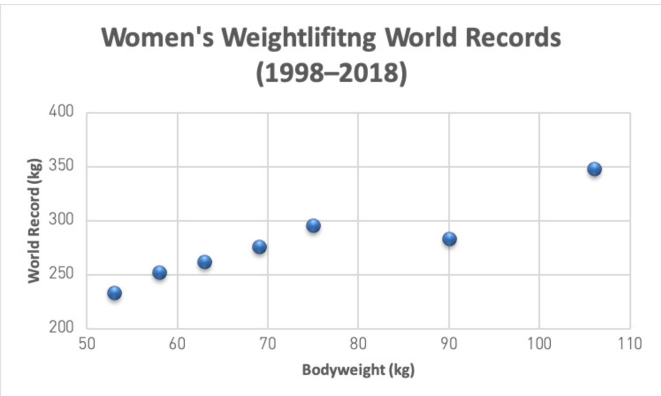
EFFECTS OF WEIGHTLIFTING ON THE NERVOUS SYSTEM

THE SCIENCE/BACKGROUND

A common misconception is that a bigger muscle is always a stronger muscle. It is true that the size of a muscle relates to how much force it can produce, but if neural adaptations have not been optimised, the potential to recruit the entire muscle may not be reached (Cormie et al., 2011). A simple way of highlighting this is the fact that smaller, lighter weightlifters are often stronger and more powerful than considerably bigger bodybuilders. It is not just about how big you are, it is about how well you can use what you have got!

It is, however, evident that when looking at loads lifted in elite weightlifting, muscle size is important and should not be discounted. As the weight categories increase (indicating potentially greater muscle mass) so do the records for total weight lifted across both lifts:





Note that the strangely low record for women at 90kg bodyweight is because this weight category was introduced very late in this era of world records. Despite this, the loads lifted by these elite athletes are not solely based on the amount of muscle they possess; neural factors have a lot to do with it too. A review by Enoka (1988) concluded that strength gains could be made without structural changes to the body, but not without neural changes. It also found that strength is not purely a property of muscle tissue but of the neuromuscular system also.

THE NERVOUS SYSTEM AND WEIGHTLIFTING

The nervous system provides a vital link in the chain between the athlete and the barbell during the technical movements of the snatch and clean and jerk. The brain acts as a computer, analysing all incoming information before selecting a response and instructing the limbs to take action. When we train weightlifting movements, it is possible to improve our internal computer's ability to process information, send out instructions and improve the output (the technique or force production capability). When starting in weightlifting, the movements can often feel quite robotic and unnatural but, after practice, the brain develops 'motor programs' to make the movement more autonomous. Through repetition and practice, an athlete's skill level improves, and these improvements in skill are often enough to lead to an increase in load lifted in the snatch and clean and jerk (Hodges and Williams, 2012).

"...strength gains could be made without structural changes to the body, but not without neural changes."

Weightlifting training emphasises the expression of muscular power and depends significantly on optimal neural recruitment for maximum performance. Neural adaptations are fundamental to optimising athletic performance, and an increased neural drive is critical to maximising the expression of strength and power (James et al., 2017). These changes occur throughout the nervous system – from the brain down to the individual muscle fibres.

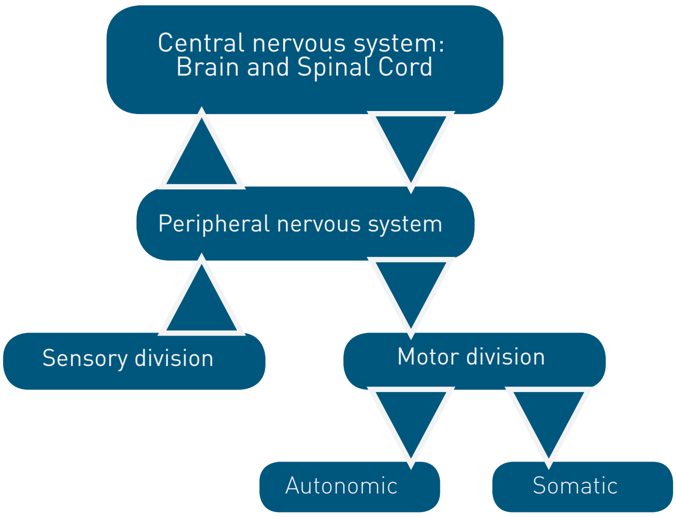
OVERVIEW OF THE NERVOUS SYSTEM

Before we look at the intricate details of the nervous system, we should first look at the bigger picture. The nervous system includes two main components:

- The central nervous system (CNS)
- The peripheral nervous system (PNS)

The CNS is the brain and the spinal cord while the PNS is made up of a further two parts: the sensory and motor divisions. The sensory division is responsible for telling the CNS about what is happening outside or inside the body (e.g. the sensation of pulling the bar from the floor). The motor division is responsible for sending information from the CNS to the various parts of the body in response to the signals that are coming in via the sensory division (e.g. how much force to apply to move the bar from the floor). The motor division is made up itself of two further parts: the somatic system that deals with voluntary movements and the autonomic system that operates mostly unconsciously.

Here is a schematic of how the nervous system is organised:



(Adapted from Wimore et al., 2008)

THE CENTRAL NERVOUS SYSTEM

The CNS is made up of the brain and spinal cord. The brain can be broken up into four major parts, the cerebrum, the diencephalon, the cerebellum and the brain stem.

Color Coding	Lobe of the Brain
	Frontal Lobe (Cerebrum)
	Parietal Lobe (Cerebrum)
	Occipital Lobe (Cerebrum)
	Temporal Lobe (Cerebrum)
	Diencephalon (behind Temporal Lobe)
	Cerebellum
	Below Cerebellum, Brain Stem

Each division has an important role to play. For example, within the cerebrum, the frontal lobe is responsible for motor control while the parietal lobe is responsible for general sensory input and its interpretation. The cerebellum is a crucial part of the brain for coordination of movement (Wilmore et al., 2008). These areas of the brain are themselves 'trained' when engaging in weightlifting.

The spinal cord is the lowest part of the brain stem. It is made up of nerve fibres that allow two-way communication of nerve impulses, the sensory fibres carrying signals into the brain and the motor fibres transmit impulses away from the brain to the muscles and body parts. A motor neuron is a unit of the nervous system which allows for electrical signals to travel between the CNS and the muscles. 'Motor unit' is the collective term for the motor neuron and all the muscle fibres that it innervates. It is this that allows communication between the CNS and the muscles via the neuromuscular junction (Cormie et al., 2011).

WHAT HAPPENS TO THE NERVOUS SYSTEM WHEN WE TRAIN WEIGHTLIFTING?

The snatch and the clean and jerk movements are complex movements that require interaction between the nervous system and the muscular system. Increased motor unit recruitment begins in the brain to support the need for an enhanced neuromuscular function above what the lifter is usually accustomed to. This occurs in the beginner athlete when learning the snatch or clean and jerk for the first time. It also happens when an advanced athlete intends to produce a maximal level of force to lift the bar with power, speed and precision.

When training, there is an increase in activity in the higher brain centres. The higher brain centre is responsible for the coordination and control of sporting movements, specifically the higher motor cortex, the basal ganglia and the cerebellum (Haff and Triplett, 2016).

- The primary motor cortex is located in the frontal lobe and is responsible for conscious motor control.
- The basal ganglia, in the cerebrum, is responsible for maintaining posture and helping to control muscle tonicity.
- The cerebellum is involved in fast, complex movements as well as balance. It assists in the coordination of movements.

These systems and their neural pathways are constantly refined as the athlete learns to improve the synchronisation of the muscles to produce the desired movements, then to produce them in a powerful and forceful manner. These motor programs are then stored in the athlete's internal computer for when they are next needed. This is why it is so important to practice performing the movements well, not just to go through the motions.

The neuromuscular system is one of the most responsive systems in the body, and many of the improvements a beginner makes are from learning how to more effectively coordinate movement and produce force. These improvements are often made in the greatest quantities in the initial stages of training which is why, when a beginner starts weightlifting, the load on the bar can often increase fairly quickly, and personal records can be achieved regularly (James et al., 2017).

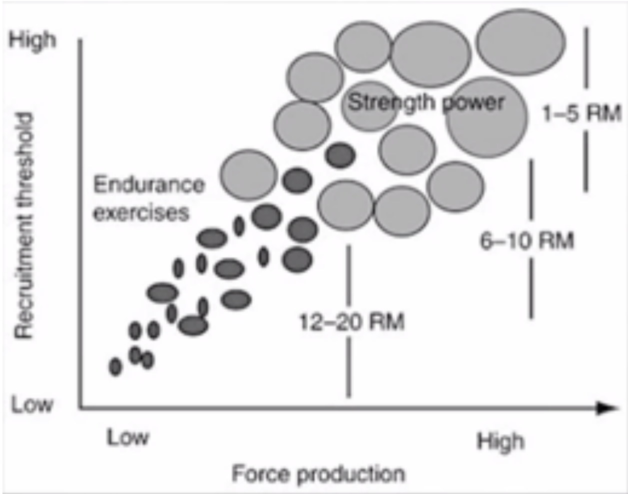
SPECIFIC ADAPTATIONS AND EFFECTS OF WEIGHTLIFTING ON THE NERVOUS SYSTEM

The following adaptations explain in part why, as an athlete trains, they are able to produce more force, often without significant changes to muscle mass.

RECRUITMENT OF MOTOR UNITS

Motor units are normally not all recruited at the same time. Instead, they are recruited as they are required. Lighter loads do not demand the same amount of muscular effort as heavier loads and so the number of motor units a lifter recruits to lift the bar is dependent on the load (relative to the athlete's strength).

This is described by ***Henneman's size principle:***



This shows that that lower threshold motor units are recruited at lower loads whilst higher threshold motor units are recruited at higher loads (or if lower loads are used to failure). With training, we can teach our neuromuscular system to recruit more of the higher threshold motor units in synchrony thus making muscular contractions more forceful (Schoenfeld et al., 2017).

"Lighter loads do not demand the same amount of muscular effort as heavier loads and so the number of motor units a lifter recruits to lift the bar is dependent on the load (relative to the athlete's strength)."

RATE CODING

This refers to the increase in the discharge of signals from motor units. If more signals are sent to the muscle more frequently, it will be able to produce more force. Due to the nature of weightlifting and the fast, powerful motions it involves, this type of training effectively increases the neuromuscular systems neural drive and ability to send signals to muscles to contract faster and more forcefully. Weightlifting improves the rate of force development via this mechanism (Schoenfeld et al., 2017).

AUTOGENIC INHIBITION AND CO-ACTIVATION OF ANTAGONIST PAIRS

These adaptations involve teaching the body to reduce the interference from the force limiting protective mechanisms within the body. For example, Golgi Tendon Organs control the muscles to stop them from exerting too much force and causing damage to themselves. Training in weightlifting can gradually reduce or counteract the inhibitory impulses that cause the Golgi Tendon Organs to 'put the brakes on' (Cormie et al., 2011). Another protective mechanism of the nervous system that can be overcome with training is the reduction in the coactivation of a muscle's antagonist.

In forceful movements, the antagonist muscle can contract to slow down joint velocity as a protective mechanism. For example, with knee extension, the quadriceps are the agonist muscle group and the hamstrings are the antagonists. To maximize force output capabilities of the quadriceps, coactivation of the hamstrings needs be minimized. Training antagonists (the hamstrings in this case) to make them stronger tells them they can 'apply the brakes' later or less. Both of these adaptations allow the athlete to access higher levels of force production (Latash, 2018).

HOW TO TRAIN TO PROMOTE NERVOUS SYSTEM ADAPTATIONS

Weightlifting training has a significant effect on the nervous system. With someone who is new to the movement, simply the learning the snatch and clean and jerk (even at lower relative loads) will have a significant impact on the nervous system. For the more advanced athlete, higher and more specific loads will be required to stimulate further adaptations to the nervous system.

In general, neural adaptations for power will be maximised when exercises are performed with a load that enables the most power to be produced. This will vary from movement to movement but for weightlifting, 70% or more of one rep maximum has been found to give peak power output. This will be done with a small number of repetitions per set in order to ensure that power output is high on all repetitions.

For strength adaptations, higher numbers of repetitions have been found to work well, perhaps because this leads to higher-threshold motor units being activated as lower-threshold ones fatigue.

"This is one reason why the snatch and clean and jerk are often used to improve performance for athletes who compete in other sports."

In order to enhance the benefits of training the nervous system, it is recommended to use the training parameters highlighted in this table:

Training Goal	Sets	Goal Repetitions	Load (%1RM)
Power (clean, power cleans, pulls)	2-6	1-2	30-95*
Strength (front squats, clean deadlifts, etc.)	3-5	equal to or < 6	equal to or > 85

Adapted from Haff and Triplett 2016

*dependent on exercise- e.g power clean peak power occurs at 70% 1RM (Comfort et al., 2011)

Training using the above guidelines can help improve an athlete's ability to produce power. Weightlifting performance is somewhat determined by an athlete's ability to produce high levels of force quickly. High peak power and rate of force development can be trained and improved through training in this manner. This is one reason why the snatch and clean and jerk are often used to improve performance for athletes who compete in other sports. As an example, mid-thigh power cleans have been reported to produce around 15,000 N·s-1 (Hori et al., 2005) Deadlifts and squats produce around 6400 N·s-1 (Swinton et al., 2011) and 5000 N·s-1 respectively.

When we train in this manner, it has a significant impact on the nervous system and provides the stimulus for the adaptations to the nervous system to occur (motor unit recruitment, rate coding and autogenic inhibition). These adaptations then enhance the athlete's ability to lift more load and produce more power.

SUMMARY

In this paper, we have looked at the impact that training using weightlifting movement has on the nervous system. You should now have an understanding of what the nervous system is and what adaptations occur when engaging in weightlifting. The nervous system is affected by both the beginner athlete learning the technique of the movements and the advanced lifter who is lifting higher loads. Programming recommendations have also been made in order to maximize neuromuscular adaptations through weightlifting.

REFERENCES

Comfort, P., Fletcher, C., & McMahon, J. J. (2012). Determination of Optimal Loading During the Power Clean, in Collegiate Athletes: Journal of Strength and Conditioning Research, 26(11), 2970–2974. https://doi.org/10.1519/JSC.0b013e318245bed4

Cormie, P., McGuigan, M. R., & Newton, R. U. (2011). Developing Maximal Neuromuscular Power: Part 1 – Biological Basis of Maximal Power Production. Sports Medicine, 41(1), 17–38. https://doi.org/10.2165/11537690-000000000-00000

Enoka, R. M. (1988). Muscle Strength and Its Development: New Perspectives. Sports Medicine, 6(3), 146–168. https://doi.org/10.2165/00007256-198806030-00003

Haff, G., Triplett, N. T., & National Strength & Conditioning Association (U.S.) (Eds.). (2016). Essentials of strength training and conditioning (Fourth edition). Champaign, IL: Human Kinetics.

Hodges, N. J., & Williams, A. M. (Eds.). (2012). Skill acquisition in sport: research, theory and practice. London ; New York: Routledge.

Hori, N., Newton, R. U., Nosaka, K., & Stone, M. H. (2005). Weightlifting Exercises Enhance Athletic Performance That Requires High-Load Speed Strength: Strength and Conditioning Journal, 27(4), 50–55. https://doi.org/10.1519/00126548-200508000-00008

James, L. P., Gregory Haff, G., Kelly, V. G., Connick, M. J., Hoffman, B. W., & Beckman, E. M. (2018). The impact of strength level on adaptations to combined weightlifting, plyometric, and ballistic training. Scandinavian Journal of Medicine & Science in Sports, 28(5), 1494–1505. https://doi.org/10.1111/sms.13045

Kawamori, N., S.J. Rossi, B.D. Justice, E.E. Haff, E.E. Pistilli, H.S. O'Bryant, M.H. Stone, and G.G. Haff (2006) . Peak force and rate of force development during isometric and dynamic mid-thigh clean pulls performed at various intensities. Strength Conditioning Research. 20(3):483–491.

Latash, M.L (2018) Muscle Coactivation; definitions, mechanisms and functions, Journal of Neurophysiology 120 88-104

Schoenfeld, B.J.,Grgic, J., Ogborn, D., Krieger, J.W (2017) Strength and Hypertrophy Adaptations Between Low vs High- Load Resistance training: a Systematice Review and Meta Analysis, Journal of Strength and Conditioning Research 31 (12) 3508–3523

Swinton, P.A, Stewart, A.D, Keogh, J.W.L, Agouris, I, and Lloyd, R. (2011) Kinematic and kinetic analysis of maximal velocity deadlifts performed with and without the inclusion of chain resistance. Journal of Strength Conditioning Research 25(11): 3163–3174

Wilmore,J., Costill, D.L., Kenney, W.L. (2008) Physiology of Sport and Exercise. Champaign IL : Human Kinetics.