Bolstering brawn with the brain

Nervous system and muscle adaptations cause strength gains during resistance training. Nervous system adaptations primarily cause the gains during the first few weeks, while muscle adaptations primarily cause gains over the longer term. There remains a gap in the research regarding the effect of chronic resistance training on the nervous system, however, due to challenges involved in collecting data over time. Dr Duane Button, Associate Dean at the School of Human Kinetics and Recreation at Memorial University, Canada, and Dr Gregory Pearcey, sensorimotor neuroscientist at Northwestern University, USA, along with Drs Kevin Power and Shahab Alizedah, review the available evidence and highlight the need to bridge this gap in the literature.

Recognising the challenges of collecting longitudinal data in this area, they nevertheless emphasise the importance of investigating nervous system adaptations that occur beyond the acute phase (a few weeks or months) of resistance training.

DEFINING ‘ACUTE’ AND ‘CHRONIC’

In their 2021 review, Button, Pearcey and their colleagues discuss the fact that there is no clear definition of the terms ‘acute’ and ‘chronic’ in relation to resistance training duration. To help ensure some degree of consistency when examining neural adaptations to longer-term resistance training, the researchers suggest that ‘chronic training’ can be defined as consistent training lasting longer than one year. However, they acknowledge that even their suggestion is arbitrary.

QUANTIFYING NEURAL ADAPTATIONS

The term ‘neural adaptation’ describes a gradual change over time in the responsiveness of the nervous system to a repeated stimulus – resistance training, for example, involves repeated exertion to lift a heavy object. Surface electromyography (EMG) is a method which has been used to measure neural adaptations. The non-invasive technique measures the electrical activity that occurs in muscles during contraction and can be used to provide an indication of the timing and intensity of muscle contraction.

Care must be taken when drawing inferences about neural adaptations using this technique. However, a well-controlled study by Balsawh and colleagues (2019), which compared agonist (contracting muscles) and antagonist (relaxing muscles) surface EMG, showed differences in strength between acutely and chronically trained cohorts, which was mostly attributed to differences in muscle size. They also showed that after accounting for fat between the muscle and sensors, which can affect the measures, the EMG of the contracting muscle was similar between the cohorts.

The study also revealed that antagonist muscle activity, which should be relaxed, had decreased significantly in the group that had trained for four years (ie, chronic training). This suggests that nervous-system control of the muscles needed to carry out the activity had become more efficient.

MUSCLE-NEURON CONTINUUM

Existing literature reveals a range of neural adaptations resulting from resistance training, from motor cortex to motoneuron. Button, Pearcey and their colleagues discuss the adaptations that occur between untrained and acute resistance training, and acute resistance training and chronic resistance training. They note that these adaptations take place alongside changes in maximum torque (the ability of the muscle to exert force on the bones, and therefore against objects we wish to move).

In acute training, the relative contribution of resistance training to strength gain is greater from the neurons than the muscle. The opposite is true in chronic training. However, the authors emphasise that it is a shift from primarily the neurons to primarily the muscles in chronic training, rather than acute training relying solely on the neurons and chronic training relying solely on the muscles. Importantly, they believe that the neurons contribute in part to strength increase resulting from chronic training, with the exact ratio being dependent on the specific details of the training plan.

CORTICOSPINAL PATHWAY

The corticospinal tract is an important pathway through which motor signals travel from the brain to the spinal cord in order to transmit voluntary motor commands. This activates the motoneurons within the spinal cord and, in turn, the skeletal muscle.

Therefore, researchers commonly examine the excitability of the corticospinal pathway to understand whether resistance training causes adaptations along this pathway. Techniques used include non-invasive magnetic stimulation such as transcranial magnetic stimulation and transmastoid electrical stimulation.

COMBINING TMS AND TMES

Researchers apply single pulse transcranial magnetic stimulation (TMS) to the motor cortex to activate motor regions of the brain, which travel down the corticospinal pathway to activate muscles of interest. Resulting motor-evoked potentials are then recorded via EMG from the muscle. Similarly, it is possible to measure spinal excitability via stimulation applied to the mastoid processes (at the back of the temporal bone of the skull) to produce cervicomediary motor-evoked potentials. Researchers now commonly use a combination of these techniques to measure alterations in supraspinal (above the spine) and spinal excitability.

EFFECT OF ACUTE RESISTANCE TRAINING

The body of literature is largely in agreement in relation to changes in corticospinal excitability showing that corticospinal (CS) neurons remain unchanged following acute resistance training. There is a range of possible explanations for any discrepancies in findings, including the training model applied, the specific activity, the stimulation model, whether the corticospinal excitability is recorded during muscle contraction or relaxation, the specific muscle under examination, and changes happening at other points along the corticospinal pathway.

EFFECT OF CHRONIC RESISTANCE TRAINING

The problem with collecting data for chronic resistance training lies in retaining study participants over a longer time and choosing appropriate methodologies. However, collecting longitudinal data would make it easier to determine whether, like acute resistance training, chronic resistance training results in continued adaptation of neural networks. Despite these limitations, using cross-sectional studies to compare chronically resistance-trained individuals with individuals who are not resistance trained can shed light on the effect of the training on neural plasticity.

WHAT OTHER PAPERS SAY

In earlier experiments, Button, Pearcey and their colleagues discuss the fact that there is no clear definition of the terms ‘acute’ and ‘chronic’ in relation to resistance training duration. To help ensure some degree of consistency when examining neural adaptations to longer-term resistance training, the researchers suggest that ‘chronic training’ can be defined as consistent training lasting longer than one year. However, they acknowledge that even their suggestion is arbitrary.
Collecting longitudinal data would make it easier to determine whether chronic resistance training results in continued adaptation of neural networks.

There is a pressing need for longitudinal studies into the effects of resistance training programmes on the nervous system.

REAL WORLD VS LAB
Button, Pearcey and their colleagues highlight the fact that resistance training during lab experiments is rarely the same as training in the real world. Furthermore, there is variation in what is deemed an ‘effective resistance-training programme’ because training programmes are highly individualised, which means they are created differently for each individual.

Effective resistance training involves progressively overloading the muscles, using a varied yet specific training programmes. Even with best endeavours, these variables are difficult to track in relation to how much exercise an individual has undertaken and how much each variable contributes to neural adaptations.

Non-neural aspects of resistance training are also critical. Through training, the nervous system learns, adapting to new conditions, but before this can occur, the muscles must be capable of producing the forces required. The research of Button, Pearcey and colleagues highlights the fact that resistance training is a complex process involving both neural and non-neural factors.

References

Personal Response
To bridge the gap between lab findings and the real world, what are the key methodological considerations for future studies focusing on the effects of chronic resistance training on the nervous system?

For human neurophysiology, many research techniques exist to give us a window into how the nervous system may adapt during chronic resistance training. The key for future studies will be collecting longitudinal data on how the central nervous system adapts and changes with chronic resistance training with specific attention to various training programmes. These training programmes should include strategies for specifically increasing muscular strength (ie, power lifting) and muscular power (ie, Olympic weightlifting) as they are unique in how the nervous system recruits the muscles(s) required to produce the given force, speed of movement, and subsequent movement patterns.