CONCURRENT ACTIVATION POTENTIATION – INCONSEQUENTIAL EVENT OR VIABLE ERGOGENIC STRATEGY

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When exerting maximal or near maximal muscular effort, such as when performing heavy resistance exercise, it is somewhat common for people to clench their jaw and create tension in the face and neck (7). Why does this happen? What is the reason for this activation of musculature that is not directly involved in the performance activity? Is it possible that it is a common occurrence in these activities because it serves to improve performance in some way?

Potentiation is the effect of augmenting or improving of something synergistically (4). In the context of exercise science, potentiation is usually described in terms of time course of action. One such case is post-activation potentiation, where the performance of one activity leads to a potentiation effect on the performance of a subsequent activity. An example of this would be complex training, where a heavy resistance exercise, such as squats, is performed prior to performing an explosive exercise with similar movement characteristics, such as vertical jumps (14).

Another instance of potentiation is concurrent activation potentiation (CAP), where one activity potentiates another activity performed simultaneously. An example of CAP in the literature is maximally clenching the jaw during vertical jump performance to enhance aspects of jump performance (8). This article aims to discuss CAP and the proposed mechanisms underlying it, summarize the available research examining the phenomenon, and provide strategies for its implementation.

DEFINING CAP

The term "CAP" first appeared in the strength and conditioning literature in 2006 (7). It is the increase in performance via simultaneous activation of muscles primarily involved and not involved in an activity. This synchronized activation of muscles not involved in the activity of interest is termed "remote voluntary contraction" (RVC) (5). Jaw clenching while resistance training is one example of an RVC (8). Other proposed RVCs include jaw opening, hand gripping, and the Valsalva maneuver.

UNDERLYING MECHANISMS

Several physiological mechanisms may contribute, at least in part, to the ergogenic outcome of CAP. Proposed contributing factors include increased alpha motor neuron activity, changes in gamma loop and muscle spindle stimulation, motor cortical overflow, and inhibition of presynaptic inhibition (7). A discussion of each possible contributing factor is outside the scope of this article. A detailed review of all proposed mechanisms is available (7). The two most probable physiological explanations for CAP are motor cortical overflow in the brain and inhibition of presynaptic inhibition (7).

The adult brain contains approximately 80 billion neurons, and each neuron can have hundreds to thousands of synapses with other neurons. The motor cortex, an area of the frontal lobe just anterior to the brain's central sulcus, is responsible for the control of voluntary movement. The motor cortex contains functional subdivisions for control of different body segments and areas (6). These subdivisions are overlapping and interconnected (6). This interconnectivity of motor areas and from one cortical hemisphere to the other means that when one area of the motor cortex is active, this activity overflows into other areas creating a functional synergy (7). In other words, when the area of the motor cortex that controls jaw musculature is firing, this activity can prime or enhance activation of other motor cortical areas, such as those that control the arms and legs, when both areas are activated simultaneously (7).

Presynaptic inhibition is a mechanism to modulate muscle force production by suppressing the release of neurotransmitters from the axon terminals of alpha motor neurons, preventing or weakening the propagation of neurotransmitters across the synaptic cleft to the target cells (17). This is accomplished through an inhibitory signal from an inhibitory neuron that synapses with an axon collateral just prior to the axon terminal (17). Changes to this modulatory mechanism, deemed inhibition of presynaptic inhibition, would allow the release of neurotransmitters by the previously inhibited axon terminal, resulting in a response of the target muscle fiber and augmented muscular performance (7).

FIGURE 1. DECEMBER 2018 COVER OF THE *STRENGTH AND CONDITIONING JOURNAL* DEPICTING AN OLYMPIC WEIGHTLIFTER MAXIMALLY OPENING THE JAW

Although the above mechanisms are the most likely physiological reasons behind CAP, the underlying processes leading to this ergogenic phenomenon are not fully understood. It is likely that CAP is the result of a combination of factors including motor overflow as well as inhibition of presynaptic inhibition. There is evidence for both in the literature (1,11,12). Regardless of the physiological reasons for the occurrence, incorporating RVCs into

TABLE 1. RESEARCH DEMONSTRATING THE POSITIVE EFFECTS OF CAP

STUDY	SUBJECTS	PERFORMANCE ACTIVITY	RVCS	IMPROVED VARIABLES
Allen et al. (1)	36 recreationally trained males	Countermovement vertical jump	Jaw clenching	Muscle activation of quadriceps, hamstring, and gastrocnemius
Allen et al. (2)	12 male and 12 female participants of mixed training backgrounds	Countermovement vertical jump and bilateral grip strength assessment	Jaw opening	Jump height and grip strength performance in males
Allen et al. (3)	36 recreationally trained males	Isometric mid-thigh clean pull	Jaw clenching	Peak force and rate of force development
Ebben et al. (8)	14 Division II male and female track and field athletes	Countermovement vertical jump	Jaw clenching	Rate of force development and time to peak force
Ebben et al. (9)	13 resistance trained males	Barbell back squat and jump squat exercises	Jaw clenching, hand gripping, Valsalva maneuver	Peak force and rate of force development during both activities; jump height during jump squat
Ebben et al. (10)	12 resistance trained males	Isometric knee extension	Jaw clenching, hand gripping, Valsalva maneuver	Average and peak knee extension torque
Ebben et al. (11)	11 male and 12 female resistance trained participants	Isokinetic knee extension and flexion	Jaw clenching, hand gripping, Valsalva maneuver	Prime mover muscle activation
Garceau et al. (12)	13 male and 15 female participants of mixed athletic backgrounds	Isometric knee extension	Jaw clenching, hand gripping, Valsalva maneuver	Peak torque and rate of torque development in males
Issurin and Verbitsky (15)	8 elite and sub-elite male swimmers	Swimming race start	Jaw clenching and abdominal muscle contractions	Race start reaction and time to 15 meter mark

sport and resistance training activities may improve muscular performance and enhance the resistance training stimulus for adaptation.

EVIDENCE OF CAP

There is considerable evidence for the ergogenic effects of CAP. Anecdotally, there is indication of the CAP phenomenon, particularly as the result of jaw clenching. Roman soldiers were said to place leather straps between their teeth to improve battle prowess, Native American women would bite on sticks during childbirth to ease delivery, and Civil War soldiers were given bullets to bite during battlefield surgery to assist with pain management (19). More recently, many Olympic weightlifting athletes, when beginning the first pull of a clean or snatch exercise, maximally open their jaw as seen in Figure 1.

Research investigating CAP has revealed largely positive results during a variety of activities. These studies have examined several RVC strategies ranging from jaw clenching alone to a combination of RVCs performed simultaneously. Table 1 summarizes the results of these studies.

Not all research analyzing CAP has demonstrated an ergogenic advantage (16,18). The inconsistency in the outcomes of research examining CAP can be explained by differences in research methodology. For example, Mullane et al. saw a 9.9% improvement in RFD during countermovement jump performance when jaw and fist clenching were utilized, but those results did not reach statistical significance (16). These researchers chose to implement the RVC three seconds prior to initiating the jump, which is different from other studies where the RVC was introduced simultaneously with the activity of interest. The authors cited this discrepancy as the major limitation in their study, and ultimately argued for the benefits of CAP on an individual basis (16).

The investigation by Ringhof and colleagues is another example of methodological discrepancy (18). These researchers sought to elucidate the effects of jaw clenching on golf swing performance. Results indicated no change in golf stroke distance or accuracy, however, the jaw clenching RVC was submaximal. CAP is directly related to the quantity and quality (i.e., strength) of RVC (12). A submaximal RVC would lead to suboptimal CAP, if at all. RVCs were performed maximally in the investigations revealing positive performance outcomes.

Collectively, this research provides several key points to remember regarding RVCs and CAP. First, the amount of potentiation achieved as a result of RVC is directly related to the quantity of remote muscle activation (12). Therefore, the second point is that if a single RVC is utilized, it should be performed maximally. Clenching the jaw maximally is the most common example of this practice, and has been demonstrated sufficient to produce CAP (1,3,7,9). The third point is that incorporating multiple RVCs has the potential to elicit greater CAP than isolated RVC due to greater quantity of remote muscle activation. Lastly, the timing of RVC is critically important (13), and should be initiated simultaneously or immediately prior to the onset of the activity to be potentiated. This is due to the short duration of the potentiation effect. If the RVC is introduced too soon or too late, CAP will not be achieved or optimized.

STRATEGIES FOR IMPLEMENTATION

With the above points in mind, a coach or athlete wanting to take advantage of CAP to improve performance should adhere to the following recommendations. First, the primary activity should be of maximal or near maximal effort such as jumping or heavy resistance training. As CAP purportedly improves muscular force production characteristics, it can also be beneficial during submaximal resistance exercise if the lift is executed at a high velocity. Therefore, if the resistance exercise is submaximal in nature, it should be executed with maximal movement intent (i.e., fast concentric velocity). Additionally, RVC implementation should also be maximal. For example, if jaw clenching is employed, it should be as forceful of a clench as the athlete can facilitate while executing the primary activity. With this in mind, athletes may wish to employ a mouth guard to facilitate the clench and provide protection, particularly if they have sensitive teeth.

Second, the RVC activity must be appropriately timed to ensure a potentiation effect. The initiation of RVC should occur simultaneously with or immediately prior to the primary activity. Research indicates that the potentiation effect achieved lasts approximately 500 – 1000 ms (0.5 – 1.0 s) (13). If the RVC is initiated too soon, even if executed maximally, the potentiation effects will have diminished prior to the onset of the primary activity. Conversely, if started too late, the athlete will not receive the benefits of potentiation.

Third, many activities are total body in nature and require contribution of many muscle groups for execution. In cases such as these where only a single RVC can be applied, maximally activating the jaw musculature via clenching or opening is the most effective RVC performed in isolation. Other RVCs, such as fist clenching, have not been as effective at generating CAP as jaw clenching or opening when performed as a single RVC (5).

Lastly, since CAP magnitude is dependent upon the quantity of RVC musculature activated, aggregate RVC should be implemented if possible. In addition to maximal jaw musculature activation, fist clenching and the Valsalva maneuver have been demonstrated to be as effective as aggregate RVCs (9,10,11,12). One example of this would be clenching the teeth, squeezing the barbell, and performing the Valsalva maneuver during execution of a barbell back squat repetition.

ADDITIONAL CONSIDERATIONS

As previously stated, jaw clenching is common during physical exertion. However, utilizing other RVCs may prove to be a novel task for many athletes, at least at first. Significant practice implementing RVCs during the performance of resistance training exercise or sporting activities may be required. This learning should occur at resistances and intensities that are well within the athletes' capabilities before RVCs are incorporated during maximal or near maximal effort activities.

It should be noted that considerable variability in individual response to RVC has been reported, meaning that some people may respond well to CAP strategies while others receive lesser benefit or are negatively affected (16). Therefore, coaches and athletes should assess performance with and without RVCs in sport and training activities to determine individual efficacy. Common assessments used in CAP research include countermovement vertical jumps and isometric strength assessments (1,2,3,8,12). Additionally, athletes with sensitive teeth or for whom jaw clenching may cause pain, a mouth guard may be used to safely facilitate clenching or alternate RVC strategies may be implemented.

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