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Supplements That Affect Cortisol Concentrations during High Intensity Exercise

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Abstract:

The body is exposed to excessive stress during high intensity exercise. There has been much research conducted about the effectiveness of certain supplements in limiting stress due to exercise. Cortisol is a permissive hormone that is secreted in response to stress, so cortisol concentrations can be used as a method of evaluating stress. This paper summarizes research conducted on various supplements and their effect on reducing stress during high intensity exercise. Focus is on cortisol concentrations in participants before and after completion of exercise when given various supplements. The most common supplements were determined to be amino acids, electrolytes, antioxidants, and carbohydrates. All supplements were shown to attenuate cortisol concentrations through various processes and under certain situations. Amino acids supplements prevent muscle from being catabolized during exercise, thus promoting muscle growth and decreasing cortisol concentration. Electrolyte supplements replace minerals and charges lost in sweat, reducing stress on the body during exercise. Antioxidants limit oxidative stress due to free radicals. Carbohydrates can repress immune response during exercise and decrease cortisol concentration if given in large enough dosages.

Introduction:

Cortisol is a permissive hormone and is essential for normal cell function. However, having excessive concentrations of cortisol can be very detrimental (Vidal et al. 2018). It is secreted from the adrenal gland in response to stress. Stress is stimulated by a variety of events, including exercise, fear, and anxiety. Since cortisol is a glucocorticoid, it is mostly catabolic which means that it breaks down tissues (Goodman, 2009). Excessive cortisol can be very detrimental to muscles because it causes protein degradation (Black 2000). However, cortisol also increases lipolysis and decreases sensitivity to insulin. Both of these processes occur during exercise. While cortisol is important to help the body react to stressful situations; however excessive cortisol can be dangerous because it can inhibit the ability of the animal to function properly and it can cause injury (Kreitschmann-Andermahr et al., 2015).

Mechanism of Action:

Goodman (2009) described that during a stressful event, the hypothalamus is stimulated and secretes corticotropin-releasing hormone (CRH). Receptors in the anterior pituitary gland receive the CRH signal which causes a conformational change of the G protein-coupled receptor. Through protein kinase activity, adrenocorticotropic hormone (ACTH) is secreted. Once stimulated, ACTH regulates the concentration of cortisol in the body by binding to the adrenal gland on the melanocortin 2 receptor and stimulating the secretion of cortisol (Sanders 2018).

Changes in Cortisol Concentration:

Fryer et al. (2006) measured cortisol concentrations secreted during high intensity exercise. They had subjects run on a treadmill to the point of exhaustion and measured the cortisol concentrations as they recovered. The venous cortisol concentrations before the test were 100.76 ng/mL and increased to 106.49 ng/mL after testing. The concentrations continued to increase until 15 minutes after the test when they peaked at 192 ng/mL. The measured increase in cortisol concentrations demonstrates that high intensity exercise is stressful.

Diet also impacts cortisol concentrations. Jankord et al. (2008) measured the concentrations of ACTH and cortisol in pigs that were given high fat diets and underwent exercise. Pigs were split into four groups: normal diet and no exercise, normal diet high exercise, high fat diet no exercise, and high fat diet exercise. The ACTH concentration of all animals fed the normal diet was around 175 pg/mL, regardless of the amount of exercise. However, the concentration of ACTH in the high fat diet pigs was close to 270 pg/mL when they were exercising and was around 100 pg/mL when they were not. Having high fat diets will decrease ACTH stress response in pigs, whereas having a high fat diet with exercise training will increase the response. Exercise in the high fat diet pigs was more strenuous due to the increased size of the animals. Diet has a direct impact on the ability to perform exercise and can influence the secretion of cortisol during exercise.

Supplements that Impact Cortisol Secretion

There are several supplements that can be utilized to improve exercise efficiency by decreasing cortisol concentrations. Since exercise stimulates stress, adding supplements can help reduce the stress in humans for more productive exercise.

Amino Acids

Luigi et al. (1999) studied the impact of amino acids on the response of the anterior pituitary gland to an exercise stimulus. During exercise, amino acids are utilized for energy and synthesizing proteins (Biolo et al., 1995). Luigi et al. (1999) supplemented two groups of men with either a solution of L-arginine hydrochloride, L-ornithine hydrochloride, and L-Branched

Chain Amino Acids (BCAA) or a placebo solution. The solution was created to measure the effect supplementing amino acids that are lost during exercise has on an individual that is working out. Each group completed a pituitary-stimulation test after the administration of the supplement; one week later, they consumed the other supplement and were subjected to the same pituitary stimulation. The participants had ACTH concentrations of 300 pmol/L/h before the stimulation. After the test, the supplemented group had ACTH concentrations of 600 pmol/L/h, which was greater than the placebo group, which had no change in concentrations. The cortisol concentrations from blood plasma, which were measured with a radioimmunoassay kit, before the test were close to $1.5x10^7$ pmol/L/h in the supplemented group, which was less than the concentration of around $2x10^7$ pmol/L/h in the placebo group. After the stimulation test, the concentration of cortisol was around $2x10^7$ pmol/L/h in the supplemented group and $2.5x10^7$ pmol/L/h in the placebo group (Luigi et al. 1999). The supplemented groups had greater percentage increases in cortisol concentrations. However, they had less concentration overall than the placebo group. Furthermore, there were reduced concentrations of ACTH in the placebo group following the stimulation test. These data indicate that amino acid supplements can help reduce cortisol concentrations in individuals, which will reduce the stress response and increase exercise capacity (Luigi et al., 1999).

Kraemer et al. (2009) tested the efficacy of Muscle Armor, an amino acid formula from Abbott Laboratories in Abbott Park, IL, at muscle repair during a three-month long resistance training program. Each day, participants received either a supplement of Muscle Armor, which contains calcium [beta]-hydroxy-[beta]-methylbutyrate, arginine, glutamine, taurine, and dextrose or a placebo supplement. Subjects completed resistance training, strength training, and power training. Initial body mass was close to 77 kilograms in all participants. After the 12-week training session, body mass increased to 80 kg in the control group and 85 kg in the supplemented group. Meanwhile, total fat percent was close to 25% at the beginning of training and decreased to 23% in the control group and 19% in the supplemented group. Cortisol concentrations did not differ between the two groups throughout the training period. However, resting cortisol concentration before the start of exercise did decrease in the supplemented group from 350 nmol/L to 250 nmol/L. The decrease in pre-training exercise concentrations could be caused by increased amino acid concentrations decreasing the need for cortisol, because catabolizing proteins for gluconeogenesis precursors is not required to the same extent.

Kramer et al. (2009) hypothesized that the decrease in observed cortisol concentrations is caused by increased amino acid concentrations in the blood. The body will use amino acids from proteins found in muscle as a source of energy; therefore, having extra amino acids in the system will reduce the need for muscle degradation and will improve exercise efficiency (Emery, 2005). Amino acids reduce the necessity of cortisol to catabolize muscle by providing an alternate energy source for the body.

Nelson et al. (2013) studies the effects of whey protein and leucine on muscle development when ingested after intense cycling. Researchers chose to supplement leucine because it had been demonstrated to regulate environmental stimuli in cells. During the experiment, the exercise metabolic rate, maximum oxygen uptake, and peak power were compared among twelve male cyclists. Participants were given a strict diet and exercise schedule for 6 days, the only difference being that one group received supplements of a leucine mixture while the other received a placebo fat control after exercise. Blood neutrophil concentration increases from $3x10^9$ cells/L to $7x10^9$ cells/L on day 1, which decreased to an average of $5x10^9$cells/L on days 2 through 6, there was no change between the supplemented and placebo group. Blood lymphocyte concentration was also not affected by supplementation; both groups maintained concentration of around 1.8 $x10^9$ cells/L. On day six, lymphocyte concentrations changed from 1.4 x 10^9 cells/L to 2.4 $x10^9$ cells/L in both groups. Cortisol concentrations were similar between the two groups on most days. The first day, the concentration was 269 nmol/L for the control group and 291 nmol/L for the supplemented group before exercise and 160 nmol/L after exercise. On day four, concentrations were 541 nmol/L and 519 nmol/L for the control and supplemented group respectively pre-exercise and 611 nmol/L and 576 nmol/L post-exercise. Day 6 concentrations were 336 nmol/L and 266 nmol/L pre-exercise and 612 nmol/L and 586 nmol/L post-exercise. The supplement decreased cortisol concentrations over time, indicating that amino acids that are consumed can make high intensity exercise less stressful over time, improving the ability of a person who is exercising to complete difficult tasks. It would have been interesting to compare the performance results of those who were taking the supplement with the control to view if supplementation actually affected performance.

Amino acids have been demonstrated to decrease cortisol concentrations in people that are training. This is due to the fact that the body can use the supplemental amino acids as a source of energy so muscle degradation is avoided, making exercise more effective.

Electrolyte Supplements

During high intensity exercise, many electrolytes are lost through sweat, which leads to fatigue (Lindinger, 2013). Without proper ion balance, it is more difficult for the body to maintain homeostasis. Magnesium has been demonstrated to inhibit cortisol secretion, which is hypothesized to be caused by negative regulatory actions (Murck, 2002). Magnesium supplements would be beneficial to athletes because cortisol can inhibit the ability of athletes to perform by causing stress. Supplements that inhibit cortisol reduce the symptoms that come with stress, which allows subjects to perform better. Dmitrašinovic´ et al. (2016) investigated the impact that magnesium ion supplements in rugby players. The authors hypothesized that the magnesium helped reduce the anxiety players felt before the game because it inhibited the secretion of cortisol. The supplemented players had decreased in cortisol concentrations after day 1 and on game day. The basal serum cortisol concentration was 490 nmol/L, whereas the first day after supplementation, the concentration was 350 nmol/L in the supplemented group and around 500 nmol/L in the placebo group. The data indicate that magnesium ion supplements can inhibit cortisol secretion. Magnesium ion supplements prevent the disbalance that occurs when magnesium ions are lost in sweat, therefore recovery time after exercise is reduced (Dmitrašinovic´, 2016). Additionally, the researchers noted that magnesium has properties that limit stress. People who experience magnesium deficiency experience anxiety and lose regulatory control of the hypophyseal adrenal axis (Murck, 2002). Having extra magnesium prevents athletes from being stressed during a game to the point of losing the ability to properly focus. Magnesium supplements could improve the efficiency of exercise, and do not have many negative consequences if taken in proper doses.

Mor et al. (2018) studied the effects of a carbohydrate-electrolyte supplement on the ability of athletes to regain energy after high intensity training. Sixteen fit male participants were divided into two groups; one received carbohydrate-electrolyte supplement that consisted of starch, sodium, and potassium, and the other received water placebo. Average age in both groups was 20 years old, maximum oxygen volume was 56 in the supplemented group and 53 in the placebo group. Participants completed a 20 m shuttle run test and then received supplementation. The study was only single blind, so while participants did not know what supplement they received, researchers did, which could cause bias in interpreting the results. Basal, post exercise, and 2 hours post supplement glucose concentrations in the supplemented and placebo group were 80 mg/dL, 114 mg/dL, 70 mg/dL and 82 mg/dL, 112 mg/dL, and 79 mg/dL respectively. Both groups had increased glucose concentrations immediately after exercise and decreased concentrations 2 hours after supplementation, but there was no difference between the two groups. Insulin concentrations were 12 mg/dL, 22 mg/dL, and 45 mg/dL in the supplemented group and 15 mg/dL, 16 mg/dL and 10 mg/dL in the placebo group. Insulin concentrations were greater in the supplemented group two hours post supplementation than basal concentrations and were greater than the placebo. Increase in insulin is likely due to the carbohydrates in the supplement rather than the electrolytes because the carbohydrates promote insulin secretion in the tissues. Cortisol concentrations in both groups were 17 µg/dL initially, 20 µg/dL in the supplemented group and 15 µg/dL in placebo group post exercise, and 10 µg/dL in both groups post supplementation. There was no difference between the two groups in cortisol concentration, but there was a decrease in both groups post supplementation compared with the basal and post exercise concentrations. These data are understandable because after 2 hours the body has had time to recover from exercise and no longer needs cortisol secretion. Carbohydrate-electrolyte supplementation in this study did not affect cortisol concentrations, perhaps due to the fact that after 2 hours, the effects of the supplementation had already worn off. Additionally, the type of exercise performed may have been more endurance-based than intensity-based. There was no indication how the athletes that were supplemented performed compared with those who did not receive supplementation; however, due to increased insulin concentration in the supplemented group, the supplemented athletes likely were able to recover more quickly than those that were not supplemented. Quicker recovery is expected due to the anabolic properties of insulin and previous research that has demonstrated that insulin can stimulate amino acid transport (Bonadonna et al. 1993).

Additional research on other electrolyte supplements supports the findings from Dmitrašinovic´ et al. (2016). Tinsley et al. (2017) gave supplements containing caffeine, green tea extract, I-carnitine, and evodiamine to a group of men. One-half of the participants were given a supplemental pill and the other one-half were given placebo pills. The participants had to complete 6 weeks of high intensity resistance training which included weight-lifting and abdominal exercises. Cortisol concentrations in the supplemented group pre-exercise were 19.7 mcg/dL whereas the placebo concentrations were 16.2 mcg/dL. The cortisol concentration after exercise was 16.7 mcg/dL and the placebo cortisol concentration was 18.6 mcg/dL, which were greater than the starting concentrations. Additionally, the musculature of legs increased in the supplemented group. The cortisol concentrations were less in the supplemented group than the baseline values before exercise started, indicating less stress during the workout.

Electrolyte supplements can improve exercise efficiency by reducing cortisol concentrations in high intensity exercise. Electrolytes are able to replace ions lost due to sweat during exercise and can help reduce stress on the body during a workout; however, their efficacy depends on the electrolyte supplements that are taken and the type of exercise that is performed.

Antioxidants

Accattato et al. (2017) focused on the inflammatory and antioxidant response to exercise in humans. The results measured the effects that exercise-induced stress on the inflammatory response in men. During high intensity exercise, reactive oxygen species (ROS) are synthesized due to the increased contraction rate of the muscles. A compound in the body that has lost an electron, is considered an ROS. These compounds are very reactive towards other sources of electrons (Gliemann et al. 2014). Mitochondria in the muscle utilize a great amount of oxygen, but during exercise, energy is obtained from non-oxidative sources (Gliemann et al. 2014). Mitochondria can form ROS which are very toxic to the muscles (Gliemann et al. 2014). Superoxide dismutase is secreted to react with these species to synthesize hydrogen peroxide which will donate an electron to the ROS and limit the toxicity. Glutathione reductase is also secreted to neutralize hydrogen peroxide and limit its toxicity. During high intensity exercise, superoxide dismutase concentrations are greater indicating that more oxidative sources of energy are being utilized (Gliemann et al. 2014). Nosaka and Clarkson (1996) researched the impact of exercise after subjects performed elbow-flexing exercises. The researchers requested that 14 students complete a set of arm-curl exercises. Participants pushed their arm as hard as they could against a machine to reach their personal limit. The muscle damage and inflammatory responses were recorded. After performing the high intensity resistance training, the students reported that their arms were sore from day 1 through day 3. The data indicated that exercise causes increased inflammation and swelling of muscles. High intensity exercise has been shown to increase inflammation and damage to muscles which is stressful to the tissue.

Levers et al. (2016) studied the impact of antioxidants on reducing the impact of ROS in muscles. They used powdered tart cherry skin as a supplement for endurance-trained athletes because vitamin E is a good source of antioxidants and cherries are a well-known source of vitamin E (Bell et al. 2014). The athletes took either tart cherry supplement made of 480 mg of CherryPURE freeze dried cherry powder from ShorelineFruit in Transverse City, MI, containing 991 mg of phenolic compounds and 66mg anthocyanins, or a placebo of rice flour, for ten days before running a half-marathon. The supplemented group finished the race in 103 minutes whereas the placebo group finished in 118 minutes. The supplemented group had a cortisol concentration 2 μg/dL greater than the starting concentration whereas the placebo group had an increase of 10 μg/dL 1 hour after completing the race. The supplement decreased cortisol concentrations in athletes. Antioxidant supplements are beneficial because they react with the ROS to prevent damage to the muscle, which reduces exercise-induced stress and improves efficiency (Gliemann et al. 2014; Levers et al., 2016).

Other researchers have also studied the effects of antioxidants on individuals that are exercising. Aijratul et al. (2016) investigated the impact of morinda leaf supplements on mice and their ability to swim. Morinda leaf is known to be an antioxidant and has been used by Polynesians as a medical remedy (Thaman., 1990). Aijratul et al. (2016) gave groups of mice either 200 mg of morinda leaf/ kg body weight (BW) or 400 mg/kg in addition to an unsupplemented control group. Initially, all mice could only swim for 400 seconds. Week 1 of treatment, the control mice could swim for 400 seconds, the group supplemented with 200mg/kg body weight swam for 1,700 seconds, and the group supplemented with 400 mg/kg swam for 1,500 seconds. By the fourth week, the group with 200mg/kg swam for 3,500 seconds, the group with 400 mg/kg swam for 2,700 seconds, and the control group swam for 1,500 seconds. The mice that received antioxidants outperformed those with no supplementation after the first week of supplementation. After several weeks of treatment, the mice receiving supplementation more than doubled the amount of time spent swimming by the control. However, the over-supplemented group did not perform as well as the group eating less. The data indicate that while antioxidant supplements can be beneficial, having too much will be less effective. The plant may have had other effects besides being an antioxidant that negatively impacted the condition of the mouse. After 4 weeks of testing, cortisol concentrations in the mice were measured. The cortisol concentration of the control mice without exercise was 0.4 ng/ml, the concentration for the control mice after swimming to exhaustion was 3.6 ng/ml, the concentration for mice with 200mg/kg after exercising was 2.3 ng/ml and the concentration for the 400 mg/kg after exercising was 0.3 ng/ml. Reduced concentrations of cortisol demonstrate the ability of antioxidants to reduce stress during exercise. However, it also demonstrates the importance of using supplements in moderation. The mice that ate a significant amount of the plant performed worse than the mice that had a smaller amount. The cortisol concentrations in the mice with less supplementation were greater than the mice with more supplementation despite the fact that they performed better during the tests. The athletic ability of the recipient of the supplement may also impact its influence.

Schroder et al. (2009) studied the effects of alpha-tocopherol acetate, ascorbic acid, and beta-carotene on male professional basketball players. The players were divided into two groups, one of which took the supplement four times a day for the entire season and the other took a placebo pill. The group that received the supplement had cortisol concentrations of 9.81 µg/dL whereas the control group had 8.28 µg/dl. Unlike the other supplements, this supplement stimulated cortisol secretion before exercise. However, after training, cortisol concentrations in both groups were close to 14.5 µg/dl. Other antioxidant supplements that were given to basketball players inhibited the cortisol secretion before the game compared with the control group. There was a decrease in the measure of lactate dehydrogenase in the supplemented group, thus indicating that there was less muscle damage in the supplemented group. However, there was no change in cortisol concentrations between the two groups. The participants of this study were trained basketball players, so it is possible that there was no difference between the two groups because neither group experienced an extremely stressful situation. Furthermore, there may have been something else in the other two supplements that was not present in the vitamins from this study.

Prasertsri et al. (2019) studied the effects of cashew apple juice in trained and untrained men after completing high intensity exercise. Cashew apple juice is believed to balance reactive oxygen species and antioxidant concentration, so it was used as an antioxidant supplement in the study (Kaewbutra et al. 2016). Ten moderately trained and ten untrained men were assigned to a cashew apple juice supplemented group that consumed 3.5 mL/kg body weight every day for 4 weeks, or a placebo group. Subjects completed high intensity cycling for 20 minutes every day for 4 weeks. There was less malondialdehyde (MDA) in the supplemented group than the placebo group before and after exercise in the trained and untrained group. A product of oxidation is MDA, so less MDA means that less oxidation has occurred, indicating antioxidant properties. Concentration of MDA in placebo and supplemented untrained subjects was 8 µmol/mL and 6 µmol/mL respectively before exercise and 12 µmol/mL and 7 µmol/mL after exercise. Meanwhile in trained subjects pre exercise MDA concentrations were 7 µmol/mL and 5 µmol/mL and post exercise concentrations were 9µmol/mL and 7 µmol/mL. Cortisol concentrations in untrained subjects before exercise were 20 µg/dL in the placebo and 15 µg/dL in the supplemental group. After exercise concentrations were 23 µg/dL in the placebo and 17 µg/dL in the supplemented group. The trained subjects all had pre-exercise concentrations of 18 µg/dL and post-exercise concentrations of 20 µg/dL. Untrained subjects had reduced cortisol concentration post-exercise than the placebo group. Cashew apple juice had antioxidant properties in both trained and untrained people pre and post exercise. However, it only decreased cortisol concentrations in untrained men after exercise. Antioxidants do help in decreasing stress during high intensity exercise but only in individuals who are untrained, there is no effect in those that are trained.

Antioxidants are beneficial because they donate an electron to the ROS, thus reducing the chance of injury in muscles (Gliemann et al., 2014). The muscle can produce more ATP, and thus more energy. Without the oxidative stress that Gliemann et al. (2014) describe, it is much easier for individuals to perform exercise. Thus, antioxidants help improve the efficiency of exercise by decreasing the stress and cortisol concentrations (Schroder et al., 2009, Aijratul et al., 2016, and Levers, 2016).

Carbohydrate Supplements:

Wakshlag et al. (2004) measured blood glucose and cortisol concentrations in sled-racing huskies before and after a 3-day race. Dogs ran 30 miles for 3 days and blood samples were collected at the start of the race, immediately following the race and 24 hours after the end of the race. Two teams of dogs were used to collect data. Team A had initial cortisol concentrations of 2.4 µg/dL, 6.4 µg/dL immediately after the race and 2.1 µg/dL 1 day following the race. Team B had initial concentrations of 1.4 µg/dL, 8.7 µg/dL following the race and 1.9 µg/dL 24 hours later. The glucose concentrations before, after and 24 hours after in Team A and B were 100.9 µg/dL and 101.2 µg/d, 66.2 µg/dL and 60.8 µg/d, and 94.9 µg/dL and 104.2 µg/dL respectively. Both cortisol and glucose concentrations changed during the race but returned to starting values within 24 hours. The decreased glucose concentrations demonstrate that glycogen is used as an energy source during sprint-racing therefore carbohydrate supplementation following high intensity exercise may be necessary. Replenishing glycogen stores will reduce stress and decrease cortisol concentrations thus carbohydrate supplements are useful in improving high-intensity exercise.

Ihalainen et al. (2014) studied the effects of carbohydrates on leukocyte and cortisol concentrations in high intensity long distance running. Researchers hypothesized that carbohydrate supplementation would decrease cortisol concentrations and reduce immune stress that runners usually experience. Fourteen subjects were chosen to participate in the study, but only seven were able to complete it. Subjects were assigned to either a light sport drink with 1.5% carbohydrate, a regular sport drink with 7% carbohydrate or placebo with flavored water. Subjects ran for 20 km and were given their drink at 1 km intervals. No change in performance between participants was recorded, all participants took around 99 minutes to complete the test. Leukocyte counts were $6x10^9$ cells in all groups before exercise started, $13x10^9$ cells in the placebo and light sport drink after exercise and $11x10^9$ cells in the normal sport drink group. The normal sports drink group had decreased white blood cell counts than the placebo group, indicating there was less of an immune response with the supplementation than with the placebo. Cortisol concentrations pre exercise were 600 nmol/L in all groups, 900 nmol/L post exercise in the placebo and light sport drink groups, and 800 nmol/L post exercise in the normal sport drink group. While cortisol concentration increased in the placebo and light supplement group, it did not change in the normal supplemented group. The data indicate that normal sport drinks have enough carbohydrates to effectively suppress the immune system response and decrease cortisol concentrations thus limiting exercise-induced stress; however light sport drinks are not effective. Carbohydrate supplementation can be beneficial in reducing stress but only if there are enough carbohydrates to actually make a difference, a slight increase will not be enough to reduce stress.

Smith et al. (2018) compared carbohydrate and branched chain amino acid supplements in upper body resistance exercise. Researchers hypothesized that carbohydrate supplementation would improve performance because the body would use supplements rather than glycogen stores in muscles. They also included BCAA supplements to test if the combination of carbohydrates and BCAA would be the most favorable environment for muscles to repair. During the study, 13 healthy males trained in resistance exercise performed various exercises at the laboratory seven times. Preliminary tests determined their baseline blood data, then beginning with the second set of exercises, they were given repetition exercises that they completed to their maximum ability. Participants received a supplement beverage of carbohydrates, BCAA, a mixture of both, or a placebo for the last four sessions and blood samples were analyzed immediately and 60 minutes post-exercise. Beverages were given immediately before and following exercise. Glucose, cortisol, and insulin concentrations in blood were measured. Insulin and glucose concentrations before exercise, immediately after exercise, and 60 minutes post-exercise were measured whereas cortisol concentrations were measured immediately after and 60 minutes post-exercise. Cortisol concentrations for the placebo, BCAA, carbohydrate, and combination supplements immediately after exercise were 220 ng/mL, 220 ng/mL, 200 ng/mL, and 180 ng/mL respectively. Sixty minutes after exercise, cortisol concentrations for the same supplements were 180 ng/mL, 160 ng/mL, 140 ng/mL and 140 ng/mL, respectively. Cortisol concentrations decreased in all groups 60 minutes post-exercise and the mixture of carbohydrate and BCAAs had less cortisol both times than amino acid supplementation. Glucose concentration for all participants was 80 mg/dL as a baseline. Immediately after exercise, glucose concentrations for carbohydrate only, BCAAs, placebo, and combination were 110 mg/dL, 100 mg/dL, 100 mg/dL, and 95 mg/dL respectively. Sixty minutes after exercise, concentrations for the same order of supplements were 65 mg/dL, 70 mg/dL, 65mg/dL, and 60 mg/dL. Glucose concentrations did not change with different supplements but they did increase to more than baseline concentration immediately after exercise and declined to below baseline 60 minutes after exercise. Insulin concentrations were 3 mU/L at baseline. Immediately after exercise, the carbohydrate supplemented group had insulin concentration of 5 mU/L whereas the others all had a concentration of 4 mU/L. Sixty minutes post-exercise, insulin concentrations for both the carbohydrate and mixed group was 6 mU/L while BCAA was 4 mU/L and placebo was 3 mU/L. Unsurprisingly, after supplementation there was greater concentration of insulin in the carbohydrate group. However it is interesting that the mixed group did not increase above the rest until 60 minutes after exercise. There was no change in performance between the placebo and BCAA supplemented group. The carbohydrate supplemented group was able to perform 63 bent-over rows and the mixed supplement group performed 67 compared with the ability of the placebo group to do 57. The placebo, carbohydrate, and BCAA groups all were able to do 38 inclined presses, while the mixed supplemented group was able to do 41. The placebo group was able to perform 54 close-grip rows while the carbohydrate group could perform 62 and the mixed group could do 70. Having the mixed supplement allowed athletes to perform better than placebo for all exercises except for bench press, everyone completed 49 repetitions, while the carbohydrate supplement allowed them to perform better in bent-over row and close-grip row. Carbohydrate supplementation, especially when mixed with BCAA, decreased blood cortisol concentration compared with just BCAA concentration and improved exercise capacity. Insulin concentrations were greater in the individuals supplemented with carbohydrates, even 60 minutes after exercising, which may help them build their muscles faster. Future studies could demonstrate the long term effects of these supplements.

Sousa et al. (2007) studied the effects carbohydrate supplementation had on endurance runners after completion of high-intensity intermittent exercise. During the study, 15 trained endurance runners performed preliminary testing to determine their normal velocity and maximum oxygen intake. The athletes 12 series of 800 m runs with a 90 second break between the series. Subjects were given either a supplement of carbohydrates or a placebo after every other series (given after the 2nd, 4th, 6th, 8th, and 10th series) . Supplements were 2 mL per kg of body weight of a 7% carbohydrate solution. After training, athletes reported the amount of physical exercise they felt they exerted. Plasma glucose, free fatty acids, plasma insulin, and plasma cortisol concentrations were measured. There was no change in duration of the exercise, heart rate, and perceived exertion. Blood glucose increased in the control group by 126%, from 80 mg/dL to 150 mg/dL and the supplemented group by 93% from 80 mg/dL to 120 mg/dL, which was not a significant difference from the placebo group. Blood lactate concentration was the same between most groups for the majority of time, starting at 2 mmol/L, then increasing to 10 mmol/L after 6 series. Immediately after the twelfth series, blood lactate was greater in the carbohydrate supplemented group, at 12 mmol/L than the placebo, at 8 mmol/L. An hour postexercise, both groups were back down to the same concentration of 3 mmol/L. Free fatty acid concentrations in the plasma remained at .15mmol/L in both groups until 60-180 minutes post exercise where the placebo group increased to 0.4 to 0.6 mmol/L while the carbohydrate supplemented group remained at 0.1 mmol/L. Plasma cortisol for both groups started as 10 μg/dL then increased to 20 μg/dL during exercise and decreasing to 10 μg/dL 120 minutes after exercise.

Results contradicted those of Smith et al (2018), which reported a change in cortisol concentrations between placebo and supplemented groups after exercise. Difference may be caused by the supplement that was used. In this study, athletes were given a 7% carbohydrate solution-- made of 61% maltodextrin, 24% glucose, and 15% glucose at a dosage of 4 mL supplement/kg body weight. Smith et al. (2018) gave the participants a 5% carbohydrate solution, made in a 2:1 glucose/fructose ratio, but delivered a total amount of 708 mL in six doses of 118 mL each. The specific carbohydrate that is used will likely determine how effective a supplement is at limiting cortisol and improving exercise capacity.

Figure 1: Summary of Supplements and their effect on cortisol concentrations

Amino Acid	Able to decrease cortisol concentration by providing extra amino acids the body can use for energy to avoid muscles from being catabolized.
Electrolyte	Depending on the specific electrolyte that is used, can help decrease cortisol concentration by replacing other electrolytes lost to sweat.
Antioxidant	By inhibiting free radicals from interacting with muscles, prevent oxidative stress thereby reducing cortisol concentrations and improving efficiency and recovery from exercise.
Carbohydrate	Can be very effective in suppressing immune response and limiting stress if there is enough supplementation. If not enough carbohydrates are used, there will be no results in minimizing effectiveness.

Conclusion:

High intensity exercise can be very stressful for an individual (Fryer et al., 2006). There are many supplements available that can help increase exercise efficiency by inhibiting cortisol and reducing stress. Amino acid, electrolyte, antioxidant, and carbohydrate supplements all improve exercise capacity within subjects and decrease cortisol concentrations. People who are looking to improve their sport performance or increase their training capabilities can change their diet to be more successful. Amino acid supplements can be taken to increase protein density in muscles (Biolo et al., 1995). People who are interested in increasing their muscle size can find amino acid supplements which will allow them to more efficiently build their strength. Additionally, people who become fatigued easily due to sweat can increase electrolyte supplements to replace the ions that are lost (Lindinger et al., 2013). Antioxidants can also help people improve their aerobic capacity by limiting ROS in the body. However, having excess supplementation can be detrimental, because it can decrease the efficiency of exercise (Aijratul et al., 2016). Cortisol is a permissive hormone so it cannot be completely eliminated from the body, however adding supplements before exercising can help reduce cortisol concentrations and improve efficiency.

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