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Can pyruvate and dihydroxyacetone (DHAP) improve athletic performance?

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Introduction

The desire for nutritional supplements that increase aerobic and anaerobic exercise performance is clear. Athletes, striving to improve performance, are constantly looking for substances that will give them the competitive edge. Pyruvate is the latest fad supplement targeting athletic and sedentary populations (1). Multilevel marketing distributors, health food stores, and body building magazines claim pyruvate improves exercise endurance capacity, augments weight (37% compared to dieting alone) and fat loss (48% compared to dieting alone), decreases appetite, increases metabolism, serves as an antioxidant, and lowers plasma lipids thereby reducing the amount of fat gained after dieting stops (1,2). The potential benefits for athletes are clear.

Pyruvate (pyruvic acid) is a three-carbon ketoacid produced in the final stages of glycolysis (3). Pyruvate can be reduced to lactate by lactate dehydrogenase in the cytosol or it can be converted to acetyl CoA by the pyruvate dehydrogenase complex in the mitochondria, depending upon metabolic conditions (4). In the early 1980s, research showed that pyruvate could prevent fatty buildup in rat livers from chronic alcohol use (5-7). Probably in response to these studies, Ronald Stanko, a researcher at the University of Pittsburgh, began to investigate whether pyruvate might also work as a weight-loss product. Currently, Stanko is responsible for a majority of the research studies on pyruvate and currently holds the US patent on "Pyruvate +" a form of pyruvate sold through Med Pro Industries. Most studies on pyruvate have in reality tested a combination of pyruvate and dihydroxyacetone (combination termed DHAP), another three-carbon metabolite formed during glycolysis. Over the counter pyruvate formulations usually contain dihydroxyacetone as well, but rarely mention it on labels (2).

Effect of DHAP on Athletic Endurance

Popular marketers claim pyruvate can enhance endurance performance by prolonging time to exhaustion (1). Dietary carbohydrate supplementation increases muscle glycogen concentration and improves exercise endurance capacity in humans (8-10). Because carbohydrate depletion is often associated with fatigue during prolonged exercise, the addition of pyruvate and dihydroxyacetone (DHAP) to the normal daily diet of humans may have ergogenic application (11). Three studies to date have demonstrated such a correlation, although two of the studies employed only a small number of untrained male athletes while the third study used rats as a model (11-13).

Stanko et al. (11) compared the effects of dietary supplementation of DHAP on endurance capacity and metabolic responses during arm exercise using 10 untrained male athletes. Subjects performed arm ergometer exercise to exhaustion (exercising at 60% VO2 peak) after consumption of standard diets for 7 days (55% carbohydrate, 15% protein, 30% fat) containing either 100 g of Polycose (placebo) or 75 g of dihydroxyacetone and 25 g of sodium pyruvate substituted for a portion of carbohydrate. Consumption of DHAP as portion of a regular diet for 1 week increased arm exercise endurance capacity by 20%. Stanko et al. (11) concludes that dietary consumption of DHAP over a 7-day period increased glucose availability to muscle, prolonging submaximal arm endurance exercise.

Using similar parameters (exercising at 70% VO2 peak), Stanko et al. (12) found similar results when comparing the effects of dietary supplementation of DHAP on endurance capacity and metabolic responses during leg exercise using 8 untrained male athletes. Subjects exhibited a 20% increase in endurance capacity as compared to the placebo group. Because Stanko et al. observed enhanced glucose muscle extraction in the treatment group, he hypothesized DHAP may not increase the rate of glucose oxidation during exercise but may instead prolong its oxidation, thereby improving endurance time (12).

Borborygmus (rumbling in the bowels due to gas build-up), flatus (gas in the intestinal tract), and diarrhea occurred in most subjects who consumed the treatment diet and one subject developed dizziness (11,12). It is also important to realize that the dosage of DHAP (75 g dihydroxyacetone and 25 g pyruvate) in these studies is many times greater than commercial pyruvate preparations, which may contain between 500 mg to 1 g of pyruvate (25 times less than the experimental dose). Currently there are no studies that demonstrate the efficacy of pyruvate in such small doses (1). Additionally, Stanko et al. used a small sample size, tested only two types of endurance exercises, and did not test well-trained athletes (which would increase the statistical power of the trial) (13).

Finally, in rats Ivy has shown that supplementation of pyruvate and dihydroxyacetone (by infusion) during prolonged treadmill exercise increases run time to exhaustion by approximately 67% and when provided as an oral supplement over several days, enhances aerobic endurance capacity. Although the mechanism of action is unclear, Ivy suggests an increased reliance on blood glucose may spare muscle glycogen, thereby enhancing endurance capacity (14). Of course this data cannot be extrapolated to human athletes but does support the findings of Stanko et al. (11,12) and warrants further study with human subjects, different types of endurance, strength and power exercises, and well-trained athletes.

Effect of DHAP on Weight and Fat Loss

The maintenance of low weight and low percent body fat is important for many athletes. Such conditions may bestow a competitive advantage, may be important for appearance, or may defined by weight limits set by the sport (e.g. wrestling) (15). Depending on the sport, excessive body fat can impair performance by hindering range of motion or by compromising an athlete's strength-to-mass ratio (16). Because in some sports this ratio is so important, loss of body fat with concomitant increases in muscle mass is very desirable.

Rat and swine studies (14,17-21) demonstrate that partial substitutes of hexoses with DHAP attenuate weight and fat gain without losing lean body mass. Increases in resting energy expenditure are postulated to account for these changes (17). Stanko et al. also noted depressed lipid synthesis within adipose tissue and reduced plasma insulin levels, suggesting that inhibition of gain in weight with DHAP added to the diet is the result of an increased loss of calories as heat at the expense of storage as lipid (19).

Three studies have been conducted on humans, using morbidly obese women as subjects (22-24). In one study (22), 30 grams of pyruvate was added to a 1000 calorie/day liquid diet for 21 days for fourteen patients. Patients in the pyruvate group increased weight loss by 37% and fat loss by 48% (22), although actual differences were small (a difference of 1.6 kg body weight and 1.3 kg more fat) (1,2). In another study (23), 16 grams of pyruvate and 12 grams of dihydroxyacetone were added to a 500 calorie/day diet for 21 days for thirteen patients. Patients in the DHAP group increased weight loss by 16% and fat loss by 23%, and again actual differences were small (a difference of 0.8 kg body weight and 0.9 kg more fat) (1,2). In the last study of 17 obese women, the effects of DHAP on weight maintenance were evaluated (24). Again, subjects gained significantly less body weight and fat when fed 20% of energy from DHAP (15 g pyruvate and 75 g dihydroxyacetone), and again changes were small 1.8 kg (36%) less weight and 1 kg (55%) less fat than the placebo group (1).

Of course, the above results cannot be extrapolated to the greater population without making a number of assumptions. Since investigations have only included morbidly obese women, it is quite possible that significant differences in weight and fat would not be observed among athletes, who already have a relatively low proportion of body fat compared to lean muscle mass. Additionally, athletes are not confined to bed (as the above subjects were) and regularly participate in physical activity. Again, the doses employed in these studies are much greater than those in commercial preparations and because bioelectrical impedance (BIA) has an error margin of at least 2-4%, it may not have been sensitive enough to detect the small changes in body composition observed (1).

DHAP as an Antioxidant

Tissue culture and isolated postischemic heart model studies (25,26) illustrate less free-radical production after perfusion with pyruvate, although no published studies have examined the effect of oral pyruvate supplementation on anti-oxidant activity. Because animal immune responses and catecholamines provide additional sources of free radicals not found in vitro, one must be careful in using this data to make conclusions about the antioxidant effects of pyruvate in vivo.

Conclusion

Almost all promotional material for commercial pyruvate supplements states that its efficacy is supported by "clinical research" (1). Although some clinical research has investigated the effects of pyruvate and dihydroxyacetone on fat metabolism, aerobic endurance, and weight loss, these studies have been conducted on a very small and skewed proportion of the population (obese women and untrained young males). More importantly, because the doses of pyruvate and dihydroxyacetone administered in the clinical trials is more than 25 times the dose taken over the counter, there is no way to assess the effects DHAP will have in smaller doses, unless it is assessed directly.

Additionally, no testing to date has verified the ingredients in the over the counter supplements, because the FDA does not regulate the supplements. For this reason, little is known about any impurities that may cause series side effects if administered in large doses. Finally, pyruvate is not stable as a compound and may degrade over time.

Until extensive experimentation has been conducted on male and female athletes in various modes of strength and endurance exercises it is impossible to draw conclusions about the possible beneficial effects of pyruvate and dihydroxyacetone on athletic performance. Although experimental results do look promising, it is important to realize that controlled laboratory conditions are very different from real world application.

To make conclusions about DHAP supplementation with regard to athletic importance, several double-blind peer-reviewed clinical trials must be conducted on male and female athletes in a wide range of endurance and strength exercises, using doses of the supplement that will be used in real world application. Only after these studies have been conducted and the results verified and replicated will it be possible to accept the claims made by multilevel marketing distributors, health food stores, and body building magazines.

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