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Milk: a smart recovery choice for athletes

Abstract

Milk is a complete beverage that provides many nutrients and minerals. It represents a good source of carbohydrates, proteins, and electrolytes; all critical nutrients to facilitate recovery from sports activities. Recently, there has been an increasing amount of research conducted on the benefits of milk as a sports beverage, especially following both strength and endurance sports. This research suggests that milk is an effective recovery beverage after exercise that results in favourable short-term changes in protein metabolism with possible long-term benefits. Milk consumption acutely increases muscle protein synthesis, leading to an improved net muscle protein balance. Milk intake following resistance training (12 weeks minimum) can lead to greater increases in muscle size and lean mass in both young men and women. Research on milk intake after endurance exercise is limited, but suggests milk as an effective post-exercise beverage for endurance activities in regards to carbohydrate and fluid recovery. Milk intake after exercise also attenuates muscle damage.

Milk represents a more nutrient dense beverage choice for strength and endurance athletes, compared to more traditional sports drinks. Low-fat milk is a safe and effective post exercise beverage for most individuals, except for those who are lactose intolerant. Understanding the physiological mechanisms by which milk exerts its favourable effects is an exciting area for future investigation.

Background

Proper nutrition is critical for optimizing sport and exercise performance, and for optimizing adaptations to sports training. There are long held nutritional beliefs in regards to trying to optimize the effects of training that even date back to the ancient Greeks. They believed that a very high intake of meat was essential for athletes, and as such the diets of Greek athletes contained excessive amounts of meat. These ideas still persist today, as many strength athletes and body builders believe they need to consume protein supplements and amino acid drinks. Intake of such dietary supplements can result in protein intakes that are more than double the recommended levels. One can hardly blame the athletes as they are bombarded with marketing for various supplements, many of which are very high in protein. However, when you look to the scientific research done in this area, it clearly demonstrates that excessive intake of protein and amino acids aren't necessary to achieve large gains in muscle mass with training. The research does show that the timing of nutritional intake after exercise is very important in optimizing adaptations as well as enhancing rates of recovery from both resistance and endurance exercise. Finally, the composition of post-exercise nutritional intake has also been shown to be important in optimizing recovery from endurance exercise and adaptations/recovery from resistance exercise.

Dairy products, especially low-fat milk, represent very good source of proteins, lipids, amino acids, vitamins and minerals. The overall health benefits of milk intake have been well documented and extensively reviewed elsewhere [1]. The nutritional characteristics of low-fat milk make it potentially a very good sport recovery beverage (Table 1). Firstly, low-fat milk contains carbohydrates (lactose) (~5%) in amounts similar to commercially available sports drinks (glucose, maltodextrin, fructose). Low-fat milk is also a good source of high quality protein. More specifically, milk contains casein and whey proteins in a ratio of 3:1 which provides for slower digestion and absorption of these proteins resulting in more sustained increases in blood amino acid concentrations after digestion [2]. Furthermore, whey protein contains a large proportion of branched chain amino acids which are important in muscle protein synthesis and metabolism. Lastly, milk contains naturally high concentrations of electrolytes, which are lost through sweating during exercise. The concentrations of the electrolytes (sodium and potassium) in milk are that what is found in more traditional sports drinks (Table 1). Electrolytes are an essential component in any fluid recovery beverage.

Based on these characteristics of milk and recent sport nutrition research, there has been growing interest and acceptance of low-fat milk as a post-exercise beverage for resistance and endurance sports, and training.

Milk and Resistance Exercise and Training

Resistance sports and resistance training/exercise are characterized by repeated sets of high intensity contractions of different muscle groups that leads to well defined adaptations in worked muscles [3]. The most consistent adaptations are skeletal muscle hypertrophy (increase in muscle size), and increased strength. For increases in muscle hypertrophy to occur there must be a chronic increase in muscle protein net balance. Muscle protein net balance represents the difference between muscle protein synthesis and muscle protein breakdown. For an increase in net balance to occur, there must be either; an increase in protein synthesis or a decrease in muscle protein breakdown, or alternatively a simultaneous increase in synthesis and decrease in breakdown. There has been a large amount of research in to the various factors that influence net muscle protein balance in response to resistance training.

Resistance exercise alone has been shown to increase protein synthesis and protein breakdown, but the increases in synthesis are greater than the increases in breakdown [4]. Interestingly, the results from Phillips et al. showed that the net balance was still negative, and this was attributed to the participants being in a fasted state [4]. Therefore, these observations also emphasise the importance of supplying nutrition following this form of exercise to positively influence protein metabolism.

There have been several research studies that have investigated the provision of macronutrients soon after resistance exercise in an attempt to optimize the protein metabolic response. The various studies have looked at the intake of amino acids [5], protein [6], carbohydrates [7] [8-9], or mixed macronutrient compounds [9-11] following resistance exercise. This work has demonstrated that the protein metabolic response following resistance exercise can be influenced through the dietary intake of the macronutrient constituents of low-fat milk; protein and carbohydrates. More recent research studies have directly investigated the impact of low-fat milk consumption on the acute protein metabolic response following resistance exercise.

One recent study looked at the influence of consuming various milk beverages on the protein metabolic response following a single session of resistance exercise [12]. They compared non-fat milk (237 g), whole milk (237 g) and an amount of non-fat milk with the same amount of energy (kJ) as the whole milk (393 g) following a bout of leg resistance exercise.

They measured amino acid net balance across the exercise leg for 5 hours following the exercise. All of the different milk beverages increased the net balance of the measured amino acids. This study did not determine what contributed to the change in net balance (change in synthesis, change in breakdown, or both), however, the evidence did show that protein metabolism was improved with milk after resistance exercise.

Other research has shown that consumption of fat-free milk increases protein net balance through an increased rate of muscle protein synthesis after resistance exercise [13]. The increase in protein net balance and muscle protein synthesis was greatest after consuming 500 mL of fat-free milk as compared to a soy-protein beverage that contained the same amount of energy and protein as the milk (745 Kj, 18.2 g protein, 1.5 g fat, and 23 g carbohydrate). The authors suggested that this might have been due to the differences in digestion of the soy based drink as compared to the milk. The soy based beverage was digested and absorbed much more rapidly leading to a large spike in the blood concentrations of amino acids possibly shuttling them to plasma protein and urea synthesis [2], whereas with the fat-free milk the elevation in blood amino acids was more sustained, providing a more prolonged delivery of amino acids to the worked muscles for protein synthesis.

Collectively, based on current scientific research it well established that milk beverages, when consumed soon after resistance exercise, can lead to enhanced improvements in protein metabolism. Such acute improvements in protein net balance and synthesis could possibly lead to more enhanced or more rapid chronic adaptations that occur with resistance training if repeated after every training session. A number of research studies have investigated the long term influence of milk consumption after resistance training.

The first study to investigate resistance training and milk consumption over a more prolonged period compared the effects of 3 days per week (for 10 weeks) of resistance training with intake of either low-fat chocolate milk (5 kcal/kg body weight) (composition described in table 1) or a commercially available carbohydrate and electrolyte beverage (5 kcal/kg body weight) immediately after each training session [14].

The post-exercise beverages contained the same amount of energy, but varied in macronutrient composition. They observed improvements in strength and body composition, however all of the changes where similar for the two groups. However, the milk group gained 1.6 ± 0.4 kg of lean tissue, while the carbohydrate electrolyte beverage group only gained 0.8 ± 0.5 kg of lean tissue. These findings were not statistically different; nonetheless, this was the first study to look at the long term interaction of milk consumption and resistance training.

More recently, consumption of three different post-exercise beverages during an extended period of intense resistance training was investigated in male novice weightlifters [15]. The three different beverages were; 1) fat-free milk (500 mL), 2) a soy beverage (500 mL) that contained the same amount of energy and protein, and had the same ratio of carbohydrate and protein as the fat-free milk, and 3) a control beverage (500 mL) that had the same amount of energy as the other beverages but only contained carbohydrates [15]. Once assigned to one of the groups, the participants trained 5 days per week for 12 weeks and consumed the appropriate beverages immediately and one hour after each training session. The group that consumed the fat-free milk had the greatest increases in muscle hypertrophy [15]. The group that consumed the milk also gained the most lean body mass and lost the most fat mass over the duration of the study [15]. The authors suggested that the greater increases in muscle fiber hypertrophy and lean mass might have been due to the previously observed acute influences of milk consumption on protein metabolism [13]. The greater decline in fat mass observed with the milk group was suggested to be related to the greater calcium intake associated with the milk consumption [15], as there is evidence that suggests dairy products can influence fat cell metabolism in a manner that attenuates lipid accretion [16]. This very well controlled study clearly showed multiple benefits to using fat-free milk as a post-resistance exercise beverage in young males.

The same research group recently repeated the study, except this time using young university aged female participants [17]. As with the males, a larger increase in lean mass and a greater decline in fat mass was observed with milk intake after each training session [17]. They also observed greater increases in strength within the milk group. They concluded that milk was an effective drink to support favourable body composition changes in young women with resistance training [17].

Another study investigated the influence of the combined effect of resistance training (3 days/week for 18 months) and the intake of 400 ml/day of reduced-fat (1%) ultrahigh temperature (UHT) milk in middle aged and older men [18]. They did not observe any benefits to combining the milk intake with training as compared to training or milk intake alone. This is in contrast to the previously discussed training studies [15, 17], but there were a number of notable differences between these various studies. Firstly, the studies investigated very different populations (young, university aged vs. middle aged and older). However, there is growing evidence that despite the age of an individual resistance training can lead to beneficial adaptations in skeletal muscle [19]. Secondly, the training programs were not consistent and varied in intensity and exercises performed. However, all were effective in inducing increases in strength. Finally, the volume and type of milk consumed in the studies was different. Kukuljan et al. provided 2 x 200 mL of UHT 1% milk, consumed 200 mL in the morning and 200 mL in the evening, while the Hartman et al. and Josse et al studies provided 2 x 500 mL of skim milk immediately after the exercise.

These differences suggest that the time of the intake of milk after training maybe critical in facilitating the beneficial effects previously described, and/or the volume of milk consumed may also be influential.

There is growing amounts of evidence, both acute and long-term, to support the use of low-fat milk as a post-resistance exercise beverage.
Consumption of low-fat milk appears to create an anabolic environment following resistance exercise and over the long term with training, it appears that greater gains in lean mass and muscle hypertrophy can be obtained [15, 17] when consumed in adequate amounts soon after resistance exerciser. Furthermore, milk intake after resistance exercise may also lead to greater declines in body fat [15, 17]. Further work is required to better understand the possible influences of age and volume of milk intake on these responses.

Milk and Endurance Exercise and Training

Endurance sports and activities are considered to be sub-maximal activities that can be performed for prolonged periods of time. These activities normally involve large muscle groups and are highly dependent on oxidative metabolism as a source of energy, leading to high rates of total energy turnover and sometimes depletion of carbohydrate stores (muscle glycogen) within the active muscles. However, due to variations in the intensity of the exercise performed there can be considerable differences in the responses observed.

From a sport nutrition standpoint, there are three different situations when nutrition is considered for endurance based activities; before exercise, during exercise, and after exercise. Each of these phases has varying nutritional objectives. Prior to exercise, nutritional goals focus on ensuring the athlete is well fuelled and that any nutritional intake will not drastically alter the normal physiological responses to the activity. The goal of nutritional intake during exercise is to provide exogenous fuel, especially carbohydrate, in an attempt to possibly delay the depletion of muscle glycogen, and to provide fluids to offset fluid losses due to sweating. Finally, the nutritional objectives following exercise are to promote muscle recovery, muscle adaptations, glycogen resynthesis, and fluid replenishment. There is limited research into the possible roles of milk as a nutritional option for endurance activities. Based on the existing scientific literature it is difficult to develop specific recommendations because of differences in design and methodology. However, recently a number of studies suggest that there is significant potential for expanded research in this area, especially in the area of recovery from endurance exercise.

During endurance exercise, dietary intake of milk leads to similar responses in many physiological variables as compared to the intake of carbohydrate based sports drinks.

Some minor differences have been reported, such as increased concentrations of essential amino acids [20], which is not unexpected based on the protein content of milk. The protein content of milk also leads to a reduction in whole body protein breakdown and protein synthesis, and a simultaneous increase in protein oxidation following exercise, when milk is consumed during prolonged exercise [21]. The decline in whole body protein synthesis might be related to preferential oxidation of the ingested protein during the exercise, possibly decreasing amino acids availability for synthesis after the exercise [21]. Participants do report greater feelings of stomach fullness with milk as compared to water or carbohydrate based beverages [22]. Increase in stomach fullness suggest that the rate of fluid intake may have been greater than gastric emptying [22]. Rates of gastric emptying have been show to decline with increased energy density of the fluid consumed [23]. Despite these reported variations in physiological responses and stomach fullness, there have been no reported differences in measures of performance. For example, when participants rode at a set intensity until exhaustion while consuming either milk or carbohydrate based sports drinks, participants had similar times to exhaustion, suggesting that milk is just as beneficial as commercially available sports drinks at delaying the onset of fatigue under these conditions [22]. Clearly, more research is required to better evaluate milk as an endurance exercise supplement beverage.
New research should include measurements of performance such as time trials, as they are more realistic to endurance sport performance. Future research should also investigate the metabolic influence of dietary milk intake during endurance exercise, as there is very limited research in this area.

Some of the first sport nutrition studies investigated the possible role of milk as a recovery beverage after endurance exercise. The main goal of any post exercise nutritional intervention is usually to promote muscle glycogen resynthesis, and fluid recovery. In regards to glycogen resynthesis, there has been no direct research into the efficacy of milk consumption to replenish muscle glycogen levels. However, there has been a number of performance based trials that suggests that chocolate milk is as effective as a commercially available sports drinks in facilitating recovery short term endurance recovery [24]. A group of trained endurance athletes completed repeated sets of glycogen depleting endurance intervals, and then consumed different endurance recovery beverages, one being chocolate milk [24]. Chocolate milk was compared to a carbohydrate recovery drink and both were controlled for carbohydrate and energy content. Participants recovered from an exhausting bout of endurance exercise for four hours and consumed the different beverages, the participants then performed a second ride to exhaustion. The time to exhaustion and total work performed during the performance trial was the same when the participants consumed the two different drinks [24]. This lead the authors to conclude that chocolate milk was as effective as more commonly used sports drink at promoting recovery, thus implying that glycogen resynthesis was likely similar [24].

However, despite these indirect observations have been no well controlled studies that have directly measured the efficacy of milk, or chocolate milk, to promote muscle glycogen recovery following prolonged endurance exercise. Clearly, future research should investigate rates of muscle glycogen resynthesis following prolonged endurance exercise and compare the efficacy of milk to other sport recovery beverages.

Another goal of a post-exercise beverage is to promote rehydration due to the excessive fluid loss that occurs as a result of sweat loss. So far, there has been a number of studies that have directly investigated the effectiveness of low-fat milk as a rehydration beverage [25-26]. For example, one study compared the effectiveness of low-fat milk alone, low-fat milk with additional sodium chloride, a sports drink, and water at restoring fluid balance after exercise in hot conditions (1.8% loss in body mass). The volume of each drink consumed after exercise was 150% of the volume of sweat lost during the exercise. Intake of 150% of fluid lost is a common rehydration strategy after exercise. By the end of 4 hours of recovery both milk groups were in a net positive fluid balance, while both the sports drink and water conditions remained in a net negative fluid balance [25]. The authors concluded that low-fat milk was an effective beverage for promoting rehydration following exercise induced dehydration, and that the low-fat milk was better than commercially available sports drinks in promoting rehydration due to lower total urine output during recovery [25]. Other studies have had similar findings as to the effectiveness of milk for rehydration [26].

The effectiveness of milk as a rehydration beverage likely relates to the nutrient composition of milk. Milk naturally has high concentrations of electrolytes (133 mg Na^+ and 431 mg K^+ in a 250 mL serving) which aid in fluid retention when consumed. Another factor that may contribute to the efficacy of milk as a post-exercise rehydration beverage is the rate at which it empties from the stomach [25]. Energy dense fluids, such as milk, empty from the stomach much more slowly, leading to slower absorption into the circulation [27]. Slower absorption buffers any large fluctuations in plasma osmolality that can occur with consumption of large volumes of water or sports drinks, subsequently preventing increased clearance rates by the kidneys.

Large fluctuations in osmolality can lead to large increases in urine output [25]. The protein content of milk may also facilitate the beneficial hydration effects that have been observed, as addition of milk protein to a carbohydrate beverage has been shown to enhance fluid retention after exercise [28].

In summary, there is growing, yet still very, limited amount of scientific evidence to support the use of low-fat milk as an endurance exercise recovery beverage. Current scientific literature suggests that low-fat milk is as effective as commercially available sports drinks at facilitating recovery for additional performance, which has been interpreted to suggest that it may be an effective beverage for promoting glycogen recovery.

Low-fat milk has also been shown to be a very effective beverage at promoting fluid recovery following dehydrating exercise in the heat. Future research should investigate how milk promotes recovery after exercise and better establish the physiological mechanisms through which it acts.

Milk and Muscle Damage

A growing area of research is the possible influence of milk intake after exercise on markers of muscle damage. Recent studies have reported lower concentrations of creatine kinase in the blood after exercise when milk or milk-protein based beverages are consumed in the post-exercise period [29-32]. These decreases have been observed following resistance exercise [29-30], endurance exercise [32] and sport specific training [31]. In all cases, participants performed the same amount of work; the only difference was the nutritional intervention following exercise. In contrast, one older study reported no differences in blood markers of muscle damage following resistance exercise, however the authors did mention that there was a trend for blood CK levels to be lower in the milk beverage condition after resistance exercise [33]. The mechanism(s) underlying these observations remain unclear, as blood concentrations of CK are a function of release from the muscle and clearance from the blood, furthermore CK responses to exercise are complicated by large inter-subject variability. Despite the observed differences in CK values, most of the research studies do not report differences in measures of performance. Therefore, future work should investigate the mechanisms underlying the declines in blood CK with post-exercise milk and/or milk-protein beverage intake.

Conclusions

There is accumulating scientific evidence supporting the use of low-fat milk and milk derived beverages following exercise by both individuals and athletes who participate in strength and/or endurance training. There is growing amount of data suggesting that low-fat milk is as effective as, and possibly even more effective than, commercially available sports drinks at promoting recovery from strength and endurance exercise. Much more work is required to better understand the physiological mechanisms through which milk exerts its actions following exercise and training. Furthermore, milk has the added benefit of providing additional nutrients and vitamins that are not present in commercial sports drinks. In summary, based on current and past scientific research, low-fat milk is a safe and effective post-exercise recovery beverage that has been shown to promote recovery from various forms of exercise. It should be considered as a viable alternative to traditional commercial sports drinks by lactose tolerant individuals. Furthermore, milk is a complex food and source of multiple anabolic nutrients, especially for bone health (vitamin D and calcium), that tend to be limiting in the diet.

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