Bovine milk is one of the best pre-and pro-workout sources for athletes owing to its rich nutritional content. Even though bovine milk consumption significantly benefits athletes’ health and performance, many athletes cannot consume bovine milk since they struggle with gastrointestinal problems caused after milk consumption. Especially, the consumption of regular milk, which contains A1 β-casein, is associated with a variety of diseases ranging from gastrointestinal discomfort to ischemic heart diseases. The main reason behind this is related to β-casomorphine 7 (BCM-7), which is derived from A1 β-casein during the digestion of A1 milk. A1 β-casein is formed as a result of a point mutation in the position of 67th in the amino acid sequence A2 β-casein by changing proline to histidine. Therefore, this mutated form of β-casein in regular milk cannot easily be digested by the human-associated digestion enzymes. A2 milk, which includes A2 β-casein instead of A1 β-casein, is the best substitute for regular milk with the same nutritional content. This natural form of milk positively affects the athlete’s health as well as performance without causing any gastrointestinal discomfort or more serious problems which are seen in the consumption of regular milk. In this review, A2 milk and its potential health effects in comparison to diseases related to A1 milk consumption are discussed.

Keywords: bovine milk, A2 milk, A2 β-casein, sports nutrition, health, athlete performance
bioactive proteins such as whey and casein (3:1 ratio) that enhance the level of amino acid in the serum, muscle protein synthesis rate, as well as muscle damage repair (22). In addition, bovine milk is an alternative hydration drink to other sports drinks due to its high concentration of some minerals namely sodium and potassium, which helps the skeletal muscle recovery (23, 24).

On the other hand, a significant number of athletes cannot easily digest regular bovine milk and therefore, exclude it from their diet. The digestion of regular bovine milk, which includes A1 β-casein, can cause lactose intolerance and potential health problems mainly linked to its A1 β-casein and its derived peptide β-casomorphine 7 (BCM-7). Moreover, this small peptide formed during the digestion of A1 milk has been linked with several health problems from intolerance to diabetes (25). Thus, regular A1 milk and based products have been excluded from the sports diet even though they benefit athlete health in several ways. The lack of bovine milk in the diet of athletes means that they miss out on essential nutrients including protein, vitamin D, calcium, and potassium for their performance (12, 20). An alternative for athletes who have GI discomfort or other health problems due to the consumption of regular milk is a critical requirement. Therefore, A2 milk, which lacks A1 β-casein and related BCM-7 expression, is considered to be a promising alternative to regular A1 milk for athletes who cannot consume it (26–28). A2 bovine milk not only offers all the health benefits of regular milk but also provides easy digestion for athletes (Figure 1). The main scope of this review is to summarize the potential benefits of A2 milk on human health as an alternative sport drink to regular milk. In addition, the review aims comprehensively discuss the relationship between regular milk consumption by athletes and various diseases such as gastrointestinal discomfort, cardiovascular diseases, and type 1 diabetes.

A2 MILK–AN ALTERNATIVE BOVINE MILK FOR ATHLETES

The easy-digest A2 milk is a noticeable alternative for athletes who come to face health problems including GI discomfort when they consume A1 milk (20–22). A2 milk does not cause such serious health problems; besides, it has nearly the same nutritional composition as regular milk (29–32). Regarding bovine milk composition, it includes approximately 87% water and 13% such milk solids as lactose, fat, proteins, and minerals. Milk proteins consist of 20% whey (α-lactalbumin, β-lactoglobulin, transferrin, albumin, and lactoferrin) and 80% casein proteins (α, β, κ-casein) (33, 34). Caseins, which exert significant biological roles, include 45% β-casein has great amino acid balance. β-casein concentrations in A1 and A2 milk are 8.59 and 8.02 mg/mL, respectively. β-casein includes 209 amino acid residues of which 16.7% are proline which causes a limitation in the formation of an α-helix. Therefore, a variety of mutations resulted in different variants of β-casein including A1, A2, A3, B, C, D, E, F, G, H1, H2, and I (35).

A1 and A2 forms are the most common β-casein variants among other β-casein forms (35). They include almost the same composition in terms of protein, fat, carbohydrate, and other contents concentration (Table 1). The only difference between A1 and A2 variants stems from a point mutation which causes the difference in a single nucleotide at the 67th position of the β-casein gene. A2 β-casein includes proline at the 67th position of its amino acid sequence. However, this amino acid was converted to histidine by a mutation which causes the formation of the A1 β-casein variant (23). Bovines, therefore, produce A1 or A2 milk depending on the β-casein form they have (37).

Several studies have shown that GI discomfort and other health problems, which are also serious problems many athletes experience when they consume A1 milk, are closely related to BCM-7 peptide (38–40). However, as A2 milk lacks A1 β-casein and derived BCM-7, does not cause such health concerns for athletes. While the digestion of A1 protein causes the formation of BCM-7; (Tyr-Pro-Phe-Pro-Gly-Pro-Ile), A2 protein digestion forms another peptide called β-casomorphin-9 (BCM-9; Tyr-Pro-Phe-Pro-Gly-Pro-Ile-Pro-Asn) (23). The proline at the 67th position of A2 β-casein hinders the BCM-7 formation in the human body, but histidine in A1 β-casein at the same position allows the cleavage by gastrointestinal enzymes to form BCM-7. This morphine-like small peptide cannot be digested by human-associated enzymes, which causes indigestion problems. BCM-7 molecule was not observed in the urine or blood samples of A2 cows since A2 β-casein is broken down into peptides and then amino acids by an easy digestion process (27, 41). In A1 milk consumption, in contrast, the peptides cannot be broken down into amino acids, which causes the transition of this molecule into the gastrointestinal tract and bloodstream through leakages in the gut (25). Several studies including epidemiological and clinical research have supported that the BCM-7 is a risk for diseases such as gastrointestinal discomfort, type 1 diabetes, ischemic heart, and, neurological diseases (42–46). Consequently, athletes may suffer not only from GI discomfort but also from health problems caused by A1 milk consumption. As an alternative drink for athletes, A2 milk is a promising option to be benefited from the nutritional content of bovine milk without health problems.

IMPACT OF A1 AND A2 MILK ON ATHLETE PERFORMANCE AND HEALTH

Milk and dairy products are associated with the concepts of physical activity, exercise, training, and health (2). The use of milk rich in amino acids, which is necessary for energy, shows branch-dependent differences in athletes. Although its health benefits are known, the thought that it will negatively affect performance drives athletes away from milk. The number of studies on this subject has started to increase day by day. It is seen that milk taken after high-intensity interval running protocol application in endurance athletes does not negatively affect the nutrition protocol in the recovery process in athletes (47). Athletes have to train continuously to maximize their performance. According to the competition calendar, athletes who train twice a day in some periods physiologically need a fast recovery period. Studies are showing that milk has positive
effects on athlete performance as well as other supplements that accelerate recovery (48). However, athletes with intolerance to dairy products are subject to a diet devoid of milk and dairy products in the cycle of regaining the lost energy after training. However, it is emphasized that A2 milk will be a suitable alternative since it does not contain the protein in A1 milk (20).

It is unclear whether A2 milk has a different effect on performance elements such as strength, speed, and endurance in comparison to regular milk. However, A2 milk might have a similar positive effect on athlete performance as regular milk because they have the same nutritional value. In addition to the positive effect of A2 milk on athlete performance quality, it can be a precise alternative for athletes who have some medical issues such as gastrointestinal discomfort, diabetes, and cardiovascular and neurological diseases.

**EXERCISE PERFORMANCE**

As for the impact of A2 milk on athlete health, several studies are focused on muscle damage and recovery which are crucial for the quality of exercise performance. In a research study, Kirk et al. (49) compared the effects of A1 and A2 milk on 20 m sprint, vertical jump, and exercise-induced muscle damage. According to the study results, both milk forms had a similar effect on sprint, vertical jump performance, and post-exercise recovery, which means that A2 milk may be a good substitute for lactose intolerant athletes (20).

In another study, regular chocolate milk and A2 milk had similar effects on recovery after physical exercise (50). In addition, A2 milk consists of more proline amino acids due to the difference at the 67th amino acid in the casein structure between A1 and A2 milk (51, 52). Proline is a multifunctional amino acid classified as one of the non-essential amino acids. It is one of the gluconeogenic amino acids and may increase endurance performance by protecting blood sugar and hepatic glycogen levels, especially in long-term endurance exercises (53). Furthermore, proline is a critical amino acid for protein synthesis and cell growth. It also plays an important role in osmoregulation, redox signaling, protein stability, cellular bioenergetics, and stress resistance (54). In addition to having all the nutritional values of A1 milk, A2 milk can be preferred by all athletes due to its easy-to-digest property and higher proline content.

**GASTROINTESTINAL DISCOMFORT**

Gastrointestinal disorders are common amongst athletes with a rate of up to 70% (55, 56). Most of the athletic population including runners, weightlifters, cyclists, and triathletes experience the discomfort problem due to mainly upper GI complaints such as nausea, vomiting, heartburn, and epigastric pain. Nutrition is of utmost importance to tackle these GI problems; however, inaccurate nutrition deteriorates symptoms. A1 milk, for instance, can cause symptoms associated with milk
intolerance such as stool frequency, fecal and serum biomarkers, constipation, and transit time (32, 35, 37, 38).

Several studies have shown that A1 milk causes some gastrointestinal discomfort problems during its digestion. A study has indicated that A1 milk causes higher stool consistency according to Bristol Scale in comparison to A2 milk. The study also showed that abdominal pain and stool consistency is positively associated with A1 milk consumption ($r = 0.52$), but this is not observed for A2 milk digestion ($r = -0.13$) (57). A study also showed that A2 milk consumption by lactose-intolerant individuals significantly diminished the intolerance symptoms (23). In another study, lactose intolerant individuals consumed A2 milk, A1 milk, regular milk without lactose, and Jersey milk to evaluate their gastrointestinal symptoms and hydrogen production during digestion. They showed that A2 milk causes considerably fewer gastrointestinal symptoms and pain (27). Another study also examined lactose intolerance symptoms after participants consume A1/A2 milk and only A2 milk. The study is resulted by that the group which consumes A2 milk presents fewer intolerance symptoms. The consumption of A1/A2 milk was linked with post-dairy digestive discomfort and a high proportion of inflammation markers and BCM-7 (35). A study performed on animals similarly showed that BCM-7 exerts different impacts on gastrointestinal function such as declining the frequency and amplitude of intestinal contractions. Barnett et al. (58) showed that A1 milk feeding on rats has an increment on myeloperoxidase which is an inflammatory marker with 65%. Generally, it is mainly shown that A1 milk consumption causes systemic inflammation and gastrointestinal mobility related to BCM-7 formation during its digestion (58).

In contrast, A2 milk consumption was not correlated with post-dairy discomfort, and it is considered to milk can be easily consumed without any gastrointestinal discomfort (20). A2 milk consumption by 10 individuals who are not tolerant to A1 milk did not cause any gastrointestinal problems. Another study also showed that A2 milk diminished gastrointestinal-related symptoms of lactose intolerant, whereas A1 milk decreased lactase activity and enhanced symptoms (25). This easy digest product is also highly preferred by athletes to consume as an energy source after their exercise. In a study related to A2 milk and athlete health, the effect of A2, regular milk, and placebo on exercise-induced muscle damage is evaluated in a group including 21 men who regularly run. The results showed that A2 milk consumption diminishes muscle function loss and improves the recovery period (49). Thus, alternate A2 milk may be a favorable drink for athletes without causing any GI concerns.

### TABLE 1 | Comparison of the nutritional content of A1 and A2.

| Component       | A2 Milk | A1 Milk | References |
|-----------------|---------|---------|------------|
| Energy (kJ/100 mL) | 278     | 270     | (25)       |
| Protein (mg/mL)  | ~33     | ~33     | (25)       |
| αs-casein       | 16.37   | 16.08   | (39)       |
| β-casein        | 8.02    | 8.59    | (39)       |
| κ-casein        | 2.44    | 2.41    | (39)       |
| β-lactoglobulin | 4.50    | 4.49    | (39)       |
| α-lactalbumin   | 1.46    | 1.43    | (39)       |
| Serum albumin   | 0.45    | 0.46    | (39)       |
| Immunoglobulins | 0.47    | 0.48    | (39)       |
| Fat (mg/mL) | 37      | 35      | (25)       |
| Carbohydrate (mg/mL) | 50      | 48      | (25)       |
| Sodium (mg/mL)  | 0.37    | 0.45    | (25)       |
| Calcium (mg/mL) | 1.17    | 1.20    | (25)       |

### TYPE 1 DIABETES

Type 1 diabetes, which is a form of diabetes mellitus, is caused by a lack of insulin due to the problem in β-cells producing insulin in the islets of Langerhans of the pancreas (59). Many athletes with type 1 diabetes are at risk of hypoglycemia during and post-exercise (60, 61). Therefore, this risky situation may hinder the sports career of athletes with type 1 diabetes. Another considerable point is that the consumption of popular post-exercise drink A1 milk can worsen symptoms related to type 1 diabetes. As regards studies on Type 1 diabetes and A1 β-casein, A1 milk causes worse symptoms of Type 1 diabetes due to BCM-7 formation, whereas it is not observed in A2 milk consumption does not cause morphine-like peptide BCM-7 release (26, 41).

The relationship between A1 milk consumption and type 1 diabetes has been debated for long years (26, 42, 43, 62). Animal studies have shown that no difference between A1 and A2 milk consumption caused to high risk of type 1 diabetes. However, A1 milk intake by susceptible rats increases the risk of type 1 diabetes. Regarding studies on humans, a specific human leukocyte antigen (HLA-DR) may be at high risk of developing Type 1 diabetes due to cow’s milk consumption (63). Another study represented that the incidence of type 1 diabetes was not strongly correlated with total protein consumption ($r = +0.402$), whereas A1 milk consumption was ($r = +0.726$) (64). Furthermore, Laugesen and Elliott showed a positive association ($r = 0.92$) between A1 milk supply by cows per capita and type 1 diabetes in 19 countries. This noticeably indicated that Finland and Sweden’s highest A1 milk intake per capita had a higher incidence rate, while low frequencies were in Venezuela and Japan where the lowest A1 milk consumption takes place per capita (44).

### CARDIOVASCULAR DISEASES

Cardiovascular diseases, to date, have been one of the major causes of mortality and morbidity at the global level. Although precise nutrition and physical exercise are recommendations for the prevention of such diseases, even elite athletes are prone to developing cardiovascular diseases as they age (65, 66). Some drinks in athletes’ diets pre- or pro-exercise were correlated with the symptoms of cardiovascular...
diseases. Especially, A1 milk was associated with some markers of cardiovascular diseases such as atherosclerosis, plasma cholesterol level, and oxidation of low-density lipoprotein (43, 67–69).

Several studies have shown that A1 milk consumption was correlated with ischemic heart disease mortality in France, Northern Ireland, and West Germany ($r^2 = 0.86$) (43, 44). Similarly, A1 β-casein per capita by milk and cream was strongly associated with ischemic heart disease in 20 different countries. BCM-7 formed after A1 milk consumption is also linked with the oxidation process of low-density lipoprotein (LDL). Macrophages absorb oxidized LDL molecules with surface receptors and converted them into foam cells, which promotes atherosclerosis in the heart (70). Another study also showed that A1 milk is more responsible for the atherosclerosis process in comparison to A2 milk. An artificial injury, in animal models, was made in the carotid artery of rabbits and was fed on A1 and A2 milk. The result of the study showed that rabbits fed on A1 milk had thicker streaks with fatty structures on the injured area than rabbits fed on A2 milk (71). Consequently, A2 milk can be preferred for athletes who have or are at risk of cardiovascular diseases instead of regular A1 milk.

**NEUROLOGICAL DISEASES**

Today, many people including many athletes suffer from various neurological diseases which seriously affect their quality of life. Balanced nutrition is a major factor that strongly affects symptoms of some neurological diseases, which could be a good way to be neurologically healthy. In contrast, BCM-7 derived from the consumption of A1 milk was correlated with the symptoms of some neurological diseases (40, 72, 73).

Studies related to A1 β-casein-derived BCM-7 show a relationship between this small peptide and a variety of neurological problems. In a study, for instance, BCM-7 in different concentrations is injected into 35 rats to examine its effects on rats’ brain functions. It showed that BCM-7 can pass the blood-brain barrier, and even more, it can activate brain cells which causes some anatomic and functional changes in brain cells (72). The relationship between BCM-7 and genes related to atopic dermatitis is also examined in another study. In this study, the MOR gene responsible for an opioid receptor which is associated with the negative effect of BCM-7 on digestion, immunity, and the nervous system was found as significantly more active because of the A1 milk consumption. In addition, the activity of the DPP4 gene, which is responsible for the production of a protein that degrades BCM-7, is decreased in dermatitis patients. In milk variants, furthermore, the highest BCM-7 concentration is observed after the hydrolysis of A1 milk (51). Furthermore, autism, which is an autism spectrum disorder, is characterized by social and behavioral problems. Some studies have shown that BCM-7 may worsen the symptoms of autism development. The worse situations of neurological symptoms have been associated with the consumption of A1 milk and wheat by autistic patients (73, 74). It can clearly be stated that there is a critical need for further investigations on A1 milk consumption and neurological diseases including autism.

**A2 MILK-BASED MEALS FOR ATHLETES**

Many athletes have been excluded A1 milk and products from their diet because of a variety of health problems ranging from intolerance to diabetes (52, 64, 69, 71, 75). Therefore, they are more prone to consuming other non-dairy alternatives such as almond or oat milk; however, these plant-based options do not include the same nutritional content and health benefits as bovine milk. Many lactose-intolerant athletes do not experience gastrointestinal problems when they ingest plant-based milk and products. However, they lack a variety of benefits of regular dairy due to its rich nutritional content (76).

Nowadays, A2 milk and products have been introduced to the diet plan of many athletes to benefit them in many aspects of health with almost the same nutritional content as regular milk. Due to the easy-digest property of A2 milk, it is a source to make A2 milk-based meals for athletes pre- and pro-workout. Moreover, several popular dieticians have started to recommend the integration of A2 milk into athletes’ diets in many ways (27, 77). For instance, A2 milk can be used to prepare a post-workout snack by mixing a piece of fruits or a pre-workout snack having it with cereal or muesli. Eventually, A2 milk-based meals may offer a precise alternative to before and after exercise food sources with important health benefits.

**CONCLUSION**

Milk has an important part of the sports diet thanks to its rich nutritional elements. However, many athletes cannot consume milk due to GI discomfort after digestion. A2 milk is a considerable alternative for athletes with such ailments. A2 dairy allows athletes to take the nutrients they can get from regular milk without any discomfort. In this review, the effects of A2 milk, which has become more important in recent years, on athletes are compressively discussed. A2 milk has noticeable positive effects on both athlete health and performance. Consumption of A2 milk has a lower risk compared to A1 milk against digestive problems, type 1 diabetes, cardiovascular diseases, and neurological diseases, which have an important place in terms of the general health status of athletes. Its similarity with regular milk in athlete performance makes A2 milk a reliable food for athletes with GI disorders. A2 milk has a higher potential to be used as a nutritional source in athletes and even more in all humans’ diets owing to its incredible functions on health. A2 milk and its derived products ranging from cheese to yogurt would be an important part of a healthy and balanced diet of a significant number of people in the future. This review paper, therefore, is of utmost importance to better understand the positive impact of A2 milk on athlete health. However, decomposing effects of regular milk and A2 milk on different physical performances such as strength, speed, and endurance are not fully known. Therefore, there is a critical need for more *in-vitro* and *in-vivo*
studies comparing the effects of regular milk and A2 milk on sportive performance.

**AUTHOR CONTRIBUTIONS**

SK organized the general content of the paper. MK was responsible for general editing and organizing the authors as well as the contribution for three sections. BB and BG were responsible for one section of the paper. AA and HD contributed one section of the paper. All authors contributed to the article and approved the submitted version.

**FUNDING**

Uluova Süt Ticaret A.S. (Uluova Milk Trading Co.) has funded this study.

**REFERENCES**

1. Karav S, Casaburi G, Arslan A, Kaplan M, Sucu B, Frese S. N-glycans from human milk glycoproteins are selectively released by an infant gut symbiont in vivo. *J Funct Foods.* (2019) 61:103485. doi: 10.1016/j.jff.2019.103485
2. Arslan A, Kaplan M, Duman H, Bayraktar A, Ertürk M, Henrick BM, et al. Bovine colostrum and its potential for human health and nutrition. *Front Nutr.* (2021) 8:1–12. doi: 10.3389/fnut.2021.651721
3. Kaplan M, Arslan A, Duman H, Karyelioğlu M, Baydemir B, Günsel BB, et al. Production of Bovine Colostrum for Human Consumption to Improve Health. *Front Pharmacol.* (2021) 12:796824. doi: 10.3389/fphar.2021.796824
4. Karav S. Selective deglycosylation of lactoferrin to understand glycans contribution to antimicrobial activity of lactoferrin. *Cell Mol Biol.* (2018) 64:52–7. doi: 10.14751/cmbv.2018.64.9.8
5. Kelly GS. Bovine Colostrums: A review of clinical uses. *Altern Med Rev.* (2003) doi: 10.1715/ajas.2011.10122
6. Stelwagen K, Carpenter E, Haigh B, Hodgkinson A, Wheeler TT. Immune components of bovine colostrum and milk. *J Anim Sci.* (2009) 87:3–9. doi: 10.2527/jas.2008-1377
7. Corrochano AR, Ferraretto A, Arranz E, Stuknyte M, Bottani M, et al. The use of bovine colostrum in sport and exercise. *Int J Sport Med.* (2016) 26:65–70. doi: 10.1123/ijsnem.2015-0056
8. Berry CW, Murray B, Kenney WL. Scientific basis for a milk permeate-carbohydrate-protein supplementation. *J Nutr Metab.* (2011) 1:1–11. doi: 10.1155/2011/623182
9. Wilkinson SR, Tanapolseny MA, MacDonald MJ, MacDonald JR, Armstrong D, Phillips SM. Consumption of fluid skim milk promotes greater muscle protein accretion after resistance exercise than does consumption of an isonitrogenous and isoenenergetic soy-protein beverage. *Am J Clin Nutr.* (2007) 85:1031–40. doi: 10.1093/ajcn/85.4.1031
10. Rivera-Brown AM, Gutiérrez R, Gutiérrez JC, Frontera WR, Bar-Or O. Drink composition, voluntary drinking, and fluid balance in exercising, trained, heat-acclimatized boys. *J Appl Physiol.* (1999) 86:78–84. doi: 10.1152/jappl.1999.86.1.78
11. Milk B, Bar-Or O. Effect of drink flavor and NaCL on voluntary drinking and hydration in boys exercising in the heat. *J Appl Physiol.* (1996) 80:1112–7. doi: 10.1152/jappl.1996.80.4.1112
12. He M, Sun J, Jiang ZQ, Yang YX. Effects of cow’s milk beta-casein variants on symptoms of milk intolerance in Chinese adults: a multicentre, randomised controlled study. *Nutr J.* (2017) 16:72. doi: 10.1186/s12973-017-0275-0
13. Reddy PRK, Reddy AN, Ramadevi A, Kumar DS. Nutritional significance of indigenous cow milk with regard to a2β-casein – an overview. (2016) 5:3576–80.
14. Ramakrishnan M, Eaton T, Sermet O, Savaiano D. A single meal of milk containing A2β-casein causes fewer symptoms and lower gas production than milk containing both A1 and A2 β-casein among lactose intolerant individuals. *Curr Dev Nutr.* (2020) 4:772–772. doi: 10.1093/cdn/nza052_041
15. Chitra P. Bovine milk: A1 and A2 beta-casein milk proteins and their impact on human health: a review. *Agric Rev.* (2021). doi: 10.1885/ag.R.2126. [Epub ahead of print].
16. Sheng X, Li Z, Ni J, Yelland G. Effects of conventional milk versus milk containing only A2 β-casein on digestion in chinese children: a randomized study. *J Pediatr Gastroenterol Nutr.* (2019) 69:375–82. doi: 10.1097/MPG.0000000000002437
17. Kaskous S. A1- and A2-milk and their effect on human health: a review. *J Nutr.* (2018) doi: 10.1093/jn/nqz279
18. Volek JS, Gómez AL, Scheett TP, Sharman MJ, French DN, Rubin MR, et al. Increasing fluid milk favorably affects bone mineral density responses to resistance training in adolescent boys. *J Am Diet Assoc.* (2010) 103:1535–6. doi: 10.1016/j.jada.2010.03.01073-3
19. Bytomski JR. Fueling for Performance. *Sports Health.* (2018) 10:47. doi: 10.1177/191473817743913
20. Roy BD. Milk: the new sports drink? a review. *J Int Soc Sports Nutr.* (2008) 5:15. doi: 10.1186/1550-2783-5-15
21. Ferguson-Stegall L, McCleave E, Ding Z, Doerner III PG, Liu Y, Wang B, et al. Aerobic exercise training adaptations are increased by postexercise carbohydrate-protein supplementation. *J Nutr.* (2011) doi: 10.1155/2011/623182
22. Wilkie SR, Tanapolseny MA, MacDonald MJ, MacDonald JR, Armstrong D, Phillips SM. Consumption of fluid skim milk promotes greater muscle protein accretion after resistance exercise than does consumption of an isonitrogenous and isoenenergetic soy-protein beverage. *Am J Clin Nutr.* (2007) 85:1031–40. doi: 10.1093/ajcn/85.4.1031
23. Rivera-Brown AM, Gutiérrez R, Gutiérrez JC, Frontera WR, Bar-Or O. Drink composition, voluntary drinking, and fluid balance in exercising, trained, heat-acclimatized boys. *J Appl Physiol.* (1999) 86:78–84. doi: 10.1152/jappl.1999.86.1.78
24. Wilkie B, Bar-Or O. Effect of drink flavor and NaCL on voluntary drinking and hydration in boys exercising in the heat. *J Appl Physiol.* (1996) 80:1112–7. doi: 10.1152/jappl.1996.80.4.1112
25. He M, Sun J, Jiang ZQ, Yang YX. Effects of cow’s milk beta-casein variants on symptoms of milk intolerance in Chinese adults: a multicentre, randomised controlled study. *Nutr J.* (2017) 16:72. doi: 10.1186/s12973-017-0275-0
26. Reddy PRK, Reddy AN, Ramadevi A, Kumar DS. Nutritional significance of indigenous cow milk with regard to a2β-casein – an overview. (2016) 5:3576–80.
27. Ramakrishnan M, Eaton T, Sermet O, Savaiano D. A single meal of milk containing A2 β-casein causes fewer symptoms and lower gas production than milk containing both A1 and A2 β-casein among lactose intolerant individuals. *Curr Dev Nutr.* (2020) 4:772–772. doi: 10.1093/cdn/nza052_041
28. Chitra P. Bovine milk: A1 and A2 beta-casein milk proteins and their impact on human health: a review. *Agric Rev.* (2021). doi: 10.1885/ag.R.2126. [Epub ahead of print].
29. Sheng X, Li Z, Ni J, Yelland G. Effects of conventional milk versus milk containing only A2 β-casein on digestion in chinese children: a randomized study. *J Pediatr Gastroenterol Nutr.* (2019) 69:375–82. doi: 10.1097/MPG.0000000000002437
30. Kaskous S. A1- and A2-milk and their effect on human health: a review. *J Nutr.* (2018) doi: 10.1093/jn/nqz279
31. Milan AM, Shrestha A, Karlström HJ, Martinsson JA, Nilsson NJ, Perry JK, et al. Comparison of the impact of bovine milk β-casein variants on digestive comfort in females self-reporting dairy intolerance: a randomized controlled trial. *Am J Clin Nutr.* (2020) 111:149–60. doi: 10.1093/ajcn/nqz279
32. Kay SIS, Delgado S, Mittal J, Eshraghi RS, Mittal R, Eshraghi AA. Beneficial effects of milk having A2 β-casein protein: myth or reality? *J Nutr.* (2021) 151:1061–72. doi: 10.1093/jn/nxa054
33. Holland JW, Deeth HC, Alwood PF. Resolution and characterisation of multiple isoforms of bovine kappa-casein by 2-DE following a reversible cysteine-tagging enrichment strategy. *Proteomics.* (2006) 6:3087–95. doi: 10.1002/pmic.200500780
34. Karav S, Le Parc A, Leite Nobrega de Moura Bell JM, Frese SA, Kirmiz N, Block DE, et al. Oligosaccharides released from milk glycoproteins are selective growth substrates for infant-associated bifidobacteria. Appl Environ Microbiol. (2016) 82:3622–30. doi: 10.1128/AEM.00547-16

35. Massella E, Piva S, Giacometti F, Luzzio G, Zambrini AV, Serraino A. Evaluation of bovine beta-casein polymorphism in two dairy farms located in northern Italy. Ital J Food Saf. (2017) 6:e6904. doi: 10.4081/ifs.2017.6904

36. Ng-Kwai-Hang KE, Hayes JF, Moxley JE, Monardes HG. Variation in milk protein concentrations associated with genetic polymorphism and environmental factors. J Dairy Sci. (1987) 70:563–70. doi: 10.3168/jds.S0022-0302(87)01045-5

37. Ciesielska A, Kostyra E, Kostyra H, Oleński K, Fiedorowicz E, Kamiński S. Milk from cows of different β-casein genotypes as a source of β-casomorphin-7. Int J Food Sci Nutr. (2012) 63:426–30. doi: 10.3109/09637486.2011.534785

38. De Oliveira EP, Burini RC, Jeukendrup A. Gastrointestinal complaints during exercise: prevalence, etiology, and nutritional recommendations. Sports Med. (2014) 44:79. doi: 10.1007/s40279-014-0155-2

39. Ter Steege RWF, Van Der Palen J, Kolkman J. Prevalence of gastrointestinal complaints in runners competing in a long-distance run: an internet-based observational study in 1281 subjects. Scand J Gastroenterol. (2009) 43:1477–82. doi: 10.1080/03005370802321170

40. Ósman A, Zuffa S, Walton G, Fagbodun E, Zanos P, Georgiou P, et al. Post-weaning A1/A2 β-casein milk intake modulates depressive-like behavior, brain µ-opioid receptors, and the metabolome of rats. iScience. (2021) 24:103048. doi: 10.1016/j.isci.2021.103048

41. Kaplan et al. A2 Milk and Sports Nutrition
75. Venkatachlapathy R T. Impact of A1/A2 milk on health: facts and implications. *J Dairy Vet Sci.* (2019) 9:11–2. doi: 10.19080/JDVS.2019.09.555761

76. Singhal S, Baker RD, Baker SS. A comparison of the nutritional value of cow’s milk and nondairy beverages. *J Pediatr Gastroenterol Nutr.* (2017) 64:799–805. doi: 10.1097/MPG.0000000000001380

77. Truswell AS. The A2 milk case: a critical review. *Eur J Clin Nutr.* (2005) 59:623–31. doi: 10.1038/sj.ejcn.1602104

**Conflict of Interest:** SK has received funding from Uluova Süt Ticaret A.S. (Uluova Milk Trading Co.).

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Publisher's Note:** All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Copyright © 2022 Kaplan, Baydemir, Günar, Arslan, Duman and Karav. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.