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DAIRY PROTEIN BENEFITS FOR PHYSICALLY ACTIVE PEOPLE

SUMMARY

In recent years, considerable research has focused on protein's role in maintaining or increasing skeletal muscle mass and improving body composition (increasing skeletal muscle and decreasing body fat). This is particularly important for physically active people to maximize physical performance and for older adults to help prevent sarcopenia (age-related skeletal muscle wasting). Both resistance exercise (e.g., weight training, using weight machines and resistance band workouts) and an adequate intake of dietary protein (defined by the Acceptable Macronutrient Distribution Range as 10 to 35% of total energy) are strategies to maintain and build muscle mass. However, not all proteins are alike or equally effective in improving body composition. Emerging research indicates that dairy protein has beneficial effects on body composition.

Resistance exercise promotes muscle hypertrophy (i.e., an increase in muscle fiber size), but a net gain in muscle mass is only possible if an adequate intake of high-quality protein is also consumed. Dairy foods are an excellent source of the highest-quality protein (80% casein and 20% whey) providing all of the essential amino acids that humans cannot synthesize and in proportions resembling amino acid requirements. Whey protein in particular is the richest source of leucine. This branched chain amino acid has been shown to stimulate new muscle protein synthesis and inhibit muscle protein degradation after resistance exercise. Casein and whey also differ in their digestion or delivery of amino acids to skeletal muscle. Casein is described as a "slow" protein, whereas whey is regarded as a "fast" protein.

Recent studies examining the effect of different protein sources on skeletal muscle growth in young men participating in resistance exercise support the benefits of consuming milk as a source of protein. In a 12-week randomized controlled trial in 56 healthy young men who participated in a weight lifting program five days/week, those who consumed two cups of fat-free milk immediately and then again one hour after exercise (four cups total) gained more muscle mass and lost more body fat than those who consumed a soy protein beverage or a carbohydrate only beverage.

Studies of individual milk proteins, casein and particularly whey, support an increase in skeletal muscle amino acid uptake, protein synthesis, or muscle mass when consumed in the hours surrounding resistance exercise. Also, whey protein has been shown to reduce body fat under similar conditions.

For older adults, adequate intake (i.e., moderately above the RDA) of high-quality protein along with resistance exercise may help reduce the risk of sarcopenia. Preserving or increasing muscle mass may reduce older adults' risk of chronic diseases such as cardiovascular disease and type 2 diabetes, as well as promote greater independence and quality of life.

Additional research is needed to clarify dairy protein's benefits for physically active adults and its role in helping to prevent sarcopenia. However, findings to date provide another reason to consume three daily servings of dairy foods, as recommended by the 2005 Dietary Guidelines for Americans. D

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May | June 2008

INTRODUCTION

Consuming an adequate amount of high-quality protein and participating in resistance exercise (e.g., weight lifting) as part of a physically active lifestyle are important contributors to skeletal muscle size and strength, the maintenance of which contributes to health and well-being (1-5). Maintaining and/or building muscle mass is particularly important for athletes involved in strength/power sports and for older adults to offset sarcopenia (1-6). Sarcopenia is an age-related loss of muscle mass, strength, and function which affects an estimated 30% of individuals over the age of 60. This condition can limit older adults' daily physical activities, increase their risk of chronic diseases (e.g., cardiovascular disease and type 2 diabetes), and reduce their quality of life (2,3,5,7).

The Recommended Dietary Allowance (RDA) for dietary protein for adults aged 19 years and older is 0.8 g/kg body weight per day (8). The Acceptable Macronutrient Distribution Range (AMDR) for protein is 10 to 35% of total calories for adults over 18 years of age (8). While the protein needs of athletes continue to be debated by some members of the scientific community, the current joint position statement on nutrition and athletic performance by the American College of Sports Medicine, the American Dietetic Association, and the Dietitians of Canada recommends protein intakes in the range of 1.2 to 1.7 g/kg body weight per day for athletes (9). In contrast to the general population which consumes an average of ~15% of calories from protein, athletes generally meet their higher protein needs by consuming 30% to 35% of calories, which is within the AMDR (10). While data are limited, protein intakes moderately above the RDA may enhance muscle mass and fat-free mass in older adults who regularly participate in resistance exercise compared to their sedentary counterparts (2,3,11,12).

Not only the amount of protein but also the type or source of protein consumed is important for maintaining or increasing muscle mass. All proteins are not created equally. The type of protein consumed may influence the results from resistance exercise due to the amino acid composition of the protein and the ability of the body to digest and metabolize the protein (6). Emerging research indicates that consuming dairy protein in close temporal proximity to resistance exercise may positively influence muscle synthesis, body composition, and ultimately physical performance (1,6).

Adequate intake of high-quality protein combined with resistance exercise can increase muscle mass and promote loss of fat mass (i.e., improve body composition).

This *Digest* provides an overview of protein's role in increasing muscle mass and of the composition of dairy protein; reviews studies supporting a beneficial effect of milk (a food source of protein) and dairy proteins in recovery from resistance exercise; and discusses the role of protein and the potential metabolic advantage of dairy protein in maintaining muscle mass and slowing the progression or treating sarcopenia in older adults.

PROTEIN'S ROLE IN INCREASING MUSCLE MASS

Resistance exercise stimulates muscle protein synthesis (13,14). However, a net gain in muscle mass occurs only when protein or essential amino acids are also consumed (1,6,9,15). Numerous studies in both young and older adults have demonstrated that increasing protein or essential amino acid intake after resistance exercise plays a key role in resistance exercise-induced muscle hypertrophy (the increase in muscle fiber size that occurs in adulthood) (16-24).

As explained by several authors, the effects of consuming protein and participating in resistance exercise on muscle protein synthesis and ultimately muscle hypertrophy and increased muscle mass are synergistic (1,4,13,15,25). Muscle protein undergoes constant change and remodeling as a result of synthesis of new proteins and breakdown of existing proteins. Muscle hypertrophy occurs when protein synthesis is greater than breakdown (i.e., positive net protein balance); muscle wasting occurs when protein synthesis is less than breakdown (i.e., negative net protein balance). These processes are influenced by external factors such as protein intake and physical activity. After protein is consumed, the rate of muscle protein synthesis increases and is faster than the rate of protein breakdown, resulting in a positive net protein balance. In the absence of protein intake (i.e., fasting state), protein synthesis decreases and protein breakdown increases, resulting in a negative protein balance or net catabolic state. This negative protein balance continues until adequate dietary protein is available to stimulate protein synthesis. Resistance exercise (e.g., weight lifting) increases muscle protein synthesis, but because protein breakdown is greater than protein synthesis, skeletal muscle remains in negative protein balance, albeit less negative, until dietary protein or amino acids are consumed.

Combining resistance exercise with a beverage containing only carbohydrate can improve net muscle protein balance, but the balance is ultimately still negative and remains so until protein is consumed (26). Cumulative periods of positive protein balance that occur after resistance exercise and protein intake sum up to increase skeletal muscle mass and, in part, strength (1,14,17). In an effort to identify specific nutritional strategies to stimulate muscle protein synthesis in response to resistance exercise, recent research has focused on the source of protein, particularly the potential advantages of dairy protein.

DAIRY PROTEIN

Cow's milk contains 3.5% protein, of which 80% is casein and 20% is whey (27). Dairy foods are an excellent source of high quality proteins providing varying amounts of all the essential amino acids that humans cannot synthesize and in proportions generally greater than most recognized amino acid requirements. Dairy proteins, particularly whey protein, are a rich source of branched chain amino acids (BCAAs) – leucine, isoleucine, and valine (28,29). The BCAA content of dietary protein sources varies with whey protein isolate containing 26%, milk containing 21%, and soy protein isolate containing 18% (29). In resting human muscle, BCAAs (specifically leucine) increase the rate of protein synthesis and decrease the rate of protein degradation; after endurance exercise, BCAAs attenuate exercise-induced muscle damage and promote recovery (28,30,31).

Among the BCAAs, leucine holds a key position as it alone can stimulate the synthesis of new muscle protein and inhibit

Dairy foods are a source of the high-quality proteins, casein and whey, which provide all the essential amino acids necessary to build and maintain muscle mass. Whey protein in particular is one of the best sources of leucine, a branched chain amino acid shown to independently stimulate muscle protein synthesis.

muscle protein degradation after resistance exercise and spare muscle mass during weight loss (28-35). Whey protein is one of the richest sources of leucine (29,33).

In addition to differences in their amino acid composition, dairy proteins also vary in their digestion/absorption or delivery of amino acids to peripheral circulation (e.g., skeletal muscle) (1,6,36-38). Casein is described as a "slow" protein because of its slower rate of digestion which results in a more prolonged delivery of amino acids to systemic circulation than whey protein (36). While casein stimulates protein synthesis, research shows that its primary benefit lies in suppressing whole body protein breakdown (36). In contrast, whey protein is known as a "fast" protein because it is digested rapidly, leads to a large but transient increase in blood levels of amino acids, and stimulates protein synthesis and oxidation (36,38).

As a result of advances in techniques to fractionate dairy protein, whey protein products such as whey protein concentrate containing 80% (w/w) protein and a whey protein isolate containing 90% to 95% protein are available for inclusion in sports drinks and energy bars (39).

PROTEIN SOURCE & RECOVERY FROM RESISTANCE EXERCISE: THE ADVANTAGES OF MILK

Studies have examined the effect of the source of dietary protein, specifically milk, on muscle protein balance and muscle accretion after resistance exercise (1,40-42). An early investigation in young adults showed that milk consumption following resistance exercise resulted in the uptake of the amino acids, phenylalanine and threonine, by the exercised leg, which is representative of net muscle protein synthesis (40).

More recently, an investigation in eight young men who regularly participated in weight lifting activities found that consuming fat-free milk after a single or acute bout of resistance exercise (i.e., lower body leg workout such as leg press, hamstring curl, knee extension) resulted in a greater net muscle protein balance and 34% more muscle protein synthesis over the three hours following exercise compared to

May | June 2008

intake of a soy protein beverage (41). The beverages were equal in protein, carbohydrate, fat, and calorie content. Because the protein (amino acid) content of the two beverages was similar, the researchers hypothesized that the differences in net muscle protein balance and muscle protein synthesis were likely due to differences in the delivery of and patterns of change in amino acids (41). Specifically, the slower digestion of milk protein (which contains an ~1:4 ratio of whey [fast] to casein ["slow"] proteins) than soy protein (which contains "fast" proteins) can be expected to result in a more gradual and sustained release of amino acids into the bloodstream that are available to muscle over time (43,44). Thus, consuming milk following resistance exercise may lead to a greater increase in muscle mass over time than intake of a soy protein beverage. The researchers speculated that milk consumption following resistance exercise may be particularly valuable for persons with compromised muscle mass, such as older adults (41).

To determine if the short-term benefits of consuming milk following resistance exercise shown in the study previously described (41) translate into superior gains in lean body mass over the long-term, researchers conducted a randomized controlled trial in 56 healthy young men who were moderately active, but not participating in any weight lifting activities (42). During the 12-week study, the men participated in a resistance exercise program five days/week and were randomly assigned to consume two cups of one of the following three beverages immediately and then again one hour after exercise: fat-free milk; a fat-free soy protein drink (calories, nitrogen content, and proportion of macronutrients matched to milk); or a flavored carbohydrate drink (calories matched to other study drinks). Skeletal muscle, body composition, and strength were measured before and after the 12-week program (42).

Results showed that muscle mass increased in all groups throughout the training period, with the greatest increase seen in the milk group. Participants in the milk group gained nearly 40% more muscle mass than the soy protein beverage drinkers and over 60% more muscle mass than the carbohydrate only beverage drinkers (42). Also, those in the milk group lost significantly more body fat (2.9 pounds) than those in the carbohydrate drink group (1.1 pounds) or the soy drink group (0.4 pounds). The researchers (42) speculated that the milk group's higher overall calcium intake (~700 mg/day greater) and/or properties of milk proteins themselves (e.g., relatively high leucine content) may explain the greater loss of body fat observed in the milk group (39,45-47).

According to a new study, young men who consistently drank fat-free milk following resistance training improved their body composition, gaining more muscle mass and losing more body fat over time, than when they consumed a soy protein or carbohydrate only beverage.

DAIRY PROTEINS & RECOVERY FROM RESISTANCE EXERCISE

Milk's protein explains in large part its beneficial effects on muscle mass and body composition described above. Milk protein has been shown to result in a greater stimulation of whole body protein synthesis and a higher whole-body retention of dietary nitrogen than soy protein (43,48). Also, milk proteins appear to be superior to, or at least equivalent to, either isolated whey or casein alone in supporting postprandial dietary nitrogen utilization (49). One study demonstrated that casein resulted in higher protein synthesis and lower oxidation of amino acids, as evidenced by lower urea production, than consumption of a soy protein meal (50).

Studies of individual milk proteins, casein and particularly whey, support an increase in skeletal muscle amino acid uptake, protein synthesis, or muscle mass under conditions of resistance exercise (6,16,18-23,51,52). A comparison of whey versus casein (20 g each) consumption one hour after resistance exercise found that both dairy proteins stimulated an equivalent net amino acid uptake (i.e., positive net muscle protein balance) compared to a placebo (18).

Considerable attention has focused on the benefits of whey protein either in various formulations or alone for persons participating in resistance exercise.

A recent investigation demonstrated greater increases in lean body mass and muscle strength following 10 weeks of resistance training and intake of 20 g protein (14 g whey and casein protein, 6 g free amino acids) consumed one hour before and after exercise compared to a carbohydrate placebo (52).

Another investigation found that consuming a beverage providing a small amount of whey protein (10 g) with carbohydrate (21 g) following resistance exercise resulted in a greater increase in muscle protein synthesis compared to a carbohydrate only beverage in eight healthy resistance-trained (weight lifting) young men (51). In a 12-week, double-blind study of 13 male recreational body builders, whey protein isolate was shown to improve body composition (i.e., increase lean body mass and decrease body fat) and strength that accompany routine resistance exercise to a greater extent than was achieved with equivalent casein consumption (20). Additional support for the benefits of whey protein (with or without creatine) on body composition, muscle fiber size, and muscle strength was provided by findings from a subsequent study in 26 resistance-trained men (22).

Studies report that whey protein is most effective in augmenting the effects of resistance exercise when consumed within an hour or so before or after resistance exercise (6,19,21).

DAIRY PROTEINS AND PREVENTION OF SARCOPENIA

Both strength training and an adequate intake of high quality protein help to preserve muscle tissue during aging (2,3,6,53). Insufficient protein intake in older adults can lead to the loss of muscle, a core process in sarcopenia (2,3,54,55). Although the optimal amount of protein to prevent or offset the progression of sarcopenia is yet to be established (55), research findings suggest that protein intakes modestly above the present RDA of 0.8 g/kg body weight/day (i.e., 1 g/kg body weight/day or higher) enhance muscle mass in older adults who regularly perform resistance exercise (2,3,11,12). Protein intake in older adults appears to have a more beneficial effect on muscle hypertrophy when consumed within an hour or so of resistance exercise (54).

Moderately increasing protein intake above the RDA by consuming high-quality protein foods such as milk, while regularly participating in resistance exercise, may help older adults retain muscle mass and reduce the risk of sarcopenia.

With respect to the source of protein, a comparison of animal (i.e., high-quality protein) vs. vegetable protein in older women showed that animal protein was associated with better preservation of muscle mass (56). Limited evidence indicates that when older adults consume an adequate intake (i.e., moderately above the RDA) of high-quality protein, the predominant source of protein (e.g., eggs, meats, dairy, soy) does not influence the response to strength training (2,3). Other emerging research suggests that dairy protein, especially whey protein, may minimize sarcopenia because of its high concentration of leucine which increases muscle protein synthesis (6,24,57-61).

Findings in older experimental animals (61) and older adults (57,59) suggest that increasing leucine intake may restore the anabolic response of muscle to protein-containing meals which typically diminishes with age (58). One study found that intake of a small amount of an essential amino acid mixture enriched with leucine (41%) reversed the attenuated response of muscle protein synthesis in older adults (59). Another investigation compared the effects of consuming carbohydrate vs. carbohydrate plus protein (whey protein hydrolysate) and leucine on muscle protein synthesis in young and elderly men after participating in normal activities of daily living (57). Although muscle synthesis rates were lower in the older than younger men after exercise, the increase in muscle synthesis rates did not differ significantly between the older and younger men after co-ingestion of protein and leucine (57). Further research is needed to determine whether various sources of high-quality protein differ in their ability to prevent or reduce sarcopenia.

CONCLUSION

The emerging beneficial role of dairy proteins in preserving or increasing muscle mass in physically active adults provides another important reason (i.e., beyond the well-recognized benefits for bone health) to consume three daily servings of dairy foods, as recommended by the 2005 Dietary Guidelines for Americans (62). D

REFERENCES

1. Phillips, S.M., J.W. Hartman, and S.B. Wilkinson. J. Am. Coll. Nutr. *24*: 134s, 2005.
2. Campbell, W.W. Nutr. Rev. *65*: 416, 2007.
3. Campbell, W.W., and H.J. Leidy. J. Am. Coll. Nutr. *26*: 696s, 2007.
4. Wolfe, R.R. J. Nutr. *136*: 525s, 2006.
5. Wolfe, R.R. Am. J. Clin. Nutr. *84*: 475, 2006.
6. Hayes, A., and P.J. Cribb. Curr. Opin. Clin. Nutr. Metab. Care *11*: 40, 2008.
7. Doherty, T. J. Appl. Physiol. *95*: 1717, 2003.
8. Food and Nutrition Board, Institute of Medicine of the National Academies. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.* Washington, D.C.: The National Academy Press, 2005.
9. American College of Sports Medicine, American Dietetic Association, and Dietitians of Canada. Med. Sci. Sports Exerc. *32*: 2130, 2000.
10. Phillips, S.M. Appl. Physiol. Nutr. Metab. *31*: 647, 2006.
11. Evans, W. J. Am. Coll. Nutr. *23*: 601s, 2004.
12. Morais, J., S. Chevalier, and R. Gougeon. J. Nutr. Health Aging *10*: 272, 2006.
13. Biola, G., K.D. Tipton, S. Klein, et al. Am. J. Physiol. *273*: E122, 1997.
14. Rennie, M.J., H. Wackerhage, E.E. Spangenburg, et al. Annu. Rev. Physiol. *66*: 799, 2004.
15. Tipton, K.D., and R.R. Wolfe. J. Sports Sci. *22*: 65, 2004.
16. Burke, D., P. Chilibeck, K. Davison, et al. Int. J. Sport Nutr. Exerc. Metab. *11*: 349, 2001.
17. Tipton, K.D., E. Borsheim, S.E. Wolf, et al. Am. J. Physiol. Endocrinol. Metab. *284*: E76, 2003.
18. Tipton, K., T. Elliott, M. Cree, et al. Med. Sci. Sports Exerc. *36*: 2073, 2004.
19. Tipton, K.D., T.A. Elliott, M.G. Cree, et al. Am. J. Physiol. Endocrinol. Metab. *292*: E71, 2007.
20. Cribb, P., A. Williams, M. Carey, et al. Int. J. Sport Nutr. Exerc. Metab. *16*: 494, 2006.
21. Cribb, P., and A. Hayes. Med. Sci. Sports Exerc. *38*: 1918, 2006.
22. Cribb, P., A. Williams, C. Stathis, et al. Med. Sci. Sports Exerc. *39*: 298, 2007.
23. Cribb, P.J., A.D. Williams, and A. Hayes. Med. Sci. Sports Exerc. *39*: 1960, 2007.
24. Paddon-Jones, D., M. Sheffield-Moore, C.S. Katsanos, et al. Exp. Gerontol. *41*: 215, 2006.
25. Tipton, K.D., A.A. Ferrando, S.M. Phillips, et al. Am. J. Physiol. Endocrinol. Metab. *276*: E628, 1999.
26. Miller, S.L., K.D. Tipton, D.L. Chinkes, et al. Med. Sci. Sports Exerc. *35*: 449, 2003.
27. U.S. Department of Agriculture, Agricultural Research Service. *USDA National Nutrient Database for Standard Reference, Release 20.* Nutrient Data Laboratory Home Page, 2007. www.ars.usda.gov/ba/bhnrc/ndl

May | June 2008

28. Ha, E., and M.B. Zemel. J. Nutr. Biochem. *14*: 251, 2003.
29. Layman, D.K. J. Nutr. *133*: 261s, 2003.
30. Shimomura, Y., Y. Yamamoto, G. Bajotto, et al. J. Nutr. *136*: 529s, 2006.
31. Blomstrand, E., J. Eliasson, H.K.R. Karlsson, et al. J. Nutr. *136*: 269s, 2006.
32. Layman, D.K., and J.I. Baum. J. Nutr. *134*: 968s, 2004.
33. Layman, D.K., and D.A. Walker. J. Nutr. *136*: 319s, 2006.
34. Norton, L.E., and D.K. Layman. J. Nutr. *136*: 533s, 2006.
35. Garlick, P.J. J. Nutr. *135*: 1553s, 2005.
36. Boirie, Y., M. Dangin, P. Gachon, et al. Proc. Natl. Acad. Sci. USA *94*: 14930, 1997.
37. Dangin, M., Y. Boirie, C. Garcia-Rodenas, et al. Am. J. Physiol. Endocrinol. Metab. *280*: E340, 2001.
38. Dangin, M., C. Guillet, C. Garcia-Rodenas, et al. J. Physiol. *549*: 635, 2003.
39. Schaafsma, G. Curr. Topics Nutraceutical Res. *4(2)*: 113, 2006.
40. Elliott, T.A., M.G. Cree, A.P. Sanford, et al. Med. Sci. Sports Exerc. *38*: 667, 2006.
41. Wilkinson, S.B., M.A. Tarnopolsky, M.J. MacDonald, et al. Am. J. Clin. Nutr. *85*: 1031, 2007.
42. Hartman, J.W., J.E. Tang, S.B. Wilkinson, et al. Am. J. Clin. Nutr. *86*: 373, 2007.
43. Fouillet, H., F. Mariotti, C. Gaudichon, et al. J. Nutr. *132*: 125, 2002.
44. Bos, C., C.C. Metges, C. Gaudichon, et al. J. Nutr. *133*: 1308, 2003.
45. Zemel, M.B. Am. J. Clin. Nutr. *79*: 907s, 2004.
46. Zemel, M. B., W. Thompson, A. Milstead, et al. Obes. Res. *12*: 582, 2004.
47. Sun, X., and M.B. Zemel. Lipids *42*: 297, 2007.
48. Morens, C., C. Bos, M. Pueyo, et al. J. Nutr. *133*: 2733, 2003.
49. Lacroix, M., C. Bos, J. Leonil, et al. Am. J. Clin. Nutr. *84*: 1070, 2006.
50. Luiking, Y.C., N.E. Deutz, M. Jakel, et al. J. Nutr. *135*: 1080, 2005.
51. Tang, J.E., J.J. Manolakos, G.W. Kujbida, et al. Appl. Physiol. Nutr. Metab. *32*: 1132, 2007.
52. Willoughby, D.S., J.R. Stout, and C.D. Wilborn. Amino Acids *32*: 467, 2007.
53. Esmarck, B., J.L. Andersen, S. Olsen, et al. J. Physiol. *535(Pt.1)*: 301, 2001.
54. Paddon-Jones, D. J. Nutr. *136*: 2123, 2006.
55. Houston, D.K., B.J. Nicklas, J. Ding, et al. Am. J. Clin. Nutr. *87*: 150, 2008.
56. Lord, C., J.P. Chaput, M. Aubertin-Leheudre, et al. J. Nutr. Health Aging *11*: 383, 2007.
57. Koopman, R., L. Verdijk, R.J.F. Manders, et al. Am. J. Clin. Nutr. *84*: 623, 2006.
58. Fujita, S., and E. Volpi. J. Nutr. *136*: 277s, 2006.
59. Katsanos, C.S., H. Kobayashi, M. Sheffield-Moore, et al. Am. J. Physiol. Endocrinol. Metab. *291*: E381, 2006.
60. Rieu, I., M. Balage, C. Sornet, et al. J. Physiol. *575*: 305, 2006.
61. Rieu, I., M. Balage, C. Sornet, et al. Nutrition *23*: 323, 2007.
62. U.S. Department of Health and Human Services and U.S. Department of Agriculture. *Dietary Guidelines for Americans, 2005.* 6th Edition. Washington, D.C.: U.S. Government Printing Office, January, 2005. www.healthierus.gov/dietaryguidelines D

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www.usdec.org
- Cribb, P.J. Sarcopenia and whey proteins. Applications Monograph, 2006.
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