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SCHOLARLY REVIEW

The Effect of Whole Egg Intake on Muscle Mass: Are the Yolk and Its Nutrients Important?

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Whole egg may have potential benefits for enhancing muscle mass, independent of its protein content. The yolk comprises ~40% of the total protein in an egg, as well as containing several nonprotein nutrients that could possess anabolic properties (e.g., microRNAs, vitamins, minerals, lipids, phosphatidic acid and other phospholipids). Therefore, the purpose of this narrative review is to discuss the current evidence as to the possible effects of egg yolk compounds on skeletal muscle accretion beyond those of egg whites alone. The intake of whole egg seems to promote greater myofibrillar protein synthesis than egg white intake in young men. However, limited evidence shows no difference in muscle hypertrophy when comparing the consumption of whole egg versus an isonitrogenous quantity of egg white in young men performing resistance training. Although egg yolk intake seems to promote additional acute increases on myofibrillar protein synthesis, it does not seem to further enhance muscle mass when compared to egg whites when consumed as part of a high-protein dietary patterns, at least in young men. This conclusion is based on very limited evidence and more studies are needed to evaluate the effects of egg yolk (or whole eggs) intake on muscle mass not only in young men, but also in other populations such as women, older adults, and individuals with muscle wasting diseases.

Keywords: albumin, cholesterol, myofibrillar protein synthesis, egg yolk, muscle hypertrophy, lean mass

Key Points

- Whole egg is a potential food source for enhancing muscle mass, irrespective of its protein content.
- Egg yolk contains several nonprotein components that may have anabolic properties.
- Cholesterol intake from eggs may exert some influence on testosterone levels, but its anabolic effect seems to be minimal for promoting muscle hypertrophy.
- Whole egg intake seems to promote a greater acute muscle protein synthesis (MPS) response when compared with egg white in young men.
- Limited evidence shows that whole egg intake does not promote higher muscle mass gains than white egg intake in young men.

Chicken eggs are commonly ingested by the general population at breakfast (U.S. Department of Agriculture [USDA], 2013), as well as by physically active individuals as a regular component of a high-protein diet (Faber et al., 1986). A medium egg weighs approximately 50 g (33 g egg white and 17 g yolk), of which 12.5% of its mass corresponds to protein (mainly albumin; USDA, 2019). Albumin is a high-quality protein source (Moore et al., 2009; USDA, 2019), requiring an intake of approximately 20 g to maximally stimulate MPS in a single meal (Moore et al., 2009). The yolk comprises ~40% of the total protein in an egg (USDA, 2019; van Vliet et al., 2017) as well as containing several other nonprotein nutrients with potential anabolic effects such as microRNAs, vitamins, minerals, lipids, phosphatidic acid, and other phospholipids (Baier et al., 2015; Capiati et al., 2002; Halevy & Lerman, 1993; Joy et al., 2014; McClung et al., 2007; Weihrauch & Son, 1983; Yasuda et al., 2014), suggesting that whole eggs may be a potential food source for enhancing muscle mass, irrespective of its protein content.

To evaluate the possible effect of yolk and its nutrients intake on muscle mass, recent studies have compared the effects of whole egg versus egg white intake on MPS (van Vliet et al., 2017) and muscle mass gain in resistance-trained individuals (Bagheri et al., 2020, 2021). Thus, the purpose of this narrative review is to discuss the current evidence as to the effects of whole egg intake on muscle mass, exploring the possible effects of egg yolk compounds that may contribute to skeletal muscle accretion beyond those of egg white alone. We also aim to highlight gaps in the current literature on the topic and help to provide direction for future research.

Nonprotein Nutrients of Egg Yolk

Besides protein content (USDA, 2019; van Vliet et al., 2017), egg yolk possesses several nonprotein nutrients with possible anabolic properties including microRNAs (Baier et al., 2015), vitamins (Capiati et al., 2002; Halevy & Lerman, 1993), minerals (McClung et al., 2007), lipids, palmitic acid (Yasuda et al., 2014), phosphatidic acid (Joy et al., 2014), choline, and phospholipids (Weihrauch & Son, 1983). Some of these nutrients are discussed in the following sections with respect to their potential role in anabolism.

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Phospholipids

One egg yolk contains approximately 6 g of lipids, of which 30% (~1.8 g) are phospholipids (USDA, 2019). The main phospholipid class found in eggs is phosphatidylcholine, which represents ~72% of phospholipids (Andersen et al., 2013). Since the habitual intake of phospholipids in the typical Western diet is 2–8 g (Cohn et al., 2010), whole egg is an important food source for this nutrient (Blesso, 2015). Dietary phospholipids and even some modified phospholipid compounds may have anti-inflammatory effects (Bretscher et al., 2015; Feige et al., 2010; Kullenberg et al., 2012).

Whole egg intake may decrease inflammatory biomarkers. In a 12-week study evaluating individuals with metabolic syndrome, the intake of three whole eggs per day, but not egg substitute, reduced tumor necrosis factor-alpha (Ratliff et al., 2008). Another study of same duration but in overweight individuals showed that C-reactive protein levels were reduced after intake of whole eggs (640 mg additional cholesterol/day provided by eggs) compared to placebo (no additional dietary cholesterol), in which both groups underwent a carbohydrate-restricted diet (Blesso et al., 2013). However, this anti-inflammatory effect does not seem to occur in all populations, such as healthy individuals (Andersen, 2015). Considering that elevated C-reactive protein and tumor necrosis factor-alpha are associated with muscle mass loss (Schaap et al., 2006, 2009), it can be hypothesized that the intake of phospholipids through whole eggs could be a protective factor for muscle maintenance in some populations, such as older adults and individuals with muscle wasting diseases. However, this rationale remains speculative, given an absence of research evaluating the isolated effects of dietary phospholipids on muscle mass.

Egg yolk contains phosphatidic acid, a phospholipid that has been investigated for its potential to increase a mammalian target of rapamycin signaling, MPS, and muscle mass (Andre et al., 2016; Gonzalez et al., 2017; Joy et al., 2014; Shad et al., 2015; Smeuninx et al., 2019). One study showed increases in a mammalian target of rapamycin signaling and muscle hypertrophy from phosphatidic acid supplementation (Joy et al., 2014), while other studies found no effects on muscle mass gain (Andre et al., 2016; Gonzalez et al., 2017). There also is evidence that phosphatidic acid supplementation can attenuate the increase in MPS induced by resistance exercise in older men (Smeuninx et al., 2019). Most studies tested the effect of soy-derived phosphatidic acid, which seems to induce a greater mammalian target of rapamycin activation than egg-derived phosphatidic acid observed in vitro (Joy et al., 2014). Therefore, the effects of phosphatidic acid supplementation on muscle mass are conflicting and it remains unknown whether the phosphatidic acid consumed through egg yolk may have beneficial effects on muscle hypertrophy.

Omega-3 Fatty Acids

Omega-3 is a class of polyunsaturated fatty acids with possible effects on muscle mass (Rossato, Schoenfeld, et al., 2020). Omega-3 may enhance the membrane fluidity of muscle fibers, improving the uptake of amino acids and, consequently, making the cell more sensitive to MPS (McGlory et al., 2016; Smith et al., 2011a, 2011b; Tachtsis et al., 2018). In addition, omega-3 possesses anti-inflammatory effects (McGlory et al., 2019), which can result in positive effects on muscle mass given that increased inflammation is an established cause of muscle loss (Breen & Phillips, 2011; Roubenoff, 2007; Schaap et al., 2006, 2009).

It is well known that fish oil is the major dietary source of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA; USDA, 2016); however, whole egg also contains omega-3 derivatives (USDA, 2019). Overall, one yolk contains approximately 0.002 g of EPA and 0.019 g of DHA (USDA, 2019), which can vary depending on how the hens are housed (outdoors on pasture or indoors; Kuhn et al., 2014), as well as by the methods to quantify omega-3 in eggs (e.g., hydrophilic interaction liquid chromatography and gas chromatography mass spectrometry; Walczak et al., 2016). The National Health and Nutrition Examination Survey data show that both young and older adults ingest low amounts of EPA and DHA in the United States (Papanikolaou et al., 2014; Rossato, de Branco, et al., 2020). The average intake of EPA and DHA from foods by adults is ~0.023 and ~0.063 g/day, respectively (Papanikolaou et al., 2014), while older adults consume ~ 0.042 and ~0.077 g/day, respectively (Rossato, de Branco, et al., 2020). To consume this amount of DHA exclusively from whole eggs, a person would need to consume ~ four eggs, whereas ~21 eggs are needed to achieve the amount of EPA. Thus, whole eggs do not seem to be a nutritionally relevant source of EPA and DHA in the American diet. In addition, it should be noted that 0.25 g/day of EPA/DHA are recommended by the Food and Agriculture Organization/World Health Organization Expert Consultation (Joint, 2010) and European Food Safety Authority for general health (EFSA Panel on Dietetic Products, Nutrition, & Allergies, 2010); a daily consumption of ~12 whole eggs would be required to reach this level.

Several interventional studies evaluated the effect of high doses of EPA and DHA supplementation (most using fish oil) on muscle mass in young and older individuals (Cornish et al., 2018; Da Boit et al., 2017; Harden et al., 2014; Logan & Spriet, 2015; Noreen et al., 2010; Robinson et al., 2008; Smith et al., 2015; Strandberg et al., 2015). Even using doses much larger than those contained in whole eggs, there is conflicting evidence as to whether EPA and DHA intakes have a beneficial effect on muscle mass (Rossato, Schoenfeld, et al., 2020). Therefore, it is unlikely that the EPA and DHA contained in yolk have important effects on regulating muscle mass.

Cholesterol

The yolk of a medium egg contains ~225 mg of cholesterol (McCance & Widdowson, 2004), which conceivably could have indirect anabolic effects, since testosterone is synthesized from cholesterol (Johnson & Wood, 2001). Testosterone is an anabolic hormone that plays an essential role in the maintenance of muscle mass and strength (Herbst & Bhasin, 2004), and many consumer websites claim that ingesting whole eggs, and consequently cholesterol, is a viable strategy to increase testosterone levels; however, these claims lack a sound scientific basis.

To date, only one study has evaluated the effect of high dietary cholesterol intake mainly through whole eggs on testosterone levels. Bagheri et al. (2021) compared the intake of three whole eggs (842 mg/day of cholesterol, being 672 mg exclusively from eggs) versus six egg whites (285 mg/day of cholesterol, being 0 mg from eggs) on testosterone levels in young adults who performed 12 weeks of resistance training. The whole egg group increased testosterone levels by 2.4 ng/ml, while the egg white group increased levels by 0.7 ng/ml; however, the additional increase in testosterone levels induced by whole eggs intake was not sufficient to enhance gains in muscle mass (Bagheri et al., 2021). It is conceivable that testosterone fluctuations within the established normal physiological range for men (i.e., ~300–800 ng/dl) does not have a meaningful impact on human anabolism (Morton et al., 2016; West et al., 2009), although some evidence challenges this hypothesis (Mouser et al., 2016). In sum, the limited evidence shows that consumption of cholesterol from eggs may exert some influence on testosterone levels, but its anabolic effect seems ineffectual for promoting exercise-induced muscle hypertrophy. More studies are needed evaluating the effects of a greater amount (greater than three eggs) of whole eggs on testosterone levels.

Vitamin D

Egg yolk contains vitamin D (USDA, 2019), which has been positively associated with muscle mass (Tieland et al., 2013). Besides their natural vitamin D content, eggs can be fortified with D_3 and $25(OH)D_3$ to avoid vitamin D deficiency (Guo et al., 2018). Eggs can naturally be fortified with vitamin D by three methods: feeding more vitamin $D_3/25(OH)D_3$ to the hens, exposing the hens to ultraviolet B (UVB), and exposing liquid egg products to UVB (Barnkob et al., 2020). Interestingly, in an 8-week randomized clinical trial conducted in winter, restricted egg intake (≤2 eggs/week) resulted in ~6–7 nmol/L lower serum 25(OH)D, while seven vitamin D_3-enhanced eggs/week or seven $25(OH)D_3$-enhanced eggs/week maintained the preintervention 25(OH)D levels (Hayes et al., 2016). These results show that vitamin D-enhanced eggs can be a viable strategy to maintain 25(OH)D levels.

A meta-analysis showed that vitamin D supplementation (300–4,000 IU/day) has a small positive effect on muscle strength (mainly in individuals presenting chronically low vitamin D levels and in older adults), but no effects were shown for muscle mass (Beaudart et al., 2014). Thus, considering that high doses of vitamin D intake have no effect on augmenting hypertrophy, it is unlikely that the vitamin D contained in egg yolk would have a meaningful beneficial effect on muscle mass, since each (nonvitamin D fortified) egg contains only 37 IU of vitamin D (USDA, 2019). Importantly, the vitamin D content in eggs can vary dramatically (fourfold) based on how the hens are housed (outdoors on pasture or indoors; Kuhn et al., 2014). Therefore, from a practical standpoint, it would be necessary to ingest ~8–100 whole eggs per day to achieve the amount of vitamin D assessed in the meta-analysis (Beaudart et al., 2014), which is not a viable nutritional strategy.

Whole Egg Versus Egg White on MPS

Considering that yolk contains nonprotein nutrients with potential anabolic properties (Baier et al., 2015; Capiati et al., 2002; Halevy & Lerman, 1993; Joy et al., 2014; McClung et al., 2007; Weihrauch & Son, 1983; Yasuda et al., 2014), van Vliet et al. compared the effects of whole egg (18 g protein and 17 g fat) versus egg white (18 g protein and 0 g fat) intakes on MPS after a resistance training session in healthy young men (van Vliet et al., 2017). The ingestion of whole eggs resulted in a greater stimulation of acute MPS when compared with egg whites (van Vliet et al., 2017; Figure 1a). This comparison is particularly interesting since it affords the ability to evaluate the isolated effects of nonprotein yolk nutrients on MPS. Another possible explanation for a higher MPS after whole egg intake is the increased energy content when compared with egg whites. It is known that increased energy is important to nitrogen balance when exercise is performed (Todd et al., 1984); thus, the greater energy content in whole eggs may also have contributed for a greater MPS. A similar result was observed comparing whole milk versus fat-free milk intakes, in which the greater energy in whole milk may have increased the net amino acid uptake for threonine (Elliot, Cree, Sanford, Wolfe, & Tipton, 2006). It is also important to note that in the van Vliet et al. study a suboptimal dose of protein was administered, since participants ingested 18 g of protein at a mean body weight equal to 88 kg (van Vliet et al., 2017). This corresponds to a consumption of ~0.20 g/kg per meal, whereas a dose of 0.25–0.30 g/kg of protein per meal is generally recommended to maximize the MPS response to resistance training (Moore et al., 2015). Therefore, the limited data to date suggests that yolk intake may provide additional increases in MPS when suboptimal doses of protein are ingested, but it remains undetermined whether these effects would persist with ingestion of adequate doses of protein (~0.30 g/kg per meal). Thus, future studies should compare the effects of whole egg versus egg whites on MPS with provision of higher doses of protein.

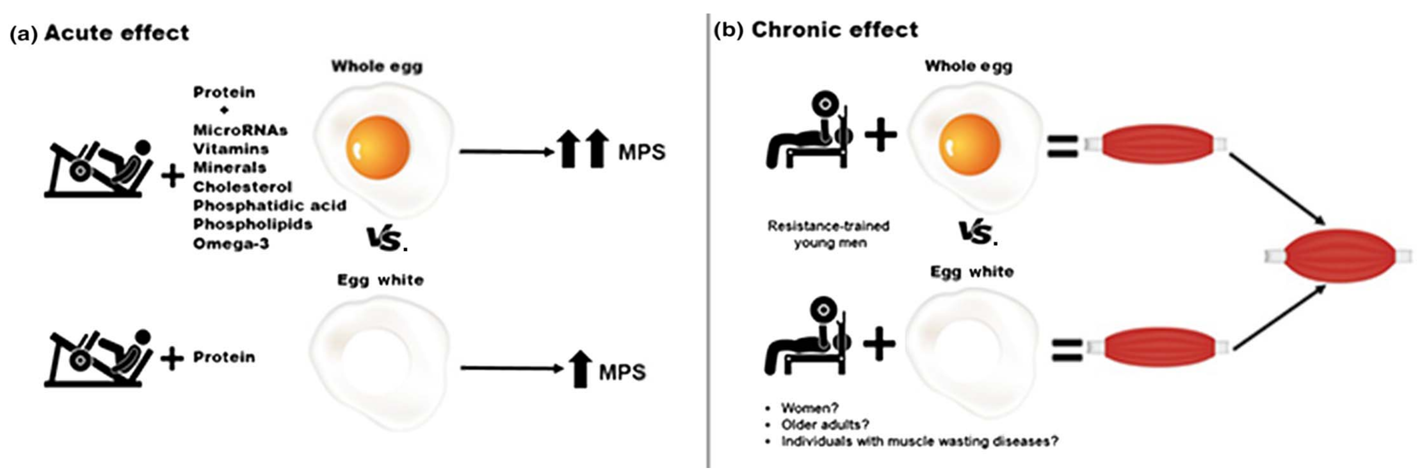

Figure 1 — Acute and chronic effects of whole egg versus egg whites on muscle mass. Panel (a) is based on van Vliet et al. (2017) study and (b) is based on Bagheri et al. (2020, 2021) studies. van Vliet et al. compared the effects of whole egg (18 g protein and 17 g fat) versus egg white (18 g protein and 0 g fat) intakes on MPS after a resistance training session in healthy young men. Bagheri et al. compared the effects of consumption of three whole eggs versus an isonitrogenous quantity of six egg whites provided immediately after resistance training in young men for 12 weeks. MPS = muscle protein synthesis.

Whole Egg Versus Egg White on Muscle Hypertrophy

As previously mentioned, whole egg intake seems to promote higher rates of MPS than egg white in young men (van Vliet et al., 2017). However, considering that acute MPS does not seem to be correlated with muscle hypertrophy at an individual level (Mitchell et al., 2014), it is necessary to evaluate the chronic effects of whole egg versus egg white intakes on muscle mass. Bagheri et al. (2020, 2021) carried out a randomized controlled trial that compared the effects of consumption of three whole eggs versus an isonitrogenous quantity of six egg whites provided immediately after resistance training in young men, with data published in two separate papers. Over the 12-week study period, consumption of whole eggs and egg whites promoted similar gains in muscle mass (assessed by computed tomography; Bagheri et al., 2021), suggesting that the consumption of yolk and its nutrients do not have additive effects on muscle hypertrophy in young men, at least when total protein intake is adequate (the groups ingested ~1.4 g/kg per day; Figure 1b). However, whole egg promoted a greater absolute increase in total lean mass compared to egg white (0.8 kg), although results did not reach statistical significance ($p = .06$). Caution is needed to interpret this result, since the change of total lean mass was assessed by bioimpedance, which has known limitations for detecting fluctuations in lean mass over time (Jackson et al., 1988; Mulasi et al., 2015). Therefore, the limited current evidence indicates that egg yolk intake likely does not enhance the accretion of muscle mass under protein-equated conditions, although findings of a potential benefit on lean mass raise the possibility of an anabolic effect that warrants further investigation. The discordancy between the acute (van Vliet et al., 2017) and long-term studies (Bagheri et al., 2020, 2021) could be partially explained because the egg whites and yolks are consumed as part of an overall dietary pattern and several of the aforementioned nutrients contained in eggs could also have been obtained from other dietary sources.

The study by Bagheri et al. (2020, 2021) also evaluated the effects of whole egg intake versus egg whites on muscle strength. Although they observed no effect on muscle strength when evaluated by one-repetition maximum (Bagheri et al., 2020), an additional increase was noted when strength was evaluated by isometric knee extension and handgrip strength (Bagheri et al., 2021). Thus, it is possible that the nutrients contained in yolk may potentiate the strength gains induced by resistance training, although this conclusion is based on conflicting and limited evidence.

Is It Safe to Consume Whole Eggs?

Whole eggs contain a relatively high amount of cholesterol (McCance & Widdowson, 2004), which is frequently associated with serum lipid concentrations (Rouhani et al., 2018; Santos, 2018), and cardiovascular disease and mortality risks (Abdollahi et al., 2019; Dehghan et al., 2020; Drouin-Chartier et al., 2020). A meta-analysis of randomized clinical trials showed that the consumption of whole-chicken eggs (~1–3 eggs per day) increased total cholesterol by 5.6 mg/dl, low-density lipoprotein cholesterol by 5.5 mg/dl, and high-density lipoprotein cholesterol by 2.1 mg/dl (Rouhani et al., 2018). However, these increases in total cholesterol and low-density lipoprotein cholesterol do not necessarily lead to cardiovascular events. A recent cohort study of 1950 men (aged 42–60 years) determined that neither whole egg nor cholesterol intakes were associated with stroke risk (Abdollahi et al., 2019). In support of these findings, Drouin-Chartier et al. (2020) evaluated the association between whole egg intake and cardiovascular disease risk among women and men in the United States, and also conducted a meta-analysis of prospective cohort studies. Results indicated that moderate egg consumption (up to one egg per day) was not associated with cardiovascular disease risk (Drouin-Chartier et al., 2020). Similarly, Dehghan et al. analyzed ~177,000 individuals, 12,701 deaths, and 13,658 cardiovascular disease events from 50 countries across six continents, and found no significant associations between whole egg intake and blood lipids, mortality, or cardiovascular disease events.

When considering the body of literature, current evidence shows that a moderate intake of whole eggs (≤3 units per day) does not impact cardiovascular disease and mortality risk (Abdollahi et al., 2019; Dehghan et al., 2020; Drouin-Chartier et al., 2020; Rouhani et al., 2018). However, it is important to mention that the aforementioned studies analyzed observational data, thus precluding the ability to find causality on the topic. Moreover, some physically active individuals, particularly athletes such as bodybuilders, sometimes ingest high amounts of whole eggs, varying from 0 to 81 eggs per week (~12 eggs/day; Faber et al., 1986). Since the meta-analytic data are specific to an intake of one to three eggs per day (Dehghan et al., 2020; Drouin-Chartier et al., 2020), it is unknown whether consumption above this amount is safe. In addition, we may pay more attention to dietary cholesterol, not egg, and cardiovascular disease risk in this debate.

Potential Limitations of the Current Evidence and Suggestions for Future Studies

We should highlight that is not fully clear whether egg yolk intake (or whole egg) has beneficial effects on MPS or muscle mass, since few studies have sought to investigate this topic (Bagheri et al., 2020; van Vliet et al., 2017). To date, only one study (van Vliet et al., 2017) assessed the effects of egg yolk intake on MPS; and one intervention (evaluated in two studies ; Bagheri et al., 2020, 2021) evaluated the chronic effects of egg yolk consumption on muscle mass. In addition, all current studies were performed in young men (Bagheri et al., 2020; van Vliet et al., 2017); therefore, the effects of whole egg intake on MPS and muscle mass in other populations such as women, older adults, and individuals with muscle wasting diseases remain undetermined (Figure 1b). For the comparison of whole egg versus egg white intake on MPS, we suggest future studies evaluating the effects of yolk intake in individuals ingesting higher doses of protein (~0.30 g/kg per meal), as well as different amounts of eggs.

The conclusion about the chronic effects of whole egg versus egg white intakes on muscle mass is still in its infancy. The only intervention on the topic showed no effects of egg yolk intake on muscle hypertrophy in young adults when performing resistance training in combination with a high protein diet (~1.4 g/kg; Bagheri et al., 2020, 2021). Hence, future studies should seek to evaluate the effects of egg yolk intake on muscle mass in individuals with suboptimal protein intake (<1.2 g/kg).

An important limitation of the current literature when comparing the anabolic effects of whole eggs and egg whites is the absence of a double-blind design, since the volunteers of the studies knew what they were ingesting. Certainly, it is difficult to blind participants to whether they are consuming whole eggs versus egg whites. Thus, the provision of powdered eggs (whole or only white), as well as liquid industrialized forms, may be an effective substitute to compare the effects of whole eggs versus egg whites in a double-blind fashion. However, it is also important to mention that liquid egg products generally have additives that can limit the extrapolation of the results to whole eggs.

Future studies also should assess the chronic effects of egg yolk intake on muscle mass when consuming higher amounts of eggs (>5 units per day) to increase the intake of yolk nutrients. We also suggest that studies evaluate the effects of egg yolk intake under conditions both with and without exercise, during bed rest, and when the goal is muscle maintenance (longitudinal studies) or the attenuation of anabolic resistance in older adults.

Conclusion

Given the relative paucity of research on the topic, strong inferences cannot be drawn as to whether egg yolk intake (or whole egg) has beneficial effects on MPS or muscle mass. The limited current evidence suggests that egg yolk intake seems to enhance acute increases on myofibrillar protein synthesis, but these effects do not seem to translate into improved muscle mass, at least in young men. That said, this conclusion is based on very limited evidence and more studies are needed to better evaluate the effects of egg yolk (or whole eggs) intake on muscle mass not only in young men, but also in other populations such as women, older adults, and individuals with muscle wasting diseases.

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