

## THE PROBLEM OF MUSCLE HYPERTROPHY: REVISITED

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**ABSTRACT:** In this paper we revisit a topic originally discussed in 1955, namely the lack of direct evidence that muscle hypertrophy from exercise plays an important role in increasing strength. To this day, long-term adaptations in strength are thought to be primarily contingent on changes in muscle size. Given this assumption, there has been considerable attention placed on programs designed to allow for maximization of both muscle size and strength. However, the conclusion that a change in muscle size affects a change in strength is surprisingly based on little evidence. We suggest that these changes may be completely separate phenomena based on: (1) the weak correlation between the change in muscle size and the change in muscle strength after training; (2) the loss of muscle mass with detraining, yet a maintenance of muscle strength; and (3) the similar muscle growth between low-load and high-load resistance training, yet divergent results in strength.

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Approximately 6 decades ago, an article was published which pointed out that a “review of the literature relating to strength and to hypertrophy has thrown very little light at the relationship that exists between increases in hypertrophy and increases in strength, but it seems unlikely that any simple, direct correlation exists.”<sup>1</sup> Despite this call for concern so long ago, little has changed with how the story is told. For example, long-term adaptations in muscle strength are still proposed to be contingent on changes in muscle size. Moritani and deVries suggested that neural adaptations explain early changes in muscle strength, with muscle hypertrophy becoming the predominant mechanism in the later portions of a resistance-training program.<sup>2</sup> Given this assumption, there has been considerable attention placed on programs designed to allow maximization of both muscle size and strength.<sup>1,3</sup> An examination of the literature reveals a less clear association between a change in muscle size and a change in strength after resistance training, suggesting that these changes may be completely separate phenomena. Considering the baseline relationship in muscle size and strength,<sup>3,4</sup> it seems intuitive that

increases in muscle strength would reflect increases in muscle size. In contrast, we suggest that there is no meaningful relationship between the change in muscle size and the change in strength with training.

Although increases in muscle size and strength appear concomitant in many situations, we must still be open to the possibility that these are separate and unrelated adaptations. Ahtiainen *et al.*<sup>5</sup> found a weak association between changes in muscle size and strength after 20–24 weeks of resistance exercise in 287 untrained individuals. In addition, they noted that some individuals responded favorably in muscle size and not strength, whereas others responded in strength but not size. This is further supported by the work of Churchward-Venne *et al.*,<sup>6</sup> who examined adaptations in nearly 200 untrained individuals after 24 weeks of resistance training exercise and found that “high responders” for strength are not necessarily the “high responders” for increases in both lean body mass and muscle fiber cross-sectional area (CSA). It appears that one does not necessarily need a high propensity for skeletal muscle growth to increase strength (and vice versa). This was further demonstrated by Erskine *et al.*,<sup>4</sup> who found that muscle hypertrophy explained approximately 23%–28% of the change in strength when utilizing a design that incorporated 3 weeks of familiarization to lessen neural contribution/adaptation. Thus, the increases in strength seen during the subsequent 12 weeks of resistance training were believed to rely primarily on muscle growth. Despite this, the hypertrophic contribution was still relatively weak for something thought to play a large role, and was reduced to below 20% when accounting for baseline strength values. In contrast to findings by Erskine *et al.*, the majority of the literature has shown that the change in muscle size explains approximately 3%–5% of the change in strength when measured through a variety of techniques.<sup>5,7</sup> Nonetheless, even if a strong correlation were found, there is evidence (discussed below) suggesting the relationship may be spurious.

The disassociation between muscle size and strength is, perhaps, most easily recognized when examining adaptations to low-load resistance

**Abbreviations:** 1RM, 1-repetition maximum; CSA, cross-sectional area  
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training. Low-load resistance training and high-load resistance training appear to result in similar strength adaptations when strength is assessed in a non-specific test to which both groups are naive (e.g., isometric/isokinetic strength).<sup>8,9</sup> However, when assessing 1-repetition maximum (1RM; i.e., the most weight that a participant can lift once but not twice on a given lift), the strength on the exact lift (e.g., bench press, leg extension) that participants trained on throughout the duration of the study, the high-load condition produces superior increases in strength nearly every time relative to the lower load condition.<sup>9,10</sup> It is hard to reconcile these differences based on the assumed relationship between muscle size and strength, especially as there is similar muscle growth between these modalities.<sup>8,11</sup> This suggests that muscle growth alone, resulting from low-load resistance training, is not sufficient to yield equivalent changes in 1RM when participants are not exposed to a high-intensity stimulus (specific to the exercise tested). In support, Morton *et al.*<sup>12</sup> showed that multiple exposures to a 1RM during a low-load resistance training program can largely abolish the difference in 1RM strength typically observed between such training modalities. They suggested that the similar strength increases are likely attributed to more “practice” of the 1RM through reassessment at 3, 6, 9, and 12 weeks throughout the training program. This is perhaps due to repeated motor patterns and skill acquisition from the repeated practice of the movement.<sup>13</sup> This may also suggest that maximal strength in a movement can be achieved with less volume than what is presently prescribed, and possibly from the simple inclusion of periodic practice.

Emerging evidence suggests that muscle hypertrophy does not rely upon the exercise intensity,<sup>14,15</sup> whereas increases in 1RM strength (despite comparable growth) are consistently greater in groups exercising near a 1RM intensity.<sup>8,9</sup> In addition, it appears that increases in 1RM strength can be achieved with minimal change in muscle size. Unpublished data from our lab demonstrated that daily 1RM training (performing a single 1RM each session) on a limb will lead to large increases in 1RM strength with no change in muscle size in trained individuals. The contralateral limb, performing fatiguing sets alongside the 1RM training, resulted in significant growth. Interestingly, the increase in muscle size did not contribute further to strength adaptation over that gained by just performing the strength test. Similarly, Zourdos *et al.*<sup>16</sup> observed large increases in 1RM squat with no changes in muscle size in a small group of trained powerlifters with high levels of baseline strength. This suggests that, in a trained

population, “hypertrophy training” appears to have little relevance for increasing strength. These changes in strength are presumably facilitated through neural adaptations (e.g., increased central motor drive, elevated motor neuron excitability, and reduced presynaptic inhibition)<sup>17</sup>. Thus, it seems unlikely that the original model of strength adaptation outlined by Moritani and deVries<sup>2</sup> (predominately neural followed by predominately hypertrophy) can explain such adaptations in trained individuals.

The dissociation between hypertrophy and strength is further realized when adaptations are examined during periods of detraining. Bickel *et al.*<sup>18</sup> found that reducing training volume to one-third (3 sets/week) or one-ninth (1 set/week) of the original volume was enough to maintain strength gains in older (60–75 years) individuals, despite a loss in myofiber CSA. Further, in young (20–35 years) individuals, strength was maintained during 32 weeks of complete detraining, despite decreases in muscle fiber CSA. However, the study design included a monthly 1RM (presumably with the intention of tracking declines in strength), which may have been enough practice (once-per-month 1RM test) to maintain strength. Taaffe and Marcus<sup>19</sup> also found that 12 weeks of detraining after a resistance training program led to a small decrease in strength (5%), despite both type I and type II muscle fiber CSAs returning to baseline in a group of older (65–77 years) men, after which 8 weeks of retraining restored strength values with no change in fiber size. Finally, Hakkinen *et al.*<sup>20</sup> noted a significant correlation between the change in muscle CSA and 1RM strength, but strength remained elevated above baseline after a detraining period despite a decrease in muscle CSA to below baseline values. Together these findings suggest that strength may be easier to maintain than muscle size. In addition, the consistent maintenance of strength despite loss of muscle mass provides strong evidence that these adaptations are largely independent of each other.

The aforementioned evidence suggests that our understanding of muscle hypertrophy may be incomplete and perhaps misplaced regarding its influence on muscle strength. Since Rasch’s publication challenging this relationship in 1955, more sophisticated methods of measuring the size of the muscle have been developed, and it has become well accepted that muscle growth is a major contributing factor to strength adaptation. However, it appears this assumption may be based on little evidence. We do not dismiss the possibility that increases in muscle size with training may be

important for increasing strength; however, the current data are insufficient to confidently make such a claim. Future research is necessary to better understand the relationship between skeletal muscle growth and strength. Much like the studies designed to examine the once-assumed association between acute increases in systemic hormones and adaptation to resistance exercise,<sup>12,21,22</sup> similar work is necessary within this paradigm. This may be accomplished through study designs that employ protocols designed to maximize strength while minimizing growth or maximizing growth while minimizing strength.

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