

**Muscle size and strength : debunking the “completely separate phenomena” suggestion**

BALSHAW, Thomas G., MASSEY, Garry J., MADEN-WILKINSON, Tom <<http://orcid.org/0000-0002-6191-045X>> and FOLLAND, Jonathan P.

Available from Sheffield Hallam University Research Archive (SHURA) at:

<http://shura.shu.ac.uk/15723/>

---

This document is the author deposited version. You are advised to consult the publisher's version if you wish to cite from it.

**Published version**

BALSHAW, Thomas G., MASSEY, Garry J., MADEN-WILKINSON, Tom and FOLLAND, Jonathan P. (2017). Muscle size and strength : debunking the “completely separate phenomena” suggestion. *European Journal of Applied Physiology*, 117 (6), 1275-1276.

---

**Copyright and re-use policy**

See <http://shura.shu.ac.uk/information.html>

# European Journal of Applied Physiology

## Muscle size and strength: debunking the "completely separate phenomena" suggestion --Manuscript Draft--

<b>Manuscript Number:</b>	EJAP-D-17-00272R1
<b>Full Title:</b>	Muscle size and strength: debunking the "completely separate phenomena" suggestion
<b>Article Type:</b>	Letter to the Editor
<b>Keywords:</b>	
<b>Corresponding Author:</b>	Thomas Grant Balshaw, PhD Loughborough University Loughborough, Leicestershire UNITED KINGDOM
<b>Corresponding Author Secondary Information:</b>	
<b>Corresponding Author's Institution:</b>	Loughborough University
<b>Corresponding Author's Secondary Institution:</b>	
<b>First Author:</b>	Thomas Grant Balshaw, PhD
<b>First Author Secondary Information:</b>	
<b>Order of Authors:</b>	Thomas Grant Balshaw, PhD Garry J Massey, PhD Thomas M Maden-Wilkinson, PhD Jonathan P Folland, PhD
<b>Order of Authors Secondary Information:</b>	
<b>Funding Information:</b>	
<b>Abstract:</b>	-
<b>Response to Reviewers:</b>	12-April-2017:  Dear Editors in Chief Westerterp/Westerblad  As requested we have now amended our letter to the editor by clarifying that we are responding to a letter to the editor (i.e Buckner et al., 2017), reducing the length of our letter to under 1,000 words, and including only 5 essential references in addition to the letter to the editor we are responding to (6 total).  Regards  Thomas G. Balshaw

12-April-2017:

Dear Editors in Chief Westerterp/Westerblad,

As requested we have now amended our letter to the editor by:

1. Clarifying that we are responding to a letter to the editor (i.e Buckner et al., 2017).
2. Reducing the length of our letter to under 1,000 words,
3. Including only 5 essential references in addition to the letter to the editor we are responding to (6 total).

Regards

Thomas G. Balshaw

[Click here to view linked References](#)

## TITLE PAGE

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65

### **Title:**

Muscle size and strength: debunking the “completely separate phenomena” suggestion

### **Authors:**

Thomas G. Balshaw<sup>1,2</sup>, Garry J. Massey<sup>1,2</sup>, Thomas M. Maden-Wilkinson<sup>3</sup>, Jonathan P. Folland.<sup>1,2</sup>

### **Affiliations:**

<sup>1</sup>Arthritis Research UK Centre for Sport, Exercise and Osteoarthritis, Loughborough University, Leicestershire, UK.

<sup>2</sup>School of Sport, Exercise, and Health Sciences, Loughborough University, Leicestershire, UK.

<sup>3</sup>Faculty of Health and Wellbeing, Collegiate Campus, Sheffield Hallam University, Sheffield, UK.

### **Corresponding author:**

T.G. Balshaw. School of Sport, Exercise, and Health Sciences, Loughborough University, Leicestershire, UK, LE11 3TU. Email: [t.g.balshaw@lboro.ac.uk](mailto:t.g.balshaw@lboro.ac.uk). Telephone: +441509 226324. Fax: +441509 22630

Dear Editor,

1  
2  
3  
4 Buckner et al. (2017) query the conclusion of our recent article (“Changes in agonist neural drive,  
5 hypertrophy and pre-training strength all contribute to the individual strength gains after resistance training,”  
6 Balshaw et al. (2017)), which stated that “muscle hypertrophy in the current study...clearly did contribute to the  
7 explained variance in strength and *further negates the suggestion that strength and hypertrophy are entirely*  
8 *separate phenomena.*” and also refuted a hypothesis of theirs that the changes in muscle size and strength after  
9 resistance training (RT) are “separate and unrelated adaptations” (Buckner et al., 2016). Here we emphasise that:  
10 (a) the aim of our study was to investigate *whether there was a relationship* between putative predictor  
11 variables/adaptations after RT, rather than the nature of the relationship (e.g. causal/coincidental); (b) the  
12 existence of the relationship we found undermines the hypothesis of Buckner et al. (2016); and (c) present  
13 theory and additional evidence that refutes their hypothesis.  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25

26 The strength changes after RT observed in our study were correlated with hypertrophy ( $r=0.461$ ), as  
27 well as the changes in agonist neural drive ( $r=0.576$ ) and pre-training strength ( $r=-0.429$ ). Subsequently,  
28 hypertrophy contributed 19% towards a total of 60% explained variance in strength changes within multiple  
29 regression analysis (Balshaw et al. 2017). In addition, our previous upper body study also found hypertrophy to  
30 explain 19-23% of the variance in strength gains after RT (Erskine et al. 2014). Thus, hypertrophy and strength  
31 gains are not “entirely separate phenomena” or “separate and unrelated adaptations,” as we have demonstrated  
32 they are consistently and systematically related. Nonetheless, we agree with Buckner et al. (2017) that this  
33 evidence alone does not demonstrate causality as these experiments were not designed to address causality.  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43

44 Experimentally, the first step in understanding the interaction of two variables is to investigate if they  
45 are related, and second consider the nature of the relationship (coincidental or causal). Our paper addressed this  
46 first step as there are several reasons why this relationship has until recently been somewhat opaque:  
47  
48  
49

- 50 (i) It is widely accepted that in humans muscular strength and size are not perfectly coupled (e.g. in cross-  
51 sectional MRI studies 38-89% of the variance in isometric strength, across various muscle groups, is  
52 explained by muscle size indices), as a number of other factors are considered to also influence strength  
53 (neural drive, muscle architecture/composition, moment arm etc.), and this may set an upper limit on the  
54 strength of the hypertrophy-strength gain relationship after RT.  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65

(ii) Most RT studies have produced limited hypertrophy (typically <12%) due to their short duration ( $\leq 3$  months) and lower body RT (less hypertrophy than upper body muscles). Limited hypertrophy has likely restricted the capability of previous research to delineate the hypertrophy-strength gain relationship, and placed a greater emphasis on other adaptations (e.g. neural). One exception was our previous elbow flexor RT study, that found muscle volume to increase by 16% which probably explains why this study found the strongest hypertrophy-strength gain relationship reported to date ( $r=0.482-0.527$ ; Erskine et al., 2014).

(iii) Measurement issues have clouded the hypertrophy-strength gain relationship after RT:

- Poor muscle size measurements, including low resolution imaging techniques (e.g. ultrasound) and single site/slice measurements, as opposed to multiple slice high-resolution MRI.
- Strength measurements on one occasion, at each time point, that are subject to day-to-day variation and measurement error.
- Additive effect of noise/error when combining measurements at two time points i.e. change data.
- Studies with small participant numbers (<20) for determining relationship.

These experimental issues and the limited evidence for an individual relationship between hypertrophy and strength gains appear to have led Buckner et al. (2016) to the spurious hypothesis that hypertrophy and strength gains could be “separate and unrelated adaptations”. In contrast we believe that our recent papers are the first consistent demonstration of a relationship between hypertrophy and strength changes on an individual basis after RT. Moreover, we hypothesise that the strength of this relationship is dependent on the magnitude of hypertrophy and thus training duration, as longer-term RT produces greater hypertrophy (Narici et al. 1996), and a progressively stronger relationship might be expected as RT duration increases, although this has yet to be tested. Finally, given our consistent evidence for a relationship between strength gains and hypertrophy it now appears timely to examine the nature (e.g. causality) of the relationship using a different approach to that taken in our previous experiments.

However, theoretically and empirically we consider Buckner et al.’s hypothesis to be highly implausible. First, in isolated animal muscle physiological cross-sectional area (PCSA) explains >95% of the variance in maximum force (Powell et al. 1984) and thus it has been widely accepted for decades that a muscle’s

1 force generating capacity is proportional to its size, and specifically PCSA which reflects the number of  
2 sarcomeres/myosin-actin cross-bridges arranged in parallel and thus able to generate tension between the  
3 tendons. Human muscle working in-vivo is clearly a more complex situation (see (i) above), that explains the  
4 lower, yet still substantial, size-strength relationship in cross-sectional human studies ( $R^2=0.38-0.89$ ). This  
5 means that in humans muscle size does not perfectly predict strength on an individual basis, rather a given  
6 muscle size may define an 'envelope' of strength expression that is regulated by other factors (e.g. neural,  
7 biomechanical etc.). Second, whereas the hypertrophy-strength gain relationship has been confounded by the  
8 experimental issues (outlined above), concurrent group level changes in hypertrophy and strength have been  
9 documented to occur following diverse processes/interventions: growth/maturation, ageing, immobilisation,  
10 testosterone administration, as well as RT. These simultaneous increases/decreases in strength and size  
11 following diverse stimuli provide strong evidence that hypertrophy and strength are in fact broadly coupled.  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22

23 In conclusion, we consider the underlying influence of muscle size and thus hypertrophy on strength in  
24 healthy muscle to be based on extensive robust evidence and logic, that is most likely underpinned by a causal  
25 relationship, although we accept that in the context of RT this has yet to be categorically demonstrated. In  
26 contrast, Buckner et al.'s hypothesis appears to deny knowledge/appreciation of theory and evidence and in our  
27 view is untenable.  
28  
29  
30  
31  
32  
33  
34  
35

## 36 References

- 37  
38 Balshaw TG, Massey GJ, Maden-Wilkinson TM et al (2017) Changes in agonist neural drive, hypertrophy and  
39 pre-training strength all contribute to the individual strength gains after resistance training. *Eur J Appl Physiol*  
40 117: 631–640.  
41  
42 Buckner SL, Dankel SJ, Mattocks KT et al (2017) Muscle Size and Strength: Another study not designed to  
43 answer the question. *Eur J Appl Physiol*.  
44  
45 Buckner SL, Dankel SJ, Mattocks KT et al (2016) The problem of muscle hypertrophy: revisited. *Muscle Nerve*  
46 54: 1012-1014.  
47  
48 Erskine RM, Fletcher G, Folland JP (2014) The contribution of muscle hypertrophy to strength changes  
49 following resistance training. *Eur J Appl Physiol* 114: 1239-1249.  
50  
51 Narici MV, Hoppeler H, Kayser B et al (1996) Human quadriceps cross-sectional area, torque and neural  
52 activation during 6 months strength training. *Acta Physiol Scand* 157: 175-186.  
53  
54 Powell PL, Roy RR, Kanim, P et al (1984) Predictability of skeletal muscle tension from architectural  
55 determinations in guinea pig hindlimbs. *J Appl Physiol* 57: 1715-1721.  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65