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DETERMINANTS OF INTRA-INDIVIDUAL VARIATION IN ADAPTABILITY TO RESISTANCE TRAINING OF DIFFERENT VOLUMES WITH SPECIAL REFERENCE TO SKELETAL MUSCLE PHENOTYPES

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Determinants of intra-individual variation in adaptability to resistance training of different volumes with special reference to skeletal muscle phenotypes

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Abstract

The preface pretty much says it all.

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List of scientific papers

I. **Hammarström D**, Øfsteng S, Koll L, Hanestadhaugen M, Hollan I, Apró W, Blomstrand E, Rønnestad B, Ellefsen S Benefits of higher resistance-training volume are related to ribosome biogenesis. The *Journal of physiology.* 2020 Feb;598(3):543-565. doi: 10.1113/JP278455.

II. Khan Y, **Hammarström D**, Rønnestad B, Ellefsen S, Ahmad R Increased biological relevance of transcriptome analyses in human skeletal muscle using a model-specific pipeline. *BMC Bioinformatics.* 2020 Nov 30;21(1):548. doi: 10.1186/s12859-020-03866-y

III. **Hammarström D**, Øfsteng S, Jacobsen N, Flobergseter K, Rønnestad B, Ellefsen S Ribosome accumulation during early phase resistance training. *Manuscript*

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3. Aims

The primary aim of this thesis was to relate the adaptive response to resistance training with low- and moderate-volume to skeletal-muscle characteristics in previously untrained individuals. The key question was whether manipulation of exercise-volume will have diverse effects in different individuals related to muscular intrinsic characteristics. A further aim was to characterize exercise-volume dependence in muscle molecular characteristics and determine a time course profile of markers of ribosomal biogenesis in response to resistance training. Based on these aims, the objectives of the present thesis were;

- to relate skeletal muscle and systemic characteristics to benefit of moderate- compared to low-volume resistance training;
- To determine volume-dependence in molecular networks related to muscle growth and remodeling in response to resistance training
- To determine a time course of markers related to ribosome biogenesis in the early phase of resistance training.

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5. Results and Discussion

5.1 Effects of different training volume on changes in muscle size and function

In Study I, the average increases in muscle strength and mass in each volume condition corresponded to what could be expected based on previous research in young healthy participants (Table 5.1) [1, 2], indicating the general efficiency of the training program.

The moderate-volume condition consistently showed favorable adaptations when compared to the low-volume condition in measures of muscle hypertrophy and strength gains (Figure 5.1). In an attempt to explain differences in training outcomes between volume-conditions, selected molecular markers with known influence on adaptations to resistance training were investigated for volume-dependency. First, activation of signaling along the mechanosensitive mTORC1-pathway has previously been shown to correlate with training-induced muscle growth [3, 4, 5]. A commonly used readout of mTORC1-signaling is the phosphorylation of S6-kinase (S6K1) at $\text{Thr}^{389}/\text{Thr}^{412}$ which in turn preceeds phosphorylation of ribosomal protein S6. In the present study $\text{S6K1}^{\text{Thr}^{389}/\text{Thr}^{412}}$

Given these limitations in using mTORC-signalling as markers of muscle hypertrophy, it is not surprising that previous studies are ambiguous in their associative approach between acute mTORC1-related phosphorylation and hypertrophy in humans. Some studies find a strong correlation

[6, 7].

[8]; [4];

This seems somewhat counterintuitive, as this pathway is a known regulator of translation initiation and elongation, as well as of ribosomal biogenesis [9, 10, 11, 12]

Indeed, in the present study we observed volume-dependence of mTOR phosphorylation at Ser2448, which could be a sign of negative feedback from mTORC1-based activation of S6K1 [13]. [14]; [15]; [16]]. Furthermore, when a combining data from

Table 5.1: Training induced changes in muscle CSA and average strength in Study I

	Sex	Volume condition	Mean (SD)	Reference
CSA %-change	Female	LOW	3.05 (3.61)	
		MOD	5.02 (4.04)	
	Male	LOW	3.83 (3.50)	
		MOD	5.10 (3.71)	
CSA %-change per day	Female	LOW	0.04 (0.05)	0.11 [0.04-0.26]a
		MOD	0.07 (0.05)	
	Male	LOW	0.05 (0.05)	
		MOD	0.07 (0.05)	
CSA %-change per session	Female	LOW	0.11 (0.13)	0.08 (0.22)b
		MOD	0.18 (0.15)	
	Male	LOW	0.14 (0.12)	0.14 (0.14)b
		MOD	0.19 (0.13)	
Average strength %-change	Female	LOW	21.0 (9.8)	
		MOD	27.8 (14.4)	
	Male	LOW	19.2 (12.4)	
		MOD	23.1 (12.0)	
Average strength %-change per session	Female	LOW	0.77 (0.36)	0.67 (0.35)b
		MOD	1.00 (0.49)	
	Male	LOW	0.72 (0.48)	0.47 (0.22)b
		MOD	0.87 (0.46)	

[a] Estimates from Wernbom et al. [1]
[b] Estimates from Ahtiainen et al. [2]

more recent studies indicates that a higher training volume is generally associated with increased muscle hypertrophy and strength gains (Figure 5.1 and 5.1.

In Study II, training efficacy was assessed by comparing outcomes to a non-training control group. The training group displayed increases compared to the control group for both strength muscle thickness measures.

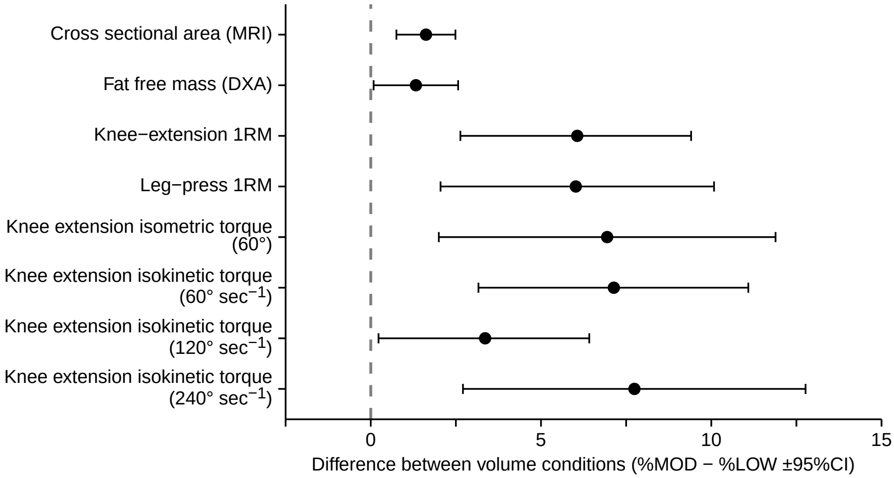

Figure 5.1: Differences in training induced relative changes in muscle mass and strength measures. Estimates are derived from ANCOVA models controling for baseline values and sex.

5.2 Acute effects of diffrent training volume on determinants of muscle protein synthesis

6. General Discussion

Conclusion

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