Muscular strength and power development to high and low resistance loads in trained individuals

8-week intervention

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Master Degree Project 47:2017
Master Program: 2015-2017
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Abstract

Aim

The purpose of this study was to examine high versus low resistance training loads performed to muscular failure and its effect on muscular strength, power and strength endurance.

Method

11 men and 3 women (age 26,4 ± 4,4 years, weight 79,9 ± 10,7 kg, height 179,4 ± 76 cm) were recruited to train for 2 days/week for 8-weeks in the leg press and leg extension. One leg was randomly allocated to a high load (HL) program performing 3-5 reps and the other leg was allocated to the low load (LL) program, performing 20-25 reps. All sets were executed to muscular fatigue. The participants were measured for 1RM strength, strength endurance and muscular power before and after the study.

Results

HL and LL leg significantly improved strength gains in the LP exercise by 20,3%, respectively 21%, $P < 0{,}001$, but no difference was noted between legs $P = 0{,}876$. HL displayed significant increases in the LE exercise by 10,3%, $P < 0{,}05$, while no significant improvement occurred for the LL leg, -2,7%, $P > 0{,}05$. Strength remained insignificantly similar between protocols $P > 0{,}05$. The mean power results indicated no significant improvements within protocols, HL $P = 0{,}309$, LL $P = 0{,}112$. There was also no significant difference between the two protocols after the intervention $P = 0{,}646$. As for muscular strength endurance, the LL performed more repetitions which was significantly greater than for the HL leg 26,5 reps, respectively 23,9 reps, $P = 0{,}045$.

Conclusion

This study concludes that similar strength gains can be accomplished when training with heavier or lighter loads as long as all resistance training is performed to muscular failure. It was also determined that performing lower loads to failure is superior for local strength endurance. Finally, traditional resistance training has no benefit for augmenting muscular power whether training with higher or lighter loads to exhaustion

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1. Introduction

Resistance training (RT) is a popular exercise modality known to enhance physical fitness. It stresses the neuromuscular system by applying an external resistance during muscular contractions. Chronic exposure to RT accompanied with progressive overload causes the skeletal muscle to gain size, strength and power (Kenney et al. 2015), which are key components for athletic performance. During the initial stages of RT, strength gains are related to neurological improvements to efficiently activate more muscles (Sale. 1998; Phillips. 2000), whereas muscle size becomes more relevant as one gains experience in RT (Ikai et al. 1968; Cureton et al. 1988; Kenney et al. 2015). As chronic exposure to RT continues, specific variables become imperative for optimizing muscular adaptations. One of the variables to consider is the loading zone. Loading zone is a concept that focuses on the load intensity (heavy-moderate-low) with the purpose to augment a certain fitness goal. Training near ones' one-repetition max (1RM) results in fewer repetitions compared to training with lighter loads for more repetitions. Current recommendations advocate heavy loading 80-100% of 1RM, or 1-5 RM (low repetitions) as favorable for increasing muscular strength, >70% of 1RM, or 6-12 RM (moderate repetitions) as favorable for muscle hypertrophy, and <70% of 1RM, or +15 RM (high repetitions) as favorable for muscular strength endurance (ACSM. 2013; Haff & Tripplet. 2015). Despite an abundance of studies investigating the so called strength-endurance continuum in RT, the topic still remains very equivocal. For example, existing studies have investigated traditional RT with higher loads (HL) versus lower loads (LL) in untrained individuals and reported similar strength gains with no difference between groups (Stone & Coulter, 1994; Léger et al., 2006). While many studies report strength gains to be load-specific (Anderson & Kearney. 1984; Aagaard et al. 1996; Moss et al. 1997; Holm et al. 2008; Schuenke et al. 2012). This makes is reasonable to agree that traditional RT with HL is superior for strength gains compared to LL. However, a common practice in RT programs and often recommended by strength and conditioning coaches is training to muscular failure, which is the inability of the muscle to perform an other contraction due to fatigue. With that said, many studies have used this method to examine strength gains in HL versus LL in individuals also unacquainted to RT. Popov (2006); Tanimoto & Ishii (2006); Tanimoto et al. (2008); Assunção et al. (2016); and Fisher (2016), all have reported no difference in strength gains between groups while a majority of studies demonstrated HL to be superior for strength improvements (Campos et al. 2002; Mitchell et al. 2012; Ogasawara et al. 2013; Van Roie et al. 2013; Jenkins et al. 2015; Fink et al. 2015). It is difficult to identify the mechanisms behind the divergent results but one important consideration is that all of the abovementioned studies have conducted research on untrained individuals with no prior experience to RT. This is a critical factor since people exhibit inter-individual responses to training (Hubal et al. 2005; Erskine et al. 2010) which is perhaps more evident in untrained populations. Thus, it is conceivable that some individuals experienced profound strength gains while others experienced little or no strength gains to the designated RT programs.

To date, five studies have investigated the strength-endurance continuum on resistance trained individuals when RT is performed to muscular failure. Schoenfeld et al. (2014) investigated the effect of volume-equated RT on well-trained men for 8-weeks. They were assigned to perform a strength-type load of 7 sets of 3 RM, or a hypertrophic load consisting 3 sets of 10 RM. They reported similar hypertrophic gains between groups but the strength gains were superior in the strength-type program. Mangine et al. (2015) had 33 resistance-trained men perform either a high volume (VOL) protocol (4 sets x 10-12 RM) or a high intensity (INT) protocol (4 sets x 3-5 RM), volume unmatched. The results were similar to previous research, observing greater improvements in strength and hypertrophy in the INT group. However, a potential issue was the difference in recovery period for the protocols (3-minutes in INT, respectively 1-minute in VOL) that could have influenced the outcome. Schoenfeld et al. (2015) investigated 8-12 repetitions (HL) versus 25-35 repetitions (LL) in 7 different exercises performed to failure for 3 sets each. Subjects were well-trained and performed RT 3 times/week on nonconsecutive days for 8 total weeks. The results are in line with previous research indicating that both HL and LL elicit similar muscular growth, but the HL training was superior for maximizing strength adaptations. Recently, Morton et al. (2016) assigned resistance-trained men to perform 12-weeks of whole-body RT. They were randomly allocated to a higher-repetition (HR) group that performed 20-25 RM, or to a lower-repetition (LR) group performing 8-12 RM. They reported similar strength increases for all groups with the only change in bench press, where superior strength gains occurred in the HR group. They suggested that load is irrelevant for hypertrophy and strength in resistance trained individuals as long as the sets are taken to volitional failure. Lastly, Schoenfeld et al. (2016) let resistance-trained men engage in heavy versus moderate load RT for 8-weeks with all other variables being controlled. They were randomly assigned to either a loading range of 2-4 repetitions per set (heavy protocol) or 8-12 repetitions per set protocol (moderate protocol). Both groups performed 3 sets of 7 exercises involving upper and lower body. In response to the RT, the 1RM squat increased significantly in the heavy group compared to the moderate group. However, the moderate group exhibited larger muscle hypertrophy compared to the heavy group. This indicates that heavy loads are superior to strength gains while moderate loading is more suited for hypertrophic responses.

In conclusion, the strength-endurance continuum literature suggests that HL is superior for strength gains in untrained subjects during traditional RT, but surprisingly, the results become very scattered when RT is carried out to muscular failure. Additionally, a scarcity of studies conducted RT on resistant trained individuals which implies that further investigations are necessary with robust methodology. Therefore, the purpose of this investigation is to examine larger repetition ranges, 3-5 RM vs 20-25 RM, on resistant trained individuals in a unilateral fashion. The larger loading zones could elicit greater differences in strength, endurance and power in RT-experienced individuals. Also, the unilateral method would limit the inter-individual variance between subjects.

2. Aim/Hypothesis

Current research aims to investigate RT with repetition ranges between 3-5 RM (HL) and 20-25 RM (LL) performed unilaterally until muscular failure in resistance-trained subjects. The research will measure strength, endurance and power for both protocols. The hypothesis is that the HL protocol will induce superior strength improvements compared to the LL. The LL protocol however, will result in larger strength endurance performance compared to the HL. Finally, the hypothesis for muscular power is that traditional RT will deteriorate or not change muscular power due to muscle fiber transitioning from velocity-, to force-specific.

3. Method

3.1 Subjects

Sixteen subjects were recruited to the study. Eleven males (27 ± 1yrs, 83 ± 3 kg, 182 ± 2 cm, means ± SE) and three females (26 ± 3 years, 67 ± 1 kg, 170 ± 0 cm, means ± SD) completed the study. Data from two subjects were excluded due to sustaining non-training injuries. The subjects were healthy and engaged in RT for a minimum of 2 years including at least one weekly lower body session prior to the study. Before inclusion in the study, the subjects were asked to fill out a questionnaire regarding their physical activity and health history. They were informed about the experimental procedure, associated benefits and potential risks involved in the investigation. An informed consent was signed and the subjects gave their verbal and written acceptance to participate in the study. The protocol was approved by the Regional Ethics Committee (2016/2159-31).

3.2 Strength

One-week before initiation of the experimental protocol, one-repetition maximum (1RM) strength testing was conducted in the inclined leg press (LP; Cybex International, Medway, MA, USA) and leg extension (LE; Cybex International, Medway, MA, USA) in a unilateral fashion. Following a brief general warm-up, the testing started by loading 10RM of the participants' predicted 1RM. The weight was then progressively increased by 10% for each successful lift until the weight no longer could be lifted (Haff & Dumke. 2012). A resting period of three minutes was given between each attempt to ensure adequate recovery. A repetition was considered valid if the participant lowered the weight to the assigned 90° angle at the knee joint while maintaining proper form without any assistance throughout the entire repetition in the LP. Whereas a valid repetition in the LE was counted when the leg extended between 160-180° with correct technique. The participants were advised to refrain from nicotine and nutritional substances 3-hours before testing procedures. They were also asked to desist from any other training 48-hours prior testing.

3.3 Power

The split squat exercise was used in a smith machine (Cybex International, Medway, MA, USA) to measure the peak power for each leg. The guidelines for split squat focuses mainly on step length (Keogh. 1998) and joint angles (Escamilla et al. 2008). Thus, the subjects descended to their 90° angle at the knee joint and the front foot placement was noted. This standardization was done by using a X and Y coordinate platform map under the smith machine. Also, a safety gadget was mounted on the smith machine to make sure the participants could not descend beyond their 90° angle. The subjects performed three repetitions per leg with a load corresponding to 25% of individual body weight. They were asked to lower the barbell with control until it slightly touched the safety gadget before rapidly extending upward on a verbal command. 1-minute rest was given between each attempt. Power was measured by a linear M-encoder (MuscleLab, Langesund, Norway) with a wire attached to the barbell that assesses the velocity, speed and force of the barbell. Obtained results were presented as power calculated by the MuscleLab software.
The same investigators supervised the testing procedures.

3.4 Strength Endurance

A local muscular endurance test was performed in the LE exercise at the end of the study after the strength and power test due to its metabolic stress. The HL leg and the LL leg attempted to perform as many repetitions as possible with the same load used as in the last RT session for the LL program. Only one set was performed for each leg separated with a 2-minute rest interval. The subjects were requested to continue the repetitions until muscular failure with correct form. The test was terminated if the subject failed to extend the leg between 160-180° for consecutive repetitions. The same leg started in all tests after randomization.

Table 1. *Participants' baseline characteristics*

	HL *(n=14)*	LL *(n=14)*	*P*
Age, yrs	26,4 ± 4,4	26,4 ± 4,4	1,00
Height, cm	179,1 ± 7,7	179,1 ± 7,7	1,00
Body mass, kg	79,9 ± 10,8	79,9 ± 10,8	1,00
BMI, kg/m^2	24,9 ± 2,8	24,9 ± 2,8	1,00
Leg press 1RM, kg	170,9 ± 43,8	169,8 ± 48,2	0,92
Leg extension 1RM, kg	68,4 ± 13,7	70,4 ± 13,4	0,98
Mean power, watts	384,7 ± 79,1	401 ± 74,7	0,77

Values are mean ± SD. BMI, body mass index.

3.5 Experimental Design

The subjects trained 2 days/week for 8-weeks in the leg press and leg extension. One leg was randomly allocated to a HL program, and the other leg was allocated for the LL program. For the HL training program, the subjects performed 3 sets of 3-5 repetitions in each set to muscular fatigue, at approximately 95% of individual 1RM. The opposing LL program consisted of 3 sets of 20-25 repetitions per set corresponding between 40 and 60% of 1RM. The RT sessions were scheduled on Mondays and Thursdays starting with a general 5-minute cycle ergometry warm-up at an optional intensity followed by a standardized LP warm-up for the HL program. No warm-up was considered necessary for the LL program due to its lower load. Subsequently, HL or the LL program was randomly selected to begin the leg press exercise for 3 sets before switching legs. Afterwards, the leg extension exercise was conducted in the same order as previously assigned. A 2-minute recovery was given between each set and the correct repetition range was maintained by adjusting the load during this time. In purpose to minimize familiarization, the selected starting leg was altered every week. Halfway through the study, one deloading week was added and the volume was significantly reduced to recover the neuromuscular system from the intensive RT program and conducive the strength gains (Harries et al. 2015). During this week, the participants performed one set of each exercise to failure for both legs, a total of two sets for respective leg. The investigators supervised each subject to ensure that every set was performed to muscular failure with proper technique and for verbal encouragement. The subjects were asked to desist from any lower body strength training outside the study. Immediately after each RT bout, the subjects consumed one serving of high-quality whey protein (136 kcal, 27 g protein, 2,5 g carbohydrates, 2,1 g fat; Tyngre© AB, Sweden) mixed with ~300 ml of water to ensure adequate protein ingestion and to enhance the training-induced muscular adaptations (Cermak et al. 2012; Aaragon & Schoenfeld. 2013).

The reports for muscular hypertrophy for the present intervention has been collected and presented elsewhere (Kalenius. 2017).

Table 2. *Experimental design*

Week:	1	2-5	6	7-10	11
Intervention:	Pre-test	Training	Deload	Training	Post-test

3.6 Validity

The power measurements were conducted by a M-linear decoder manufactured by MuscleLab (Langesund, Norway). The stationary decoder measures velocity, power and force with a wire attached to the barbell. To validate the MuscleLab system, an optoelectronic 3D motion analysis was used with two cameras (OQUS 4, Qualisys AB, Gothenburg, Sweden) operating at 100 Hz for sampling frequency of spherical reflective markers (19 mm diameter). The cameras were positioned at different angles to target the coronal plane of the smith machine and the voluntary executor. The spherical reflective marker was placed at the top-side of the barbell for full visibility to the cameras. Following the installation, the voluntary executor was asked to replicate the split squat exercise for equal amount of repetitions as present study at 25% of individual body weight. The 3D motion system measured each repetition performed in conjunction with the MuscleLab system. The observational differences from both systems were deviated and presented as root-mean-square-error (RMSE) of 0,03 m/s. The calculated result indicate that the MuscleLab software is highly reliable and valid for power measurements.

3.7 Statistical Analysis

All statistical analysis was performed with the SPSS software (Chicago, IL, USA). The baseline characteristics between protocols and the strength endurance test were analyzed using an independent t-test. The differences within protocols were analyzed using a paired samples t-test. Postexercise values in muscular strength and muscular mean power between protocols were analyzed using a two-factor repeated measures analysis of variance (ANOVA). The significant alpha-level was set to 5% ($P < 0{,}05$). Data is presented as mean ± standard deviation (SD) unless otherwise specified. All exercises passed the normality test assessed by Kolmogorov-Smirnov ($P > 0{,}05$), except the LL LE prevalue ($P = 0{,}018$) and the HL leg for strength endurance ($P < 0{,}05$).

4. Results

Descriptive characteristics. A total of fourteen participants completed the study (Table 1), 2 individuals dropped out before completion due to sustaining non-intervention injuries. Overall intervention attendance was high with a participation rate of 95,8% of those who fulfilled the study.

Muscular strength. Maximum LP strength increased significant equally in both HL (170,9 ± 43,8 to 205,6 ± 49,8 kg; $P < 0{,}001$) and LL (169,8 ± 48,2 to 205,5 ± 50,3 kg; $P < 0{,}001$). Following the intervention, there was no significant difference between the HL and LL protocol ($P = 0{,}876$; Figure 1). The paired samples t-test revealed significant strength increases for the HL protocol in the LE exercise (68,4 ± 13,7 to 74,3 ± 15,9 kg; $P < 0{,}05$), while no difference was observed in the LL protocol (70,4 ± 13,4 to 68,5 ± 14,3 kg; $P > 0{,}05$). No postvalue significance was revealed between protocols in the LE exercise ($P > 0{,}05$; Figure 2).

Muscular power. The mean power results indicated no significance within protocols, HL (384,7 ± 79,1 to 376,5 ± 71,9 W: $P = 0{,}309$), LL (401 ± 74,4 to 385,6 ± 84,4; $P = 0{,}112$). There was no significant difference between the two protocols after the intervention ($P = 0{,}646$; Figure 3).

Strength endurance. The independent t-test showed significantly ($P = 0{,}045$) better strength endurance for the LL leg (26,5 ± 3,4 reps) vs the HL leg (23,9 ± 3,3 reps; Figure 4).

Figure 5-8 is a representation of the participants' initial and final training loads for all training exercises for the HL and LL leg.

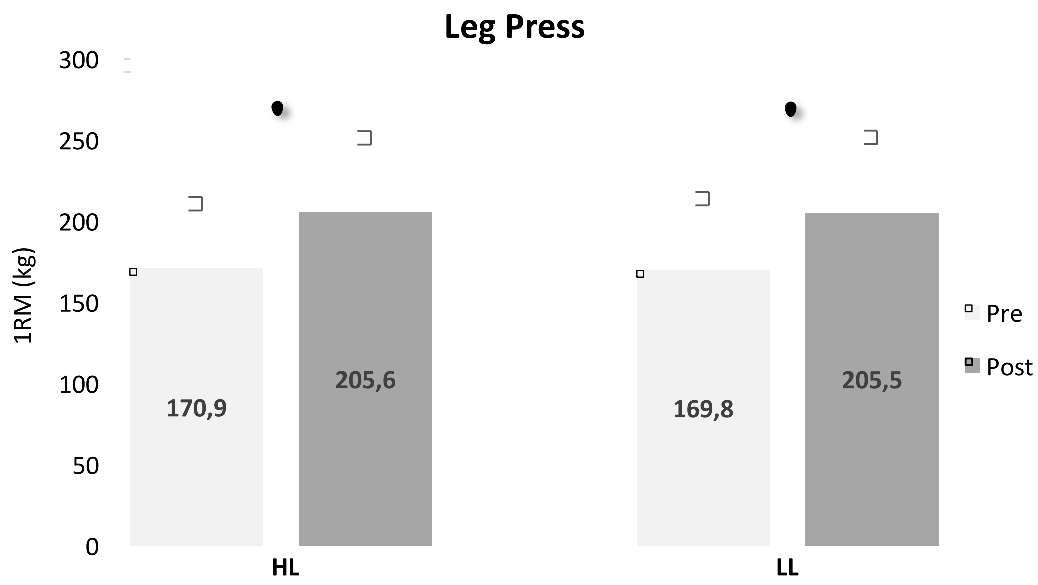

Figure 1. Graphical representation of 1RM values in the LP exercise before and after the intervention for HL and LL protocols, mean (±SD). Values expressed in kilograms (kg). •Significantly greater than corresponding pretraining values.

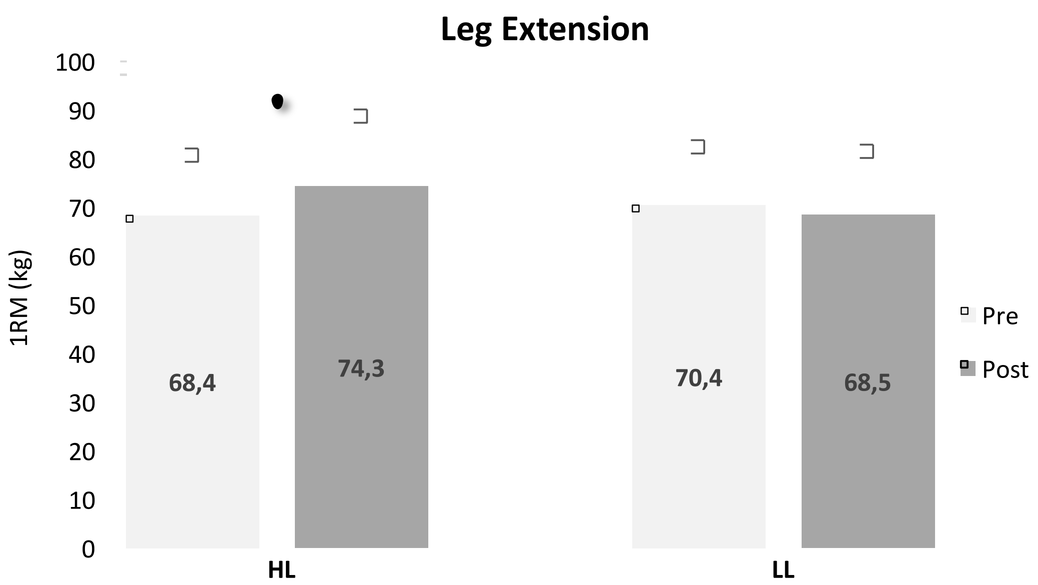

Figure 2. Graphical representation of 1RM values in the LE exercise before and after the intervention for HL and the LL protocols, mean (±SD). Values expressed in kilograms (kg). •Significantly greater than corresponding pretraining values.

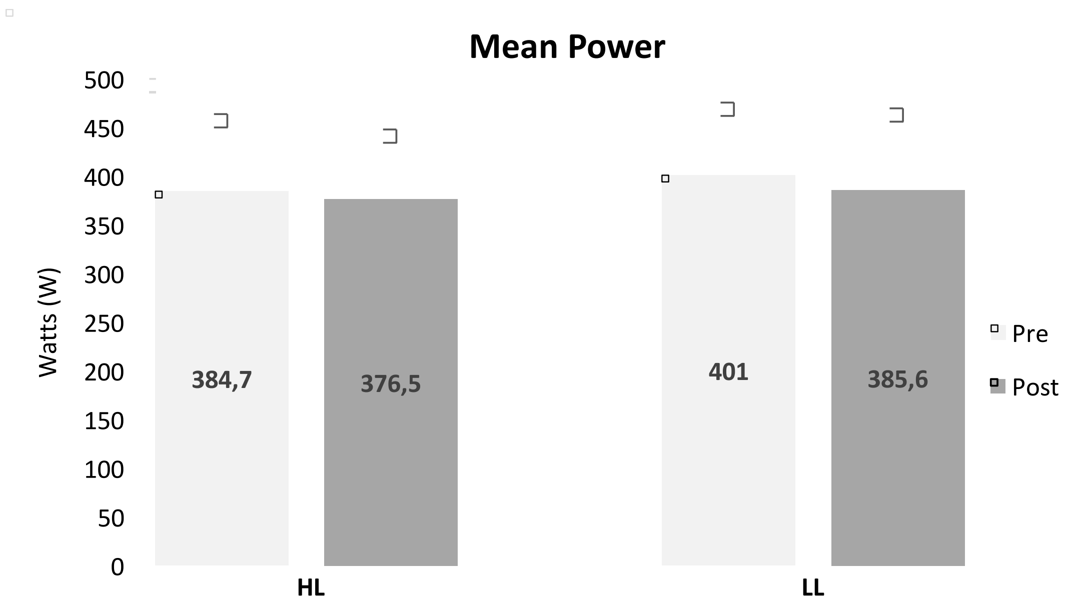

Figure 3. Graphical representation of mean power values in the LE exercise before and after the intervention for HL and LL protocols, mean (±SD). Values expressed in watts (W).

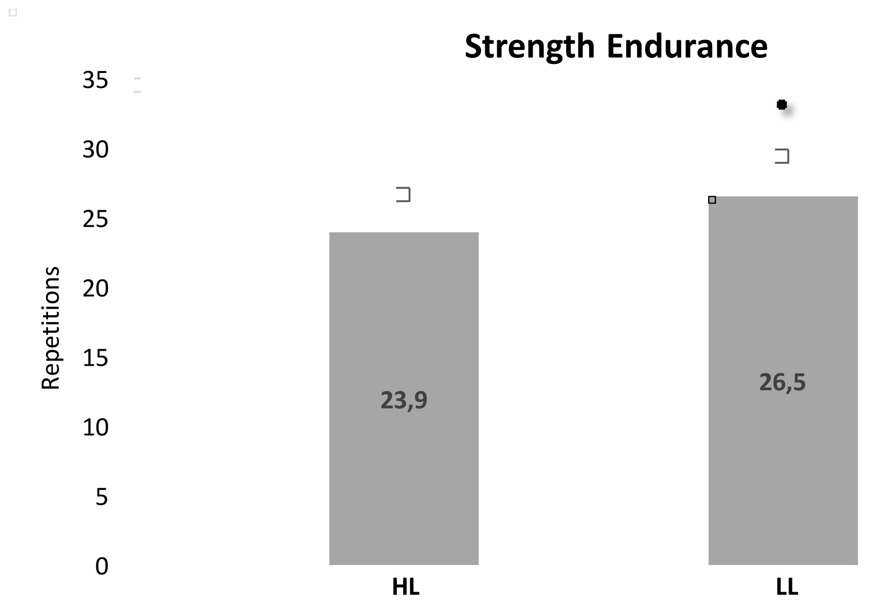

Figure 4. Graphical representation of local strength endurance values in the LE exercise before and after the intervention for HL and LL protocol, mean (±SD). Values expressed as total repetitions. •Significantly greater than the corresponding protocol.

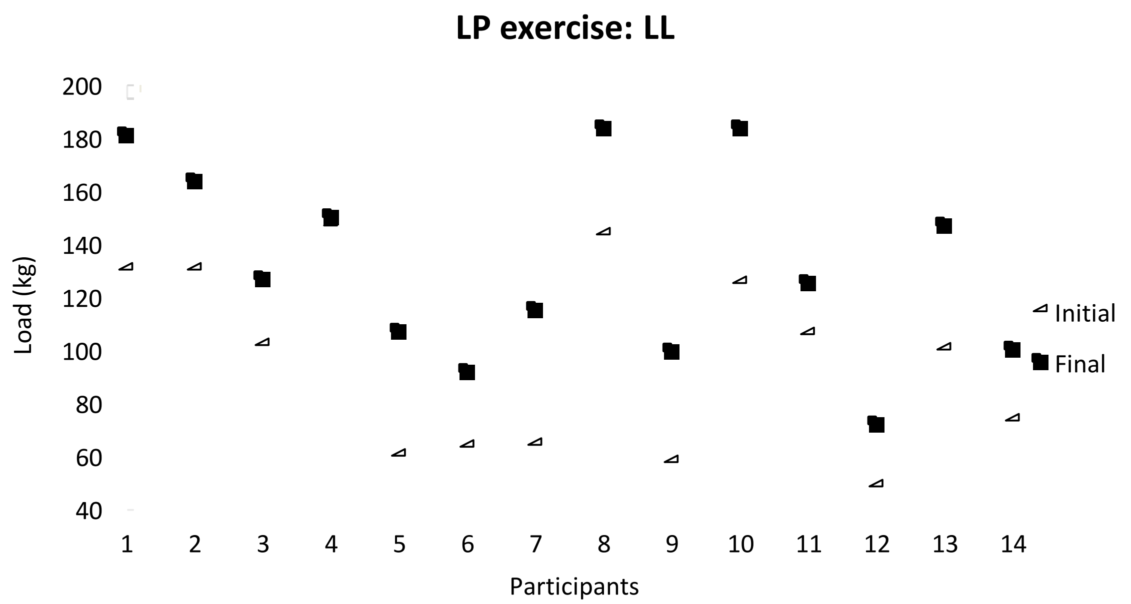

Figure 5. Graphical representation of the participants' initial and final training loads in the leg press exercise for the LL protocol.

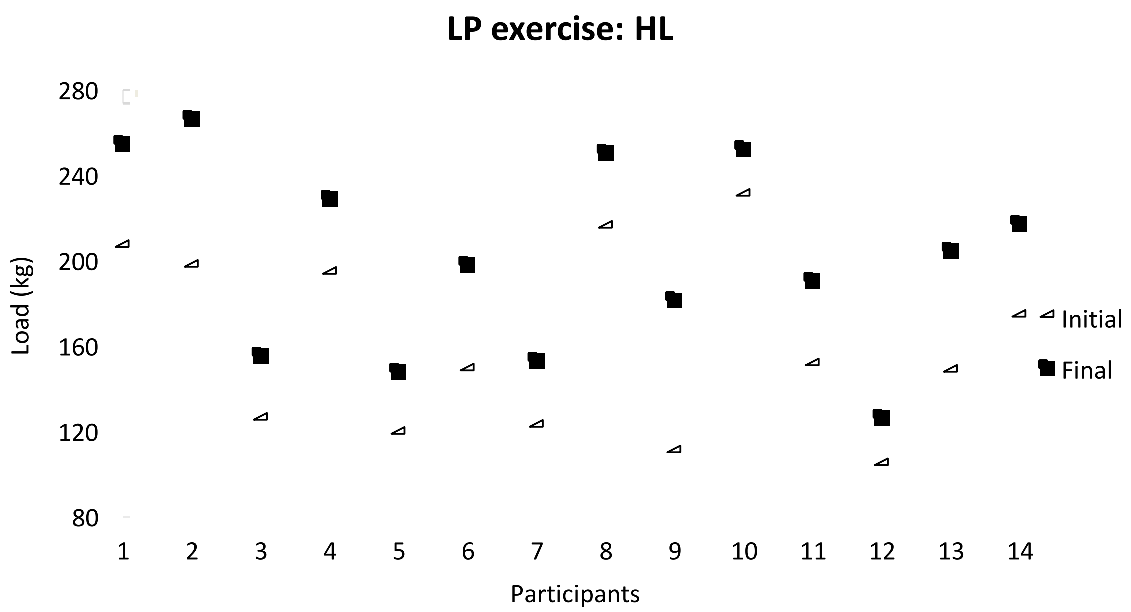

Figure 6. Graphical representation of the participants' initial and final training loads in the leg press exercise for the HL protocol.

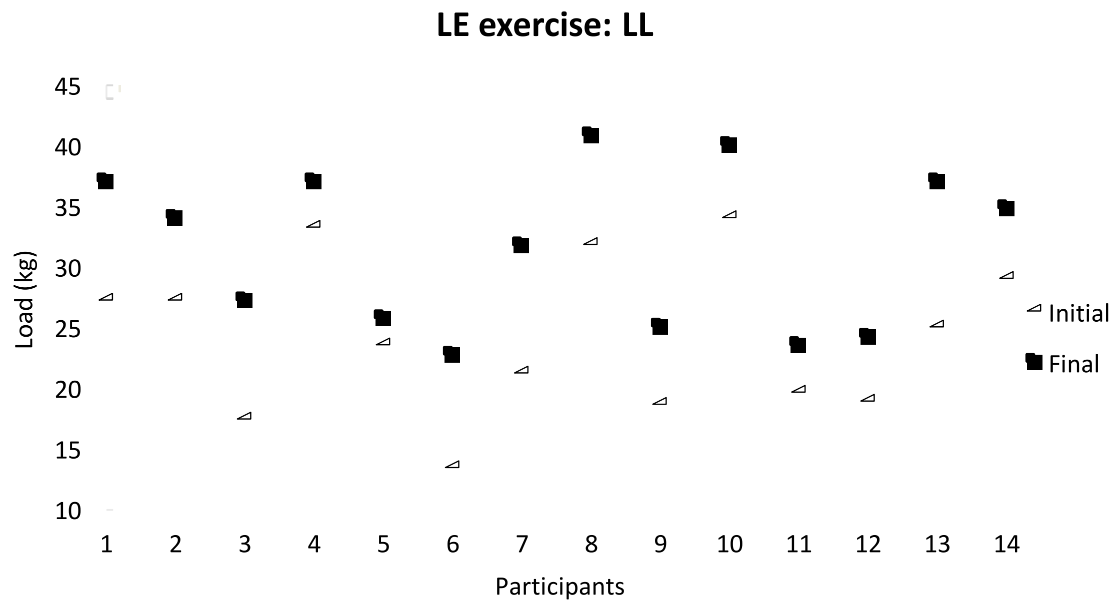

Figure 7. Graphical representation of the participants' initial and final training loads in the leg extension exercise for the LL protocol.

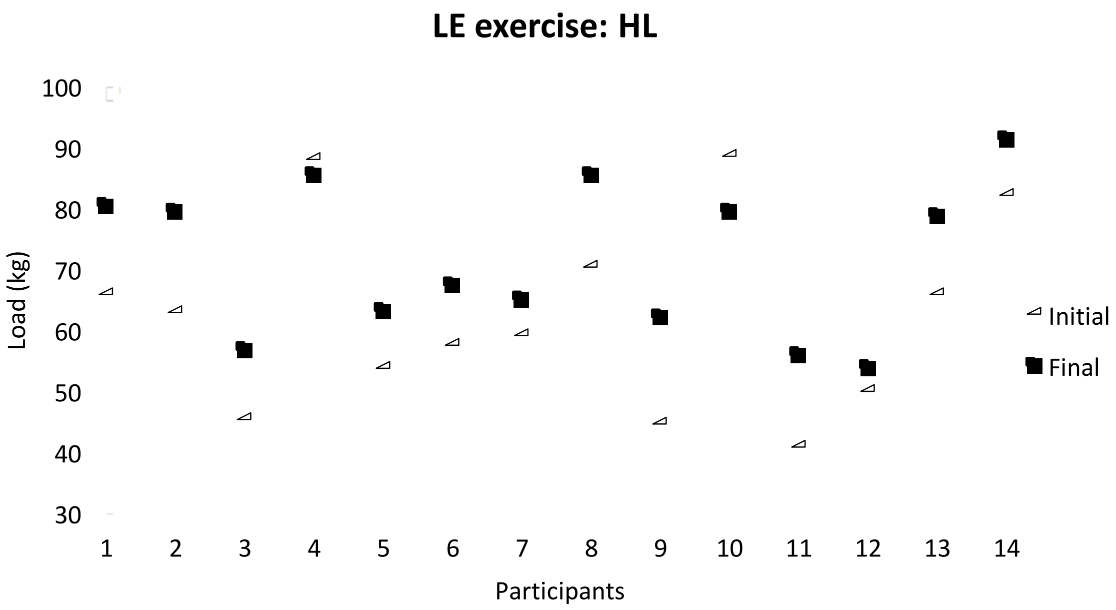

Figure 8. Graphical representation of the participants' initial and final training loads in the leg extension exercise for the HL protocol.

5. Discussion

To date, the current study is the first to examine repetition ranges between 3-5 RM and 20-25 RM in resistance trained individuals performing unilateral RT. The present study showed that lifting heavy loads compared to low loads elicit similar adaptive affects when the protocols were executed to muscular failure in resistance trained subjects. Strength gains were significantly improved for both the HL leg and the LL leg (20,3%, respectively 21%) in the LP exercise but remained insignificant between protocols. Strength gains were observed within the HL protocol in contras to the LL protocol (10,1%, respectively -2,7%), but the results remained insignificant between legs. Furthermore, a significant difference was presented in muscular endurance where the LL leg performed more repetitions versus the HL leg (26,5 reps, respectively 23,9 reps) at the end of this study. While the mean power was reduced for both protocols post-exercise (HL -2,1%, respectively LL -3,8%), no statistical differences between legs was observed. The presented data is congruent with a recent study investigating differences in loading zones on resistant trained individuals (Morton et al., 2016). Their results are in line with current findings demonstrating similar strength gains between HL and LL. Conversely, current results are against majority of the existing studies examining the strength-endurance continuum concept in well-trained subjects (Schoenfeld et al. 2014; Mangine et al. 2015; Schoenfeld et al. 2015; Schoenfeld et al. 2016). Furthermore, present findings are divergent to current, and generally accepted, lifting recommendations for strength-specific RT (ACSM. 2013), which profess loads >80% of 1RM to be essential for enhancing strength. Thus, it is plausible that present recommendations overlook RT performed to muscular failure with lighter loads compared to old-fashioned RT lifting.

The mechanisms responsible for strength gains remain complex and not completely understood. It is believed that lifting heavier loads maximizes neuromuscular strength due to larger neural activation and there is good evidence for this. Studies have suggested that lifting >65% of 1RM is preferred to maximize strength gains and lifting beyond this recommendation as one becomes accustomed to RT (Rhea et al. 2003; Kreamer & Ratamess. 2004), to achieve full motor unit recruitment. Yet, lower loads executed to failure necessitates near maximal motor unit activation to sustain muscular contractions (Fallentin et al. 1993; Fuglevand et al. 1993). Recent evidence investigating motor unit activation in different loading zones observed higher electromyographic (EMG) activation in heavy loads during all sets when repetitions were taken to failure (Alkner et al. 2000; Akima & Saito. 2013; Schoenfeld et al. 2014; Jenkins et al. 2015; Gonzalez et al. 2016). Thus, it is likely that muscular activation was higher in the HL protocol for the LP and LE exercise throughout the present study (Cook et al. 2013), creating greater potential for strength adaptations. However, acute surface EMG recordings has its methodological limitations as proven (Vigotsky et al. 2016a; Vigotsky et al. 2017), and assumptions based merely on such premises are insufficient to fully explain maximal strength. Although the mechanisms responsible remains to be determined, one can speculate that practicing the intended movement with a relative heavy load optimizes maximal strength for future 1RM attempts (Dankel et al. 2016; Mattocks et al. 2017).

RT volume (repetitions x load) between protocols was unmatched for this study as the experimental design created purposeful discrepancies in total volume lifted. The LL protocol averaged significantly larger volumes in contrast to the HL protocol (9289,2 ± 2830,5 kg, respectively 2671,3 ± 678,3 kg; $P < 0,001$). Schoenfeld et al. (2014) investigated volume-equated RT in resistance trained subjects performing either 3 sets of 10 RM or 7 sets of 3 RM and presented significant strength gains for the HL. This observation is consistent with previous studies examining volume-matched RT for untrained individuals where maximal strength gains favored HL (Anderson & Kearney. 1982; Campos et al. 2002). Volume matched situations consequently favor HL in muscular strength and hypertrophy as it would prevent LL to reach complete muscular failure and hinder the muscles to fully adapt from RT stimuli. Therefore, the LL protocol in this study allowed them to reach muscular failure and produce similar results as the HL protocol, which are accordant findings with Morton et al. (2016).

It remains no surprise that training at the far right of the strength-endurance continuum for 8 weeks generated larger local strength endurance abilities for the LL protocol versus the HL protocol. It is widely accepted that training with lighter loads (more repetitions) is superior for increasing repetition strength compared to heavier loads (less repetitions) (Campos et al. 2002; Rhea et al. 2003; Rana et al. 2008; Schoenfeld et al. 2015). The suggested physiological mechanisms responsible are that high repetition RT would preferentially induce hypertrophic gains in the slow twitch, type I muscle fibers, which are more resistant to fatigue than type II muscle fibers (Ogborn & Schoenfeld. 2014) If such, the hypertrophic gains would contribute to minute strength endurance gains as they are less susceptible to fatigue. However, a group of studies have presented non-significant results in fiber-specific hypertrophy when RT with either lighter loads or heavier loads (Campos et al. 2002; Schuenke et al. 2012; Morton et al. 2016). Therefore, whether type I fibers actually affect strength endurance is debatable and future investigations should thoroughly examine this relationship. An other mechanism that could potentially influence muscular endurance is capillarization. Chronic exposure to training causes angiogenesis (formation of new capillaries) around the muscle fibers that enriches oxygen delivery to the working muscles (Gavin. 2009; Kenney et al. 2015). However, existing studies on this topic are very limited in the strength-endurance continuum as only Campos et al. (2002) rigorously assessed this matter, showing no significant differences in capillary density when training with higher or lighter loads. Notably, no perception of effort (RPE) was measured during the protocols and the endurance test as this was expected to be maximal when training to muscular fatigue. Lighter loads tend to produce more muscular discomfort compared to heavier loads (Shimano et al. 2006; Smirmaul. 2012; Fisher et al. 2016a; Fisher et al. 2016b). It is plausible to hypothesize that the LL leg has gained more resistance to pain which caused it to squeeze out more repetitions in the local strength endurance test compared to the HL leg.

Power is the component of muscular strength and velocity which is crucial for any competitive athlete. Recurrent findings show that muscular power is reduced when performing traditional RT (Liu et al. 2003; Pareja-Blanco et al. 2015). The current results imply an insignificant attenuation in muscular power following 8 weeks of regular RT. This is probably the cause of muscle fiber transitioning from explosive type IIX fibers to the force-specific type IIA fibers (Liu et al. 2003).

There are some limitations in this study that should be considered before drawing any conclusions. First, the inclusion criteria for this investigation was a minimum RT experience of 2 years, including one weekly lower body session. However, when testing for baseline 1RM, the values revealed profound strength differences between individuals ranging from 105 to 250 kg in the LP, and from 46,7 to 87,1 kg in the LE. This denotes large participant dispersion and can affect the neuromuscular response for respective protocol. Secondly, current training intervention lasted 8 weeks, which might be insufficient to provoke strength differences in the lower limbs (Chen et al. 2011). Thus, a longer training duration is necessary to determine whether the HL or LL protocol is advantageous to influence strength improvements in resistance trained populations. Third, we employed a unilateral RT model and a potential downside is the transmission of strength from one trained limb to the contralateral untrained limb via neurological pathways (Zhou. 2000; Shima et al. 2002). The magnitude of transferred strength varies and one meta-analysis documented around 8% to be normal (Carrol et al. 2006), but can be considerable greater (Fimland et al. 2009). However, there is a scarcity of studies investigating this phenomenon when both limbs are involved in RT and it is uncertain whether the cross-education effect persists.

5.1 Conclusion

This study concludes that training to muscular failure can elicit similar strength adaptations regardless of resistance load in well-trained individuals. The results also determine that lighter weight executed to failure are superior for inducing local strength endurance adaptations compared to heavier loads. Finally, traditional resistance training to failure does not seem to benefit muscular power regardless of loading zones and specific velocity training is recommended to improve this trait.

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Appendix 1

Information till försökspersoner:

Projekttitel:

Muskulära effekter av tung respektive lätt styrketräning.

Ansvariga:

Forskningshuvudman: Gymnastik- och idrottshögskolan (GIH).

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Bakgrund/syfte:

Större och starkare muskler är till nytta ur både en hälso- och prestationssynvinkel. Avgörande faktorer för att öka muskelmassan är belastning, träningsfrekvens och total träningsmängd. Nyligen publicerad forskning visar att träning med lätta vikter till utmattning kan generera samma träningseffekt som medeltung styrketräning. Det råder däremot oklarhet i om detta även gäller då tung styrketräning jämförs med lätt styrketräning till utmattning. Syftet med den här studien är att undersöka huruvida lätt respektive tung styrketräning påverkar muskeltillväxt (hypertrofi), styrka och kraftutveckling i lårmuskulaturen samt olika muskelfibertyper i den yttersta lårmuskeln (vastus lateralis).

Vetenskapliga frågeställningar:

1.Hur påverkas hypertrofi, styrka och kraftutveckling i lårmuskulaturen till följd av tung respektive lätt styrketräning?

2. Hur påverkas hypertrofi, styrka och kraftutveckling i typ 1 respektive typ 2 muskelfibrer till följd av tung respektive lätt styrketräning?

Metod:

Under 10 veckor ska vältränade män och kvinnor utföra styrketräning under kontrollerade former på Gymnastik & Idrottshögskolan, GIH. Ena benet tränas med en hög belastning (ca 90% av max) och andra benet med en lättare belastning (ca 30% av max) där varje set utförs till utmattning. Träningen består av två övningar; unilateral (utförs med ett ben) benpress och unilateral benspark som anses tekniskt enkla och säkra att utföra. Före och efter träningsperioden utförs styrkemätningar och lårmuskulaturens storlek bedöms med hjälp av

ultraljud. Utöver detta tas muskelprover (biopsier) både före och efter träningsperioden för att kunna studera effekterna på muskelfibernivå.
Vad är en biopsi?
En biopsi är ett invasivt ingrepp där man med hjälp av en tång tar ut en bit av lårmuskeln. Detta utförs under lokalbedövning. Det kan upplevas något obehagligt under ingreppet. Ingreppet utförs under strikt sterila förhållanden och risken för komplikationer är mycket låg. Med biopsi kan vi utläsa vilken typ av muskelfibrer som är dominant och hur stora respektive fiber är. Vi kommer även att kunna bedöma styrkan hos varje enskilt muskelfiber.

Kunskapsvinster:
Det är viktigt att förstå hur olika typer av träning påverkar muskeltillväxten så att den kan optimeras hos både idrottare, motionärer och patienter. Äldre och sjuka som inte kan träna med tung belastning kan ha nytta av att träna på lätt belastning som kan generera hypertrofi och ökad muskelstyrka. Från ett rehabiliteringsperspektiv kan detta ge förståelse för hur träningsrespons kan ske även på lätt belastning. Ur idrottsperspektiv kan detta ge förståelse för hur muskeltillväxt och styrka ska maximeras i syfte att öka prestationsförmågan.

Hur går studien till?
Studien är uppdelad i flera delmoment:

1. Första steget är att via telefonmöte informera och intervjua dig kring projektet. Anledningen till intervjun är att vi vill ha information angående din hälsa och träningsbakgrund för att du skall kunna inkluderas i studien.
2. Vid nästa delmoment kommer du att få fylla i en hälsoenkät, därefter mäter vi din maximala styrka i benpress och benspark. Vid ett separat tillfälle kommer vi även att ta muskelprov från yttre sidan av lårmuskeln på vardera ben, samt mäta muskeltjocklek i framsida lår med hjälp av ultraljud.
3. Efter dessa förberedande tester kommer du att genomföra styrketräningspass två gånger/vecka i 10 veckor. Träningen kommer att bestå av unilateral benpress och benspark där ena benet tränas med tung belastning och andra benet med lätt belastning. Träningen kommer utföras på måndagar och torsdagar på GIH, varje pass tar ca 30 min.
4. Efter träningsperioden upprepas samtliga tester och prover som utfördes före träningen.

Vilka är riskerna?

Muskelbiopsi innebär att en liten bit muskelvävnad (0,05-0,10 gram) tas ut med en specialnål. Muskelbiopsi utförs efter lokalbedövning av huden och underliggande bindväv. Ett 4-5 mm långt snitt görs genom huden, genom vilket biopsinålen förs in och ett muskelprov tas ut. Själva ingreppet med biopsinålen är över på ett par sekunder. I allmänhet känns en muskelbiopsi som ett trubbigt slag mot benet. I vissa fall kan en skarpare smärta kännas, som går över så fort nålen tas ut. För att förhindra blodutgjutning i muskeln lägger vi ett lokalt tryckförband över biopsistället, som skall vara kvar under 1-2 timmar. Liksom vid alla hudsnitt kan en hudnerv skäras av med lokalt känselbortfall i huden som följd. Vid den här typen av biopsi är denna komplikation mycket ovanlig. I de fåtal fall där denna komplikation har ägt rum har allt normaliserats efter 6-12 månader.

Skötselinstruktioner vid muskelbiopsi: Under veckan före muskelprovtagning får du ej använda magnecyl eller någon annan medicin som innehåller acetylsalicylsyra (alvedon går bra). Två dygn (48 timmar) före testerna får du ej utföra något tungt fysiskt arbete (>30 min) eller dricka alkohol. Under veckan efter undersökningen skall du inte bada (p.g.a. infektionsrisk) och när du duschar skall du skydda området över biopsistället med plast. De inre vita långsmala plåstren skall du inte byta själv – de ramlar av efter ca 1 vecka.

Biobanksprover/hantering av data/sekretess:

Uppgifterna om din hälsostatus kommer endast att finnas tillgängliga för försöksledare och projektmedarbetare och kommer att förvaras så att inga obehöriga kan ta del av dessa. Du har rätt att ta del av dina registrerade uppgifter. Ändamålet med hälsoenkäten är att ge underlag för deltagande i studien. Proverna och undersökningsresultaten kommer att kodas. Endast försöksledare och medarbetare kan koppla provresultaten till namn. Dina resultat kommer att behandlas så att inte obehöriga kan ta del av dem. Vid publicering av forskningsdata kommer dessa inte kunna kopplas till dig som individ. Blod- och muskelprover fryses och förvaras vid -80˚C på Åstrandslaboratoriet vid GIH i väntan på analys. Proverna kodas löpande under försökets gång. Proverna är kodade och kan inte utan kodnyckel hänföras till en viss person. Proverna kommer att förvaras i en biobank registrerad vid Socialstyrelsen (se bif. underbilaga). Om proverna kommer att användas till projekt med andra frågeställningar kommer ny etisk prövning att genomföras och Du kommer ånyo att kontaktas för samtycke. Du har rätt att ta del av Dina resultat och få rättelse av evt. felaktiga personuppgifter (personuppgiftsansvarig se ovan).

Försäkring/ersättning:

Personskadeskyddsförsäkring tecknad av GIH gäller under studien. Ersättning per biopsitillfälle utgår med 500 kr (före skatt). Detta medför en total ersättning på 4x500 = 2000 kr om du deltar i hela studien.

Vilka sökord har du använt?

Muscular failure, loading zones, high vs low,

Var har du sökt?

PubMed, Google Scholar

Sökningar som gav relevant resultat

Jag sökte i databaserna som står ovan och sökorden har varit de som nämndes högst upp.

Kommentarer

Material kunde hittas i databaser som ovannämnt men de flesta studierna hittades från andra artiklar som hade använde studierna som referens. Så jag använde mig mest av artiklar och skrollade ner till referenslistan för att hitta passande artiklar.