MASTEROPPGAVE

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Effects of training frequency on muscular strength for trained men under volume matched conditions

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Abstract

Background

The effects of resistance training frequency have been discussed the last couple of years, but the total volume of literature on the topic is small. Especially for trained subjects under volume equated conditions. Therefore, in an effort to increase the number of studies on the topic, the purpose of this paper was to investigate the effects of training frequency of two versus four sessions per muscle group on muscular strength for trained men when the total weekly volume was equated between the two conditions. Another metric of interest was the rate of perceived exertion after barbell back squat, bench press and the training session.

Methods

Participants were randomly assigned in one of two experimental groups: a SPLIT (n=10), where the training protocol was divided in two session training barbell back squat and exercises for the lower body and two sessions training bench press and exercise for the upper body, or a FULLBODY (n=11), where they trained four full body sessions with barbell back squat and bench press for every session, together with four other exercises for the whole body. Subjects were tested pre- and poststudy one repetition maximum strength in barbell back squat and bench press. All other variables were held constant over the eight-week training period. They were also instructed to rate their perceived exertion (RPE) after each sessions barbell back squat, bench press and after the full session.

Results

Both groups achieved a significant increase in strength from pre- to posttest in both barbell back squat (Both groups $p < 0,001$) and bench press (SPLIT, $p = 0,012$ and FULLBODY $p = 0,045$). A 2x2 repeated measures ANOVA showed no significant effect for training frequency on 1RM strength for both barbell back squat ($p = 0.640$) and bench press ($p = 0.431$).
A 2x8 ANOVA showed an interaction effects on RPE after barbell back squat ($p = 0.012$). The 2x8 repeated measures ANOVA for RPE after bench press and after the training bout did not show any significant interactions.

Conclusion

The primary finding in this study is there are no additional benefits of increasing the training frequency from two to four sessions under volume equated conditions.

1. Introduction

In the last couple of decades, the interest in strength training has risen in popularity (Wernbom, Augustsson, & Thomee, 2007). Several studies and articles point to many potential health benefits of conducting strength training for people of all ages (Winett & Carpinelli, 2001). Improvements in general strength through strength training has also been seen in the context of increased performance among athletes in a wide variety of sports (Suchomel, Nimphius, & Stone, 2016). Resistance training is an important factor in maintaining and developing muscle mass and muscle strength. To try to maximize these adaptations in the human muscle the manipulations of various resistance training variables are key (Kraemer & Ratamess, 2004). Manipulations of resistance training variables, as volume, intensity, load, frequency etc., can be done in different ways. In the academic literature, the manipulation of the variables training intensity and volume has received most of the attention, leaving training frequency may have been overlooked (Grgic et al., 2018; Ralston, Kilgore, Wyatt, & Baker, 2017).

The role of training frequency has been debated and the optimal frequency is not clear. The first studies on the topic was published in 1985 by Hunter et al., but there are few studies in total that have been published that control for the effect of training frequency. Training frequency is defined in the literature as the number of training sessions performed for a given period, usually described on a weekly basis (Kraemer & Ratamess, 2004). Frequency can be further characterized by the number of training sessions done per week per muscle group or exercise (Schoenfeld, Ratamess, Peterson, Contreras, & Tiryaki-Sonmez, 2015), which will be the definition used in this article.

In 2009 the American College of Sport Medicine (ACoSM) published an article where it was recommended that untrained and novices should train every muscle group 2-3 times a week (American College of Sports, 2009). ACoSM's position on recommendations of training frequency has been the subject of some criticism, as they are based on limited evidence on the topic (Grgic et al., 2018; Ralston, Kilgore, Wyatt, Buchan, & Baker, 2018; Schoenfeld, Grgic, & Krieger, 2019) Since ACoSM published its article and recommendations, there has been a small renaissance on the topic in the last couple of years. One study that got much attention was the "Norwegian Frequency Project", which showed positive results favoring higher frequency training for elite/trained powerlifters (Raastad, Kirketeig, Wolf & Paulsen, 2012). The problem with this study is that it was only used as a conference paper and never published in a journal, so it is difficult to control and verify the methods used in the project.

Although there is an increase in the number of studies published in recent years, the total pool of studies is still limited. To my knowledge there are published just eight studies that explore the effects of training frequencies on muscle adaptations on trained males under volume equal conditions(Brigatto et al., 2019; Colquhoun et al., 2018; Gentil et al., 2018; Gomes, Franco, Nunes, & Orsatti, 2019; Lasevicius et al., 2019; Mclester, 2000; Saric et al., 2019; Schoenfeld et al., 2015)). The majority of the focus of these studies has been on lower training frequencies, i.e. three or lower. Only three of these studies controlled for the effect of training frequencies higher than three (Colquhoun et al., 2018; Gomes et al., 2019; Saric et al., 2019). Two recent meta-analyses on the topic noted that the literature on training frequency under volume equal conditions is small and suggested that future research is needed(Grgic et al., 2018; Ralston et al., 2018). Ralston et al. noted in particular that studies with a trained sample were needed (Ralston et al., 2018).

Some articles have also suggested that an increase in training frequency can be advantageous to spread the total training volume to counteract muscle fatigue and overtraining (Dankel et al., 2017). Training with very high volume in one training session can induce high levels of fatigue and prolonged recovery time, which can be suboptimal for athletes that try to induce specific neuro muscular adaptations (Pareja-Blanco et al., 2018).

Seen in the context of motor learning theory, it also can be assumed that more frequent training of a movement could lead to higher increase in strength, due to an improvement in neural efficiency (Shea, Lai, Black, & Park, 2000).

Since it is still unclear whether exercise frequency affects muscular strength under equal total exercise volume, especially in higher training frequencies (Grgic et al., 2018), the purpose of this paper was to investigate the effect of training frequency. This was done by comparing the effect on muscle strength by training the barbell back squat and the bench press two times per week using a split program (SPLIT), versus training the barbell back squat and the bench press four times a week using a full body program (FULLBODY) in a group of trained male under matched volumes. In order to control for volume, the total weekly resistance training volume (repetitions x set x intensity) was equated between the groups. The volume was equated as other papers have shown a dose-response relationship between volume and increase in muscular strength (Heaselgrave, Blacker, Smeuninx, McKendry, & Breen, 2019; Ralston et al., 2018; Rhea, Alvar, Burkett, & Ball, 2003) This will be, to the best my knowledge, the first study that controls training frequencies two versus four in trained males under equal training volumes.

This study will also try to investigate the effects of different training frequencies on felt fatigue among the participants. This will be done using the Borg CR10 scale, which is a scale of rating of perceived exertion (RPE). RPE scales have been well-established as methods of determining exertion during exercise (Helms, Cronin, Storey, & Zourdos, 2016) The Borg CR10 has earlier been used to quantify the perception of physical exertion (Morishita, Yamaucgi, Fujusaqa, & Domen, 2013). Comparing two training frequencies on trained subjects using the RPE scale to evaluate the perceived fatigue has, to the best of my knowledge, not been done before.

My hypothesis for this study is that training with a frequency of four (FULLBODY) would promote greater increase in strength compared to a weekly training frequency of two (SPLIT). I also hypothesize that the group with split program will have higher self-reported rate of perceive exertion than the full body group, due to the higher workload per muscle group per training bout.

2. Methods

2.1 Experimental Approach to the Problem

The study was conducted with a pretest-posttest randomized groups design. Participants were randomly assigned to one of two experimental groups: a SPLIT group where the training protocol was divided in two sessions training barbell back squat and exercises for the lower body and two sessions training bench press and exercise for the upper body; or a FULLBODY group where they trained four full body sessions with barbell back squat and bench press each time, together with four other exercises for the whole body. Throughout the eight-week training period all resistance training variables were held constant, especially total training volume (repetitions x set x intensity), between the two conditions, except the training frequency. The training protocol was built up with a pretest the week before the training period and a posttest the week after.

2.2 Subjects

Subjects were 21 male volunteers (Height = 1.85 ± 0.06 m. Body mass = 85.3 ± 12.3 kg, Age = 27.6 ± 7.6 years) and they were recruited from the local gym participants. All the subjects could be defined as trained, i.e. with a training age of minimum one year. The mean training age of the group was 4.7 ± 2.8 years. All subjects met the following inclusions criteria; 1. Could be defined as trained (a least a year's experience of resistance training with minimum two workout a week), 2. Experience with training the lift of barbell back squat and bench press, 3. Male, 4. Subject was free of injuries and stated they had not taken any performance enhancement drugs.

The subjects were randomly assigned to one of the two experimental groups: SPLIT (n=10) and FULLBODY (n=11). All subjects signed a declaration of consent before the pretest and had the option to withdraw from the study at any point. The study has been approved by "Norsk Senter For Forskningsdata (NSD)".

2.3 Resistance Training Procedures (Protocol)

The group SPLIT trained with a training frequency of two session per muscle groups and had the training protocol divided in to two lower- and two upper body workouts. The group FULLBODY had a training frequency of four sessions per muscle group and trained four full body workouts a week. The group SPLIT trained the two-strength assessment exercises of barbell back squat and bench press two times a week on alternative days. While FULLBODY trained the two exercises on all of their four weekly workouts.

The training protocol for both groups also included a mixture of single- and multi-joint exercises for the rest of the body. A schematic layout of the protocol can be found in Table 1. The weekly total training volume of the two groups was equal. The two exercises back squat and bench press had the training intensity determined based on their one repetition maximum (1RM) and was a percentage of the 1RM. The repetition ranges for these exercises were between two and ten, with the higher repetitions in the first couples of weeks. The intensity was between 65% and 90% of their 1RM. The intensity and repetition ranges for the bench press and back squat was periodized with more repetition and lower intensity the first weeks, and throughout the training period the repetitions and intensity gradually shifted to lower repetitions with high intensity. Weekly repetition ranges and intensity can be found in Table 2. The weekly set volume of these exercises was set to eleven, which follows the recommendation from Ralston et al 2017, that recommended a medium to high weekly set count for maximizing strength gain.

In the other exercises the repetition ranges ran between eight and twelve repetitions, with the intensity set to 2RIR (Reps in Reserve). Reps in reserve can be described as the amount of repetitions the athlete feel he has left in the tank. This means that with the 2RIR the subject had to feel that he has a maximum of two repetitions left to fatigue after a set of one exercise on that weight. If the subject felt that he could do more, he was instructed to increase the weight with 2-10% on the next set.

Protocol	Day 1	Sets	Day 2	Sets	Day 3	Sets	Day 4	Sets
Split	Bench press	6	Back squat	6	Bench press	5	Back squat	5
	Bent over row	3	Stiff legged deadlift	3	Lat pulldown	3	Leg press	3
	One arm dumbbell row	3	Lunges	3	Seated cable row	3	Leg curl	3
	Overhead press	3	Leg extension	3	Lateral raises	3	Calf raises	3
	Biceps	3			Triceps	3		
	Facepulls	3			Facepulls	3		
Full body	Back squat	3	Bench press	3	Back squat	3	Bench press	3
	Bench press	3	Back squat	3	Bench press	2	Back squat	2
	Bent over row	3	Seated cable row	3	One arm dumbbell row	3	Lat pulldown	3
	Leg curl	3	Leg extension	3	Leg press	3	Stiff-leg deadlift	3
	Biceps	3	Overhead	3	Triceps	3	Lunges	3
	Facepulls	3	Calf raises	3	Facepulls	3	Lateral raises	3

Table 1. Schematic overview of the training protocol.

Back Squat			**Bench press**	
Week	Rep range	Intensity (% of 1RM)	Rep range	Intensity (% of 1RM)
1	5-7	70-75 %	7-10	65-70 %
2	3-7	72.5-80 %	6-10	67-72.5 %
3	3-6	75-80 %	6-10	70-75 %
4	2-5	77.5-87.5 %	4-8	72.5-80 %
5	3-5	75-82.5 %	3-5	72.5-82.5 %
6	3-5	75-85 %	3-5	77.5-85 %
7	2-4	77.5-87.5 %	2-5	77.5-87.5 %
8	2-5	77.5-90 %	2-4	80-90 %

Table 2. Schematic overview of the load and repetitions ranges.

2.4 Measurements of Muscle Strength

Maximal strength in barbell back squat ($1RM_{SQUAT}$) and bench press ($1RM_{BENCHPRESS}$) was assessed by a one repetition maximum (1RM) test. The 1RM test was done following the guidelines established by the National Strength and Conditioning Association (Haff, Triplett, & National Strength & Conditioning Association (U.S.), 2016). Before the subjects started the testing of 1RM in both exercises they completed a 5-10-minute general warmup. The testing started with the test of 1RM in barbell back squat. Following the completion of the squat test the subject started the test of 1RM in bench press. The 1RM test was structure with first a set of five repetitions on around 50% of estimated 1RM, followed by 2-3 sets of 2-3 repetitions around 60-80 % of estimated 1RM. The subjects then performed one repetition sets with increasing load to establish a 1RM. They had a maximum of five attempts to determine the 1RM. Between every successful attempt the subject had a rest period of 3-5 minutes before the next set with increased weight. To get the attempt approved in the barbell back squat the subjects had to meet the parallel depth and a green light from the test leader. In the bench press the subject had to have head, shoulders and bottoms placed on the bench and the feet placed on the floor during the lift. They had to lower the barbell to their chest and had to achieve full extension in the elbow to get the lift approved. The participants were asked to refrain from any other exercise 24 hours before testing

2.5 Measurements of Rating of perceived exertion

A rating of perceived exertion (RPE) was used to see if there was a difference between the two groups conditions after the workouts. The Borg CR10 scale was used as the RPE scale in this study. This scale is presented in table 3 and is based on the scale from Morishita et al. 2013. After completing each of the exercises of barbell back squat and bench press and after completing the exercise session, the subject was instructed to rate their perceived exertion by choosing a number on the CR10 scale. A rating of 0 can be categorized as no effort or at rest, and a rating of 10 as the maximal effort they can achieve.

Rating RPE	Descriptor
0	Rest
1	Very easy
2	Easy
3	Moderat
4	Somewhat hard
5	Hard
6	-
7	Very hard
8	-
9	-
10	Maximal

Table 3. *Borgs CR10 Rating of perceived exertion (RPE) scale used in this study. Based on Morishita et al. 2013.*

2.6 Statistical Analyses

All Statistical analyses were performed using SPSS 24.0 for Windows (SPSS Inc., Chicago, IL, USA). The normality and homogeneity of the variances were verified using the Shapiro-Wilk and Levene's test. Descriptive statistics (mean ± SD) were calculated for every dependent variable for the pretest and posttest ($1RM_{SQUAT}$, $1RM_{BENCHPRESS}$). To compare the effect of the two protocols, a two way ANOVA 2 (pre- and posttest) x 2 (groups: FULLBODY and SPLIT) was performed for each of the strength assessment. A paired-samples t-test was used to determine whether there was a significant difference between pre- and posttest for both groups and for both exercises. Effect sizes was calculated using Cohen's d. The formula that was used was the difference between post- and pretest divided by the standard deviations of the pretest (Thomas, Nelson & Silverman, 2015, s.271).

The d results were qualitatively interpreted using the following thresholds: < 0.2 trivial, 0.2-0.5 small effect, 0.5-0.8 moderate, 0.8-1.2 large (Cohen, 1988), 1.2-2.0 very large and > 2.0 enormous (Sawilowsky, 2009). Percentage increase was also calculated for $1RM_{SQAUT}$ and $1RM_{BENCHPRESS}$.

A two-way ANOVA 2 (groups: FULLBODY and SPLIT) x 8 (weekly mean of RPE, week 1 to 8) was done for the three different RPE (RPE after bench press, squat and the workout). Assumptions of sphericity were evaluated using Mauchly's test. Where sphericity was violated ($p < 0.05$), the Greenhouse–Geisser correction factor was applied.

An independent t-test was also done to determine if the subjects reported significant difference in weekly RPE means (After squat, benchpress and the training bout) on the three different RPE for each week. The p-value for significance was set at 0.05 with 95% confidence intervals.

3. Results

Group	n	Age	Height	Weight	Pretest Squat	Posttest Squat	Pretest Bench	Posttest Bench
SPLIT	10	30.6 (± 9.5)	183.9 cm (± 4.7)	87.0 kg (± 13.3)	118.5 kg (± 17.9)	132.0 kg (± 19.3)	101.0 kg (± 25.4)	108.7 kg (± 24.9)
FULLBODY	11	24.8 (± 4.0)	186.7 cm (± 7.0)	83.7 kg (± 11.6)	126.6 kg (± 22.0)	139.0 kg (± 24.0)	91.6 kg (±24.0)	100.4 kg (± 22.1)

Table 4. *Descriptive statistics for both groups, displayed as mean (± SD)*

3.1 One repetition maximum (1RM)

3.1.1 1RM Barbell Back Squat

The two-way ANOVA showed a significant effect for time on $1RM_{SQUAT}$ ($F_{1,19}$ = 152.9 p < 0.001 partial n^2 = 0.889). Neither the groups ($F_{1,19}$ = 794.6, p = 0,687, partial n^2 = 0,977) or the interactions of groups*time ($F_{1,19}$ = 0.226, p = 0.640, partial n^2 = 0.012) showed a significant effect on $1RM_{Squat}$. The effect size for the protocol was 0.71 and 0.56 for SPLIT and FULLBODY, respectively. Both groups showed a significant increase in $1RM_{SQUAT}$ from baseline to poststudy by 13.25 kg and 11.2 % (t_9 = 9.5, p < 0,001) for the SPLIT group and for the FULLBODY group 12.27 kg and 9.69% increases (t_{10}=7.9, p < 0.001) (Figure 1).

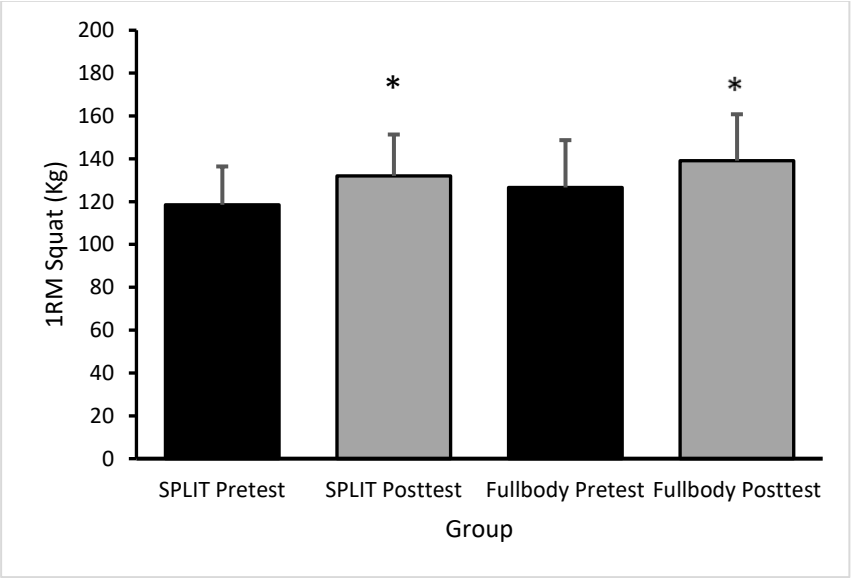

Figure 1. *Graphical representation of 1 repetition maximum squat values pre- and postintervention for Split and Fullbody, respectively, mean (± SD). Values are expressed in kilograms. * Significantly greater than the corresponding pretest value.*

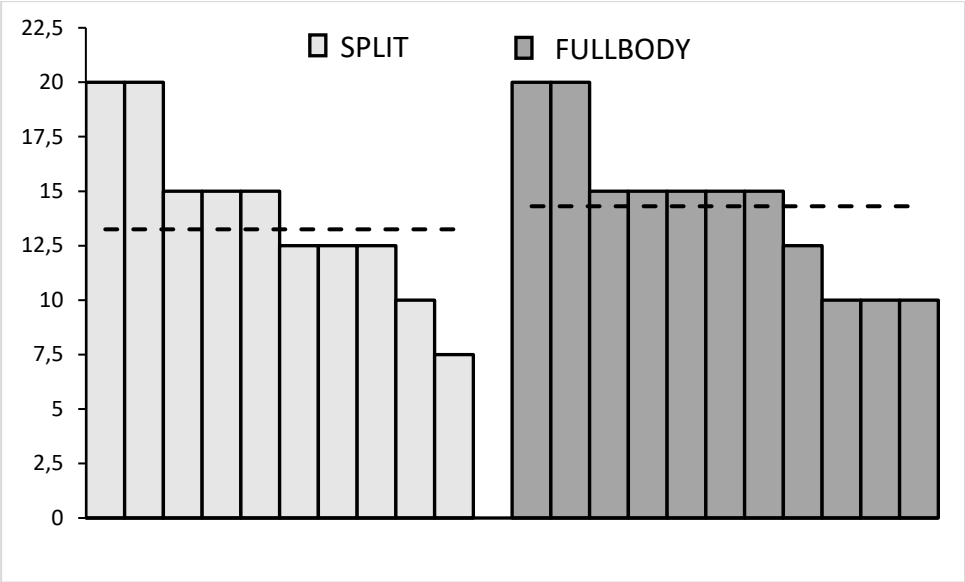

Figure 2. *Changes in 1RM in barbell back squat from pretest to posttest per participants for the two groups. Reported in kilogram (Kg). With the average change per group indicated by a horizontal line.*

3.1.2 1RM Bench Press

The two-way ANOVA showed a significant effect for time on $1RM_{BENCHPRESS}$ ($F_{1,19}$ = 223.9, p < 0.000, partial n^2 = 0.922). Neither groups ($F_{1,19}$ = 0.708, p = 0.401, partial n^2 = 0,036) or the interactions of groups*time ($F_{1,19}$ = 1.006, p = 0.328, partial n^2 = 0.050). Both groups showed a significant increase in $1RM_{BENCHPRESS}$ from baseline to poststudy by 7.75 kg and 7.67 % (t_9 = 13.28, p < 0,001) for the SPLIT group and the FULLBODY group had increase by 8.86 kg and 9.69 % (t_{10} = 9.69 p < 0,001) (Figure 2). The effect size for the protocol was 0.31 and 0.38 for SPLIT and FULLBODY, respectively.

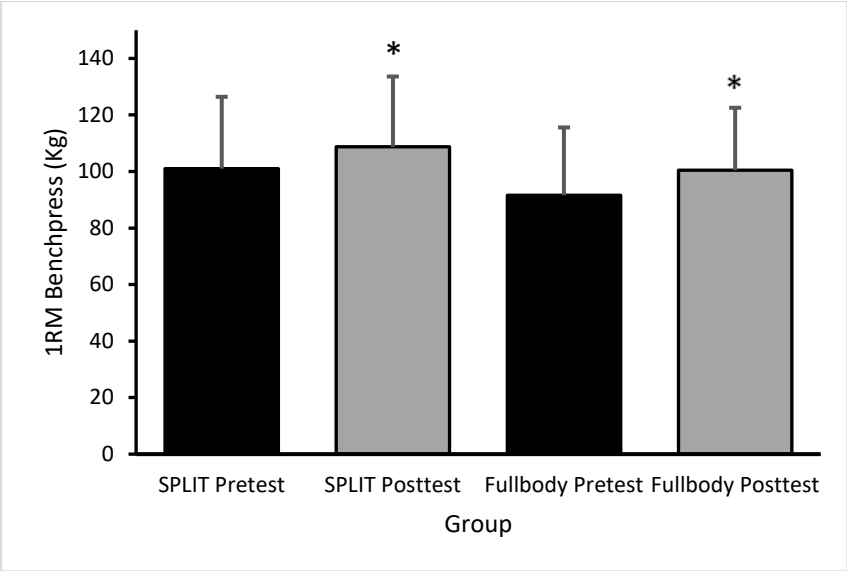

Figure 3: *Graphical representation of 1 repetition maximum bench press values pre- and postintervention for Split and Fullbody, respectively, mean (± SD). Values are expressed in kilograms. * Significantly greater than the corresponding pretest value, $p < 0.05$.*

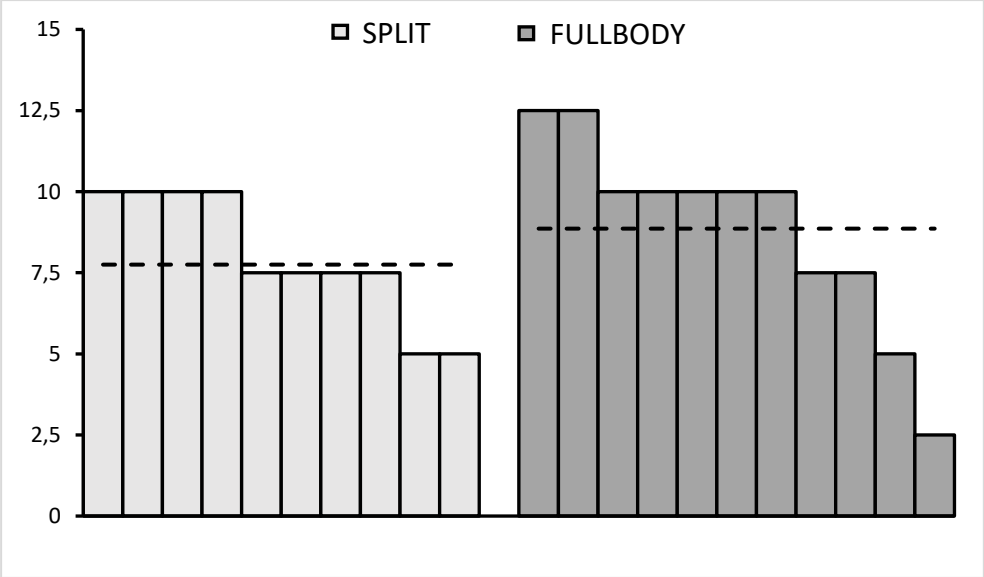

Figure 4. *Changes in 1RM in Bench Press from pretest to posttest per participants for the two groups. Reported in kilogram (Kg). With the average change per group indicated by a horizontal line.*

3.2 Self-reported rating of perceived exertion (RPE)

3.2.1 RPE the exercise bout

Figure 5. shows the self-reported rating of perceived exertion (RPE) for the exercise bout. The analysis showed that which week had a significant influence on the rating of perceived exertion ($F_{4.1,78.4} = 4.9$, $p = 0.001$, partial $n^2 = 0.205$) with Bonferroni adjusted, post hoc test revealing that the subject reported significant higher RPE in week 3 ($p = 0.040$) and week 4 ($p = 0.012$) than in week 2. Post hoc also revealed a that the subject reported significant higher RPE in week 4 than in week 5 ($p = 0.002$), week 6 (0.005) and week 7 (0.042). Neither the group ($F_{1,19} = 0.2$, $p = 0.635$, partial $n^2 = 0.012$) or the interaction of group*week ($F_{4.1,78.4} = 1.4$, $p = 0.225$, partial $n^2 = 0.069$) had a significant effect on self-reported RPE after the exercise bout. The independent t test showed no significant difference between the reported RPE between the subjects in any of the eight weeks ($t_{19} = 1.43$, $p > 0.167$),

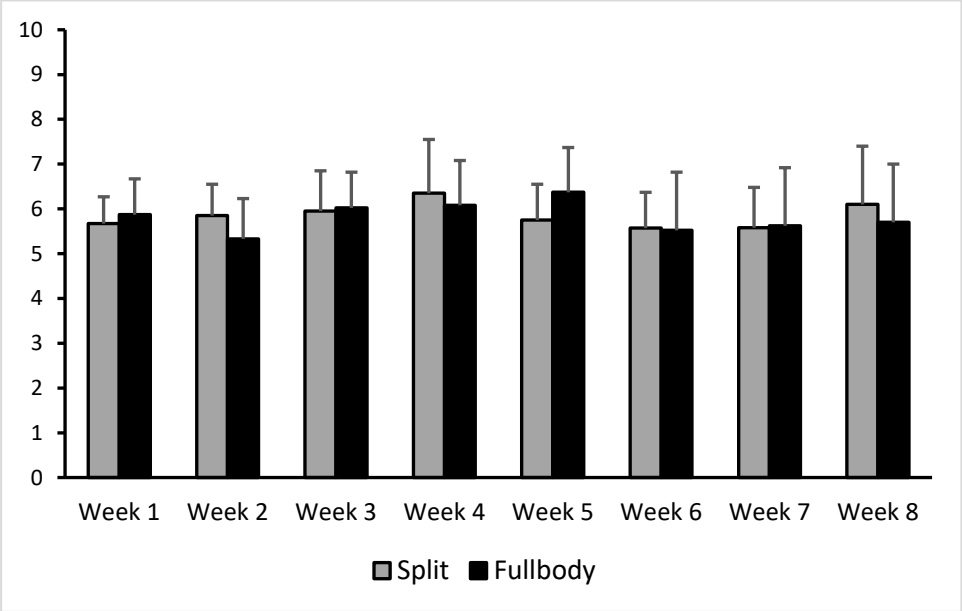

Figure 5. *Graphical representation of rating of perceived exertion for after the training bout, expressed as weekly mean (± SD).*

3.2.2 RPE barbell back squat

Figure 6. shows the self-reported rating of perceived exertion (RPE) for the Squat exercise. The analysis showed that week had a significant influence on the rating of perceived exertion ($F_{3.9,75,9} = 10.2$, $p < 0.001$, partial $n^2 = 0.350$) after the squat exercise. A Bonferroni adjusted post hoc test revealed that the subjects reported significant higher RPE in week 4 than in week 2 ($p = 0.030$), week 6 ($p < 0.001$) and week 7 ($p = 0.023$). Post hoc also showed that the subject reported significant lower RPE in week 5 than in week 1 ($p = 0.002$), week 2 ($p =$

0.003), week 3 (p = 0.006), week 4 (p < 0.001) and week 8 (p = 0.001). The subjects also reported significant higher RPE in week 8 than in week 5 (p = 0.001) and week 6 (p = 0.003). The interaction of week*group also showed a significant effect ($F_{3.9,75,9}$ =3.5, p = 0.012, partial n^2 = 0.350). Group had non-significant effect ($F_{1,19}$ = 3.3, p = 0.083, partial n^2 = 0.150) on self-reported RPE after squat exercise.

The independent t test showed two significant differences in weekly RPE between groups, in week 4 (t_{19}= 3.14, p = 0.005) and week 5 (t_{19}= 3.41, p = 0.003), the other six weeks showed no significant difference (t_{19}= 1.90, p > 0.072).

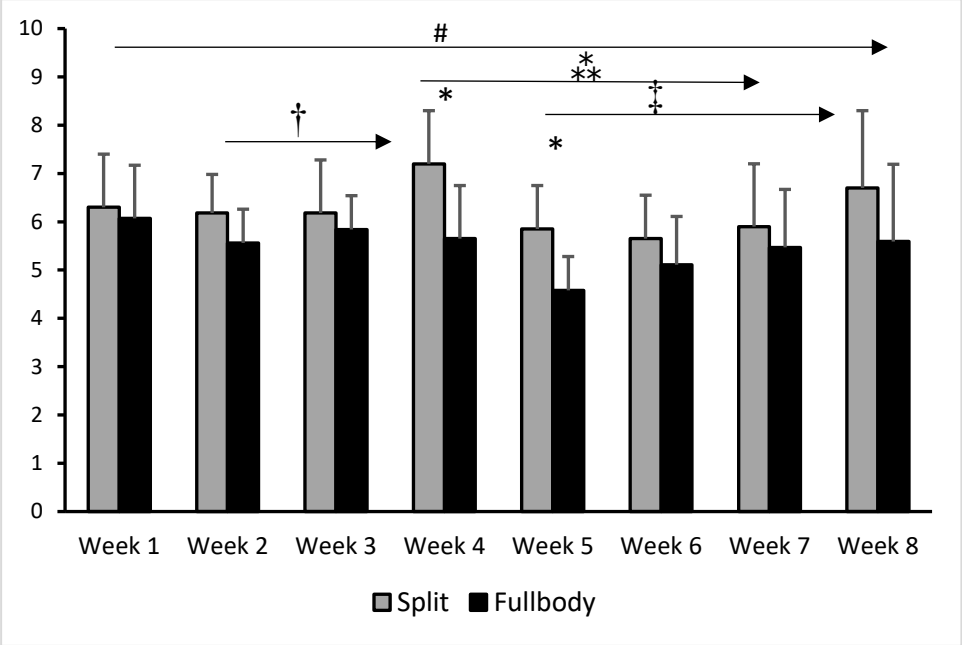

Figure 6. *Graphical representation of rating of perceived exertion for after barbell back squat, expressed as weekly mean (± SD). * Significantly difference between the two groups, p < 0.05. # a significant effect for the interaction of week*group, p =0.012. † A significant RPE for both groups in week 4 than 2. ⁂Significant higher reported RPE for both groups in week 4 than through week 5 (p < 0.001), 6 (p < 0.001) and 7 (p = 0.023). ‡ A significant increase in RPE for both groups from week 5 (p = 0.001) and 6 (< 0.001) to week 8*

3.2.3 RPE bench press

Figure 7. shows the self-reported rating of perceived exertion (RPE) for the bench press exercise. The analysis showed that week had a significant influence on the rating of perceived exertion ($F_{2.8,\ 53.9}$ = 3.0, p = 0.043, partial n^2 = 0.135) after the bench press exercise. A Bonferroni adjusted post hoc test revealed that the subject reported significant higher RPE in week 4 then week 2 (p = 0,050).

Neither the group ($F_{1,19}$ = 0.3, p = 0.611, partial n^2 = 0.014) or the interaction of group*week ($F_{2.8, 53.9}$ = 0.8, p = 0.477, partial n^2 = 0.042) had a significant effect on self-reported RPE after the exercise bout.

The independent t test showed one significant difference in weekly RPE between groups, in week 2 (t_{19}= 2.18, p = 0.042). The other seven weeks showed no significant difference (t_{19}= 0.84, p > 0.414).

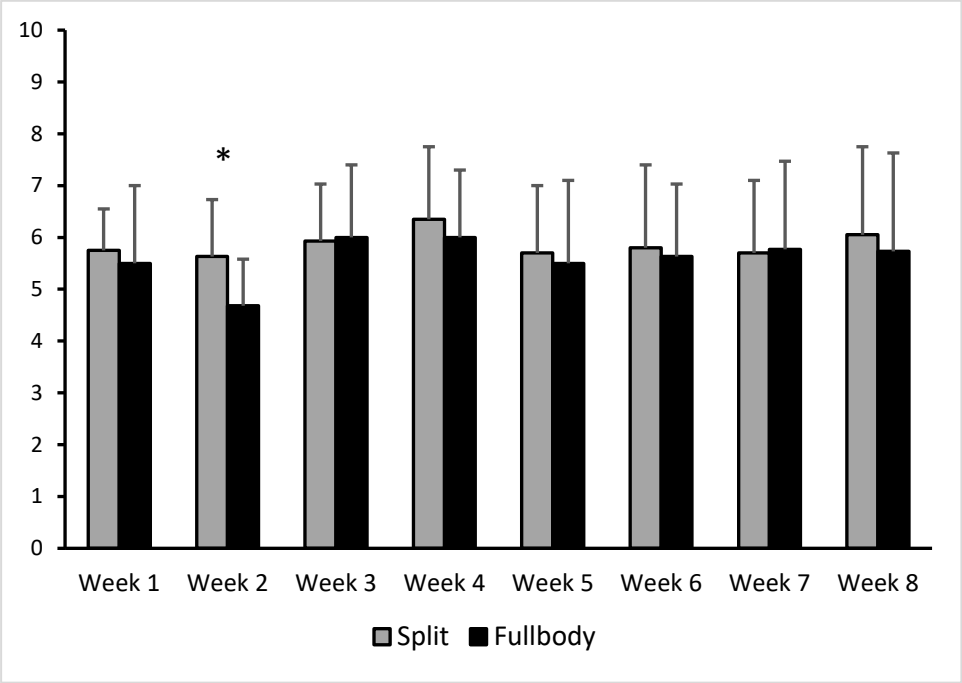

Figure 7. *Graphical representation of rating of perceived exertion for after bench press, expressed as weekly mean (± SD). * Significantly difference between the two groups, p < 0.05.*

4. Discussion

The main aim of this study was to investigate the effect of resistance training frequency by training two versus four times a week on muscular strength. It was hypothesized that the group with the higher training frequency (FULLBODY) would have a higher increase in strength than the group training with a frequency of two (SPLIT). The primary finding of this study is that both training frequencies achieved a significant increase in muscular strength in the two exercises barbell back squat and bench press over the eight weeks of training. The analyzes showed no significant difference in strength gains for $1RM_{SQUAT}$ or $1RM_{BENCHPRESS}$. Both the SPLIT and FULLBODY group had a nearly similar increase in strength from pretest to posttest in both $1RM_{SQUAT}$ (13.25 vs. 12.27 kg, respectively) and $1RM_{BENCHPRESS}$ (7.75 vs 8.86 kg, respectively). The results also show that a training period of eight weeks, regardless of frequency, will be proficient to increase muscle strength, as long as you hit the recommended weekly training sets in the exercises barbell back squat and bench press. These findings contradict my hypothesis before the start of the study, that we will see a difference in increase in muscle strength between the two training frequencies. Both frequencies groups obtained a moderate effect size (0.71 vs 0.56, respectively) for the treatment for $1RM_{Sqaut}$, with a trivial difference favoring the SPLIT group compared with the FULLBODY group. The effect size for $1RM_{BENCHPRESS}$ was nearly identical (0.31 vs. 0.38, for SPLIT and FULLBODY), with both groups obtaining a small effect.

To my knowledge, this study is one of the first to investigate the effects of training barbell back squat and bench press performed two versus four times a week in trained men, while the total training volume is equated between the two groups. Both frequencies showed to be sufficient to make an increase in strength over the eight weeks of training. The result of this study follows the trends shown in the other studies on the topic, with the effect of an increase in frequency not giving a significant higher effect on strength. A comparison with other studies can be done, but as mention in the introduction few studies have been done to investigate the effects of training frequencies under volume-equal conditions for trained subjects. Most of the published studies have showed no significant difference between lower frequencies and higher frequency (Brigatto et al., 2019; Colquhoun et al., 2018; Gentil et al., 2018; Gomes et al., 2019; Lasevicius et al., 2019; Saric et al., 2019; Schoenfeld et al., 2015).

McLester et al. 2000 result are the only one of these studies that contradicts this with reporting that the lower frequency group receiving only 2/3 of the increase in strength the high frequency group achieved.
It can also be noted that most studies published had a focus on different metrics and did not have the sole purpose to investigate the strength gains. Many of the studies mentioned had the subjects train on repetition ranges from 6 to 12. Earlier studies have shown that increase in 1RM can happen after training on many repetitions' ranges, but the ranges between one and five could be favorable for strength gains (Campos et al., 2002).

Although there was no significant difference between the groups on increase in maximum strength, one can see a trivial difference between the effect sizes (ES) between the two groups for 1RM for barbell back squat. The ES favors the SPLIT group (ES = 0.71) over the FULLBODY (ES = 0.56), which can indicate that training with split setup with training frequency of two session per muscle group per week could be more favorable then training an full body program four times a week. But the interpretation of this data must be taken with precautions, as the difference between the groups are not significant. The difference in ES could be explained in the difference in standard deviation for $1RM_{SQUAT}$ (see table 4.)

If you look at the increase in squats and bench press, regardless of frequency, you can see a clear difference in gained strength between the two exercises, with a higher percentage increase and ES in barbell back squat than in bench press. This can probably be explained by two mechanism. The first explanation could be in the difference in loading schemes for the exercises. The protocol for bench press had lower percentage of 1RM in the first couple of weeks, which could have been less optimal scheme than the scheme for the barbell back squat. The second explanation could have been the higher set-volume on the muscles in the legs, by the "support" exercises prescribed in the protocol. The protocol prescribed both multi-joint, as lunges, and single-joint, as leg extensions, for the legs (See Table 1.) that some articles argue have to be counted in the weekly sets on the muscles (Schoenfeld, Grgic, Haun, Itagaki, & Helms, 2019). While for the chest muscles it was only trained by the bench press, with three weekly sets of a triceps exercise as "support exercises".

This study summed together with corresponding studies and with the two meta-analysis on the topic (Grgic et al., 2018; Ralston et al., 2018) it seems that the effect of increasing the training frequency does not have an equally important role, as volume and load on strength gains (Ralston et al., 2017; Rhea et al., 2003).

Nevertheless, as the current findings show that weekly resistance training volume is more important than training frequency in trained men, it is not the end of training frequency. Although exercise frequency does not have an overall effect by itself on muscle strength, it can be an important variable to consider when developing training programs. Especially as the level of athletes increases and manipulation of training variables becomes more important (Kraemer & Ratamess, 2004). One of the methods to ensure further adaptation for athletes, when the level increases, is increasing the total weekly volume. This can be done in different ways as increasing weekly sets, reps per sets and load (Kraemer & Ratamess, 2004). When the total weekly sets for athlete increases into the higher ends, it could be advantageous to spread it out over several training sessions, as suggested by Hartmann et al. (2007) to reduce the likelihood of overtraining. Exercising at too high a volume per session can be less effective at maximizing muscle adaptations.

Thus, as there is a limit to amount of sets of good quality, due to fatigue (Boyas & Guevel, 2011), where this threshold lies is individual. Some studies have shown favorable outcomes to strength when training at a lower set per sessions is induced (Amirthalingam et al., 2017). Amirthalingam et al. 2017 concluded that exercising at 4-6 sets per muscle group within a workout was optimal for muscular adaptations, and increasing the number of sets over this, within a session, did not appear to produce greater effect. An increase in training volume in one session and therefore nearer to failure has also been shown to significantly increases recovery time needed (Pareja-Blanco et al., 2018).

My study has difficulty controlling for such an effect, since the total volume was at a medium level (Weekly sets were at 11) and the intra session sets were also low, with 5-6 sets per session for the SPLIT group and only 2-3 for the FULLBODY group.

This effect could be the reason why the Norwegian Frequency Project show positive effects favoring higher frequency (Raastad et al. 2012), as higher levels/elite athletes need a higher weekly set volume to get adaptations. But this is just speculation as the methods of the study cannot be verified or controlled.

Then it is a possibility that frequency can have an effect when weekly sets are very high, but further research is required to develop understanding of this, as no studies is conducted on very high weekly sets (20+).

These finding also contradicts the idea about motor learning theory put forward in the introduction, with the thoughts of practicing an exercise more frequently will induce higher strength gains, due to higher improvement inn neural efficiency (Shea et al., 2000). The findings follow the thoughts of Sale (1988) that this effect is limited for trained subjects. These results can be interpreted as that practicing a strength exercise twice a week could be proficient to increase neural efficiency for trained subjects, but more research is needed to conclude.

Rating of perceived exertion (RPE) can be an important tool for resistance trained subjects and coaches during exercise execution or training sessions (Foster et al., 2001). Regarding the measurement of rating of perceived exertion in this study, the main findings is that the subjects reported that RPE had a significant effect for week in all the three measurements (RPE after the training bout, barbell back squat and bench press). This can be interpreting as an effect of the intensity change throughout the training period. This follows earlier studies that has shown a correlation between the reported RPE and the intensity prescribed of 1RM under strength training (Naclerio et al., 2011; Pincivero, Coelho, & Campy, 2003). This study also showed a significant effect for the interactions of week and frequency for only the RPE after the barbell back squat, with an indicator that the subjects reported higher RPE after the squat for the SPLIT group then the FULLBODY group (Figure 4.) through the training period. The two other measurement of RPE (After exercise bout and bench press) did not show a significant interaction effect. This difference between the exercises RPE's can indicate that a higher number of sets with of barbell back squat in one session can induce higher felt fatigue and splitting the totals sets of barbell back squat in to two session can be favorable for perceived exertion.

It can also be noted that it can be an effect of the number of sets done with "support exercise" and single joint exercise in the training protocol. The increased number of sets done on the muscles that are used, can increase the subjects' fatigue and increase the recovery time needed after the training session.

Limitations

This study had several limitations that must be mentioned and considered when attempting to draw a conclusion and practical applications. The first limitation that should be noted is that the study only lasted 8 weeks. Although the duration was sufficient to achieve a significant increase in strength for both barbell back squat and bench press, it can be speculated that over time the difference between the group could increase. Second, the small sample size affected the statistical power, as the majority of longitudinal studies in this field. Third, this studies result is specific to resistance trained men. Men and women could have, as Hunter 2014 reported and suggested, a difference in fatigability. It's suggested that women have a higher recovery rate on muscle fatigue then men after resistance training (Judge & Burke, 2010), and therefore may have better effects of higher frequency then men. This must be explored more as, to my knowledge, there is no studies testing the effects of training frequency on trained women. The fourth limitation is that study this did not control for the dietary intakes of the subjects. The subjects may not have an optimal nutritional intake during the training period, which may affect the result. The randomization of the subjects should have prevented such a bias. The last limitation that must noted is the subjects was not controlled in the training period, other than weekly conversations about the training and RPE. They all trained by them self in their local gym.

Conclusions

Based on my finding, I will conclude that both training with a frequency of two and four session per muscle group are both viable approaches to increase muscle strength in the exercise barbell back squat and bench press for trained males, as long as the total weekly training volume is equal. As for the rating of perceived exertion it is possible that spreading the weekly volume to different days could be favorable, especially for exercising the muscle in the lower body. The group training with a training frequency of four reported a lower RPE for barbell back squat than the group training with a frequency of two.

Practical Applications

The result of this study suggests that both training with a training frequency of two and four gives similar increase in muscular strength for trained subjects under the same total weekly volume. This gives coaches and athletes greater variety in how to structure a training program with different training frequencies without sacrifice an increase in performance. Programs can then be periodized with different training frequencies to follow the athlete's personal preferences, time constraints or when the daily training volume are no longer manageable. It is in my opinion that coaches should increase the training frequency as the total weekly training volume increases to the higher end of the spectrum, to counteract higher recovery time. As mentioned before this hypothesis has to be investigated more.

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