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

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Background In resistance training, the role of training frequency to increase maximal strength is often debated but the limited data available does not allow for clear training frequency "optimization" recommendations. The purpose of this study was to investigate the effects of training frequency on maximal muscular strength and rate of perceived exertion (RPE). The total weekly training volume was equally distributed between two or four sessions per muscle group. **Methods** Twenty-one experienced resistance-trained male subjects (height: 1.85 ± 0.06 m, body mass: 85.3 ± 12.3 kg, age: 27.6 ± 7.6 years) were tested prior to and after an eight-week training period in one-repetition maximum (1RM) barbell back squat and bench press. Subjects were randomly assigned to a SPLIT group (n = 10), in which there were two training sessions of squats and lower-body exercises and two training sessions of bench press and upper-body exercises , or a FULLBODY group (n = 11), in which four sessions with squats, bench press and supplementary exercises were conducted every session. In each session, the subjects rated their RPE after barbell back squat, bench press, and the full session. **Results** Both groups significantly increased 1RM strength in barbell back squat (SPLIT group: +13.25 kg; FULLBODY group: +14.31 kg) and bench press (SPLIT group: +7.75 kg; FULLBODY group: +8.86 kg,) but training frequency did not affect this increase for squat (p = 0.640) or bench press (p = 0.431). Both groups showed a significant effect for time on RPE on all three measurements. The analyses showed only an interaction effect between groups on time for the RPE after the squat exercise (p = 0.002). **Conclusion** We conclude that there are no additional benefits of increasing the training frequency from two to four sessions under volume-equated conditions, but it could be favorable to spread the total training volume into several training bouts through the week to avoid increased RPE sometimes, especially after the squat exercise.

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6 Original research

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23 **ABSTRACT**

24 **Background**

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26 but the limited data available does not allow for clear training frequency "optimization"
27 recommendations. The purpose of this study was to investigate the effects of training frequency
28 on maximal muscular strength and rate of perceived exertion (RPE). The total weekly training
29 volume was equally distributed between two or four sessions per muscle group.

30 **Methods**

31 Twenty-one experienced resistance-trained male subjects (height: 1.85 ± 0.06 m, body mass: 85.3
32 $\pm$ 12.3 kg, age: 27.6 ± 7.6 years) were tested prior to and after an eight-week training period in
33 one-repetition maximum (1RM) barbell back squat and bench press. Subjects were randomly
34 assigned to a SPLIT group (n = 10), in which there were two training sessions of squats and lower-
35 body exercises and two training sessions of bench press and upper-body exercises , or a
36 FULLBODY group (n = 11), in which four sessions with squats, bench press and supplementary
37 exercises were conducted every session. In each session, the subjects rated their RPE after barbell
38 back squat, bench press, and the full session.

39 **Results**

40 Both groups significantly increased 1RM strength in barbell back squat (SPLIT group: +13.25 kg;
41 FULLBODY group: +14.31 kg) and bench press (SPLIT group: +7.75 kg; FULLBODY group:
42 +8.86 kg,) but training frequency did not affect this increase for squat (p = 0.640) or bench press
43 (p = 0.431). Both groups showed a significant effect for time on RPE on all three measurements.
44 The analyses showed only an interaction effect between groups on time for the RPE after the squat
45 exercise (p = 0.002).

46 **Conclusion**

47 We conclude that there are no additional benefits of increasing the training frequency from two to
48 four sessions under volume-equated conditions, but it could be favorable to spread the total training
49 volume into several training bouts through the week to avoid increased RPE sometimes, especially
50 after the squat exercise.

51

52 **KEY WORDS:** RPE, rate of perceived exertion, bench press, squats

54 **INTRODUCTION**

55 The interest in resistance training has risen in popularity (Wernbom et al., 2007). Several studies

56 pointed out that conducting resistance training had many potential health benefits for people of all

57 ages (Winett & Carpinelli, 2001). An increase in overall strength through resistance training is

58 also seen in the context of an increase among athletes in a variety of sports (Suchomel et al., 2016).

59 Resistance training is an important factor in maintaining and developing muscle mass and muscle

60 strength. To maximize these adaptations in human muscles, the manipulations of various resistance

61 training variables (e.g. volume, intensity, load, and frequency) are key (Kraemer & Ratamess,

62 2004). Manipulations to training intensity and volume have received most of the attention but

63 training frequency has largely been overlooked (Grgic et al., 2018; Ralston et al., 2017).

64 The role of training frequency has been debated, and the optimal frequency is not clear. Training

65 frequency is defined in the literature as the number of training sessions performed for a given

66 period, usually described on a weekly basis (Kraemer & Ratamess, 2004). Frequency can be

67 further characterized by the number of training sessions per week per muscle group or exercise

68 (Schoenfeld et al., 2015), which is the definition used in this article. The American College of

69 Sports Medicine (2009), recommends that novices and untrained individuals should train every

70 muscle group 2-3 times per week (1). However, this recommendation of training frequency has

71 been the subject of some criticism since it is based on limited evidence (Grgic et al., 2018; Ralston

72 et al., 2018; Schoenfeld et al., 2019b). As a result, there has been a small renaissance on training

73 frequency, with multiple studies published on the topic. One study that has received much attention

74 was the "Norwegian Frequency Project," which showed positive results favoring higher frequency

75 training for elite/trained powerlifters (Raastad, 2012). The problem with this study is that it was

76 only used as a conference paper and never published in a journal, so it is difficult to control and

77 verify the methods used in the project.

78 Although the number of studies published is increasing, the total pool of studies is still limited. To

79 the best of our knowledge, there are eight published studies that explore the effects of training

80 frequencies on muscle adaptations on trained males under equal volume conditions (Brigatto et al.,

81 2019; Colquhoun et al., 2018; Gentil et al., 2018; Gomes et al., 2019; Lasevicius et al., 2019;

82 Mclester et al., 2000; Saric et al., 2019; Schoenfeld et al., 2015). Most of these studies have focused

83 on lower training frequencies, i.e. three or lower. Only three of these studies controlled for the

84 effect of training frequencies higher than three (Colquhoun et al., 2018; Gomes et al., 2019; Saric

85 et al., 2019). Most of these studies did not find any differences in gains in 1RM between training

86 frequencies except Mclester et al. (2000), who reported that the gains in 1RM by training once a

87 week were 33% lower than training three times per week. However, in this study the volume was

88 very low compared with the other studies and men and women were combined, which could

89 influence the results.

90 Two recent meta-analyses noted that the literature on training frequency under equal volume

91 conditions is small and suggested that future research is needed (Grgic et al., 2018; Ralston et al.,

92 2018). Ralston et al. (2018) noted that studies with trained subjects were needed. Dankel et al.

93 (2017) suggested that an increase in training frequency could be advantageous to spread the total

94 training volume to counteract muscle fatigue and overtraining. Training with a very high volume

95 in one training session can induce high levels of fatigue and prolonged recovery time, which can

96 be suboptimal for athletes that try to induce specific neuromuscular adaptations (Pareja-Blanco et

97 al., 2018). Seen in the context of motor learning theory, it also can be assumed that more frequent

98 training of a movement could lead to a higher increase in strength, due to an improvement in neural

99 efficiency (Shea et al., 2000).

100 Since it is unclear whether exercise frequency affects muscular strength under equal total exercise

101 volume, especially in higher training frequencies (Grgic et al., 2018), the purpose of this paper was

102 two-fold: first, to investigate the effect of training frequency of two versus four times per week

103 when matched on total training volume upon maximal muscle strength in strength-trained males;

104 second, to investigate the effects of training frequency on felt fatigue (rate of perceived exertion)

105 among the subjects. We hypothesized that training with a frequency of four sessions per week

106 would promote greater increases in maximal strength with a lower self-reported rate of perceived

107 exertion (RPE) compared to two sessions per week due to the lower workload per muscle group

108 per training session.

109

110 **METHODS**

111 ***Subjects***

112 Subjects were 21 male volunteers (height: 1.85 ± 0.06 m, body mass: 85.3 ± 12.3 kg, age: $27.6 \pm$

113 7.6 years) who were recruited subjects that attend the local gym. The inclusion criteria were the

114 subject had to be male, could be defined as trained (a least one year experience of resistance

115 training with a minimum of two workouts per week) with experience training on barbell back squat

116 and bench press, was free of injuries, and stated they had not taken any performance enhancing

117 drugs. The mean resistance training age of the group was 4.7 ± 2.8 years. Each subject was

118 informed of the testing protocol, training procedures, and possible risks; and written consent was

119 obtained from the subjects prior to the study. The study was conducted with the approval of the

120 Norwegian Center for Research Data project number: 42440 and conformed to the latest revision

121 of the Declaration of Helsinki.

122

123   ***Study design***

124   To investigate the effect of training frequency with the same training volume upon strength (1

125   repetition maximum in the bench press and squats) and RPE, a pretest-posttest randomized group

126   design was used. Subjects were randomly assigned to one of two experimental groups: a SPLIT

127   group where the training protocol was divided into two sessions training barbell back squat and

128   exercises for the lower body and two sessions training bench press and exercises for the upper

129   body; or a FULLBODY group where subjects trained four full-body sessions with barbell back

130   squat and bench press each time, together with four other supplementary exercises for the whole

131   body. A summary of the resistance training protocol can be found in Table 1. Throughout the eight-

132   week training period, all resistance training variables were held constant, especially total training

133   volume (repetitions x set x intensity), between the two conditions, except the training frequency.

134   The training protocol was built up with a pretest the week before the training period and a posttest

135   the week after.

136

137   ***Procedures***

138   One week before and after the intervention period, maximal strength was assessed by a one-

139   repetition maximum (1RM) test in barbell back squat ($1RM_{SQUAT}$) and bench press

140   ($1RM_{BENCHPRESS}$). The 1RM test was done following the guidelines established by the National

141   Strength and Conditioning Association (Haff et al., 2016). The subjects started with a 5-10-minute

142   general warm-up consisting of running on a treadmill, followed by a set of five repetitions at

143   around 50% of an estimated 1RM and 2-3 sets of 2-3 repetitions around 60-80% of the estimated

144   1RM. The subjects then performed one repetition sets with increasing load to establish their 1RM.

145   They had a maximum of five attempts to determine the 1RM. 1RM in barbell back squat was

146   always tested first followed by testing 1RM in bench press. Between each successful attempt, the

147   subject rested for 3-5 minutes before the next set with increased weight. To get an attempt

148   approved in the barbell back squat, the subjects had to meet the parallel depth and a green light

149   from the test leader. In bench press, the subject had to have head, shoulders, and bottoms placed

150   on the bench and the feet placed on the floor during the lift. They had to lower the barbell to their

151   chest and had to achieve full extension in the elbow to get the lift approved. The subjects were

152   asked to refrain from any other exercise for 24 hours before testing.

153   A rating of perceived exertion (RPE) was used to test if there was a difference between the two

154   groups after the exercises and workouts. RPE scales have been well-established as methods of

155   determining exertion during exercise (Helms et al., 2016). The Borg CR10 scale was used as the

156   RPE scale to quantify the perception of physical exertion (Morishita et al., 2013). After completing

157   each of the exercises (barbell back squat and bench press), and a couple of minutes after the

158   exercise session, the subject was instructed to rate their perceived exertion by choosing a number

159   on the CR10 scale. A rating of 0 was categorized as no exertion or at rest; a rating of 10 was the

160   maximal exertion they can achieve. The RPE measurement for each of the three rating points was

161   analyzed as a weekly mean for each of the subjects. All ratings through the training week for each

162   of the three measurements were summed and divided by the total number of measurements in that

163   week. The subjects were familiar with using the CR10 scale since they regularly evaluated their

164   training intensity by using this scale.

165   After the pretest, the subjects were randomly assigned to one of the two experimental groups:

166   SPLIT (n = 10, height: 1.84 ± 0.05 m, body mass: 87.0 ± 13.3 kg, age: 30.6 ± 9.5 yrs.) and

167   FULLBODY (n = 11, height: 1.87 ± 0.07 m, body mass: 83.7 ± 11.6 kg, age: 24.8 ± 4.0 yrs.);

168 each group trained under matched volumes. To control for volume, the total weekly resistance

169 training volume (repetitions x set x intensity) was equated between the groups. The volume was

170 equated because a dose-response relationship between volume and increase in muscular strength

171 has been previously reported (Heaselgrave et al., 2019; Ralston et al., 2018; Rhea et al., 2003).

172 The SPLIT training group trained with a frequency of two sessions per muscle group; the training

173 protocol was divided into two lower-body and two upper-body workouts. The FULLBODY

174 training group had a training frequency of four sessions per muscle group; they trained four full-

175 body workouts per week.

176 The training protocol for both groups also included a mixture of single- and multi-joint exercises

177 for the rest of the body (Table 1). The weekly total training volume of the two groups was equal.

178 Back squat and bench press had the training intensity determined based on their one-repetition

179 maximum (1RM) and was a percentage of the 1RM. The repetition ranges for these exercises were

180 between two and ten, with the higher repetitions in the first of weeks. The intensity was between

181 65% and 90% of their 1RM. The intensity and repetition ranges for the bench press and back squat

182 was periodized with more repetition and lower intensity during the first weeks; throughout the

183 training period, the repetitions and intensity gradually shifted to fewer repetitions with high

184 intensity. Weekly repetition ranges and intensity is reported in Table 2. The weekly set volume of

185 these exercises was set to eleven, which follows the recommendation from Ralston et al. (2017),

186 who recommended a medium to high weekly set count for maximizing strength gain.

187 In the other exercises, the repetition ranges were between eight and twelve repetitions, with the

188 intensity set to two repetitions in reserve (2RIR), i.e., is the number of repetitions the athlete feels

189 he has left in the tank. This means that with the 2RIR, the subject had to feel that he had a maximum

190 of two repetitions left to fatigue after a set of one exercise on that weight (Zourdos et al., 2016). If

191   the subject felt that he could do more, he was instructed to increase the weight by 2-10% on the

192   next set. 2RIR method for the supplementary exercises was used to have the possibility for

193   autoregulation within each subject and to avoid that the subject performed until full exhaustion

194   which could influence training the main exercises.

195

196   **TABLE 1 AND 2 AROUND HERE**

197

198   ***Statistical Analyses***

199   All statistical analyses were performed using SPSS 25.0 for Windows (SPSS Inc., Chicago, IL,

200   USA). The normality and homogeneity of the variances were verified using the Shapiro-Wilk and

201   Levene's tests. Descriptive statistics (mean ± SD) were calculated for each dependent variable for

202   the pretest and posttest ($1RM_{SQUAT}$, $1RM_{BENCHPRESS}$). To compare the effect of the two protocols,

203   a two-way ANOVA of 2 (pretest and posttest) x 2 (groups: FULLBODY and SPLIT) was

204   performed for each of the strength assessments. The percentage increase was also calculated for

205    $1RM_{SQUAT}$ and $1RM_{BENCHPRESS}$.

206   A two-way ANOVA of 2 (groups: FULLBODY and SPLIT) x 8 (weekly mean of RPE, week 1 to

207   8) was performed for the three different RPEs (RPE after bench press, squat, and workout).

208   Assumptions of sphericity were evaluated using Mauchly's test; where sphericity was violated (p

209   < 0.05), the Greenhouse–Geisser correction factor was applied. A one-way ANOVA (weekly mean

210   of RPE, week 1 to 8) was also done per group for the three different RPEs to identify the

211   development per group. When significant differences occurred, Holm-Bonferroni post hoc tests

212   were conducted to identify statistically significant comparisons. The level of significance was set

213   at p < 0.05, and all data were expressed as mean ± SD. Effect size was evaluated with η^2 (eta

214   squared) where $0.01 < \eta^2 < 0.06$ constitutes a small effect, $0.06 < \eta^2 < 0.14$ constitutes a medium

215   effect, and $\eta^2 > 0.14$ constitutes a large effect (Cohen, 1988).

216

217   **RESULTS**

218   At baseline, no significant difference in 1RM in squat (p=0.55) and bench press (p=0.46 were

219   found between the groups. Each group increased in the bench press (SPLIT group: +7.75 kg;

220   FULLBODY group: +8.86 kg; F = 223.9, p < 0.001, $\eta^2 = 0.92$) and squat exercise (SPLIT group:

221   +13.25 kg; FULLBODY group: +14.31 kg; F = 152.9, p < 0.001, $\eta^2 = 0.89$) significantly from pre

222   to post test (Figure 1). Relatively, the SPLIT and FULLBODY training groups increased by 7.7%

223   and 9.7%, respectively, in 1RM bench press and by 12.1% and 11.5%, respectively, in 1RM squats.

224   The relative gain in 1RM in squats was significantly higher than in 1RM in bench press (p=0.022).

225   The was no effect of group (F $\leq$ 0.71, p $\geq$ 0.40, $\eta^2 \leq 0.036$) or interaction effect of group*time (F

226    $\leq$ 1.0, p $\geq$ 0.33, $\eta^2 \leq 0.05$) for strength (Figure 2).

227

228   FIGURE 1 AND 2 AROUND HERE

229

230   The rating of perceived exertion (RPE) for the exercise bout (F = 4.9, p < 0.001, $\eta^2 = 0.21$), after

231   the squat (F = 10.2, p < 0.001, $\eta^2 = 0.35$) and bench press (F = 3.0, p = 0.043, partial $n^2 = 0.14$)

232   exercises per week were influenced during the intervention period. Only a significant time*group

233   effect was found in RPE after the squat exercise (F = 3.5, p = 0.002, $\eta^2 = 0.15$). In addition, a non-

234   significant but large effect was found between the two training groups in RPE after the squat

235   exercise (F = 3.34, p = 0.083, $\eta^2 = 0.15$).

236   The post hoc comparison revealed that the subjects in the split group reported significantly higher

237   session RPE in week 4 compared with week 3 and 5; the RPE increased again from week 6 to 8

238   (Figure 3). In the FULLBODY group, the session RPE decreased from week 1 to 2 followed by

239   an increase until week 4. In week 5, it decreased again significantly (Figure 3).

240   RPE after the squat was significantly higher in the SPLIT group in weeks 4 and 5 compared with

241   the FULLBODY group. Also, the development of the RPE per week after squats followed a

242   different development: while the RPE increased in week 4, decreased in week 5, and increased

243   again the last two weeks for the SPLIT group, the RPE of the FULLBODY group decreased to a

244   minimum in week 5, after which it increased again in week 6 (Figure 3).

245   RPE after bench press only changed in week two, in which only the FULLBODY group had a

246   significantly lower RPE compared with the other weeks during training. This also resulted in a

247   significant difference with the SPLIT group in week two (Figure 3).

248

249   Figure 3 around here

250

251   **DISCUSSION**

252   The main aim of this study was to investigate the effect of resistance training frequency on

253   maximal muscular strength and RPE by training twice versus four times a week when matched on

254   total training volume. The main findings were that both training frequencies achieved a similar

255   significant increase in maximal strength (1RM) in the barbell back squat and bench press over the

256   eight weeks of training. However, RPE developed differently during the training period in which,

257   especially after the squat exercise, RPE seems to be higher some weeks for the SPLIT group

258   compared with the FULLBODY group.

259   Both SPLIT and FULLBODY groups had a similar increase in strength from pretest to posttest in

260   both $1RM_{SQUAT}$ (13.25 and 12.27 kg, respectively) and $1RM_{BENCHPRESS}$ (7.75 and 8.86 kg,

261   respectively), which indicates that eight weeks of training, regardless of frequency, will increase

262   muscle strength, as long as the weekly training volume in the exercises, barbell back squat, and

263   bench press are high enough. The result of this study follows the trends shown in other studies

264   (Brigatto et al., 2019; Colquhoun et al., 2018; Gentil et al., 2018; Gomes et al., 2019; Lasevicius

265   et al., 2019; Saric et al., 2019; Schoenfeld et al., 2015) on the topic, with the effect of an increase

266   in frequency not yielding a significantly greater effect on maximal strength. Only Mclester et al.

267   (2000) reported that a lower frequency group achieved only 2/3 of the increase in strength of the

268   high-frequency group, but they compared one session per week with three sessions per week.

269   Regardless of frequency, the relative 1RM gain in squats was higher than in the bench press. This

270   can be explained by two mechanisms. The first explanation could be in the difference in loading

271   schemes for the exercises. The protocol for bench press had a lower percentage of 1RM in the first

272   couple of weeks, which could have been a less optimal scheme than the scheme for the barbell

273   back squat. The second explanation could have been the higher set-volume on the muscles in the

274   legs by the "support" exercises prescribed in the protocol. The protocol prescribed both multi-

275   joint, such as lunges, and single-joint exercises, such as leg extensions, focused on the legs (Table

276   1). Some researchers argue these have to be counted in the weekly sets on the muscles (Schoenfeld

277   et al., 2019a). The chest muscles were only trained by the bench press, with three weekly sets of a

278   triceps exercise as a "support exercise."

279   Although exercise frequency does not have an overall effect by itself on muscle strength, it can be

280   an important variable to consider when developing training programs. As the level of athletes

281   increases, manipulation of training variables becomes more important (Kraemer & Ratamess,

282   2004). One of the methods to ensure further adaptation for athletes when the training level

283   increases, is to correspondingly increase the total weekly volume. This can be done in different

284   ways, such as increasing weekly sets, repetitions per set, and load (Kraemer & Ratamess, 2004).

285   When the total weekly sets for an athlete reaches an upper limit, it could be advantageous to spread

286   volume over several training sessions, as suggested by Hartmann et al. (2007), to reduce the

287   likelihood of overtraining. Exercising at too high of a volume per session can be less effective at

288   maximizing muscle adaptations. There is a limit to the number of good quality sets due to fatigue

289   (Boyas & Guevel, 2011), but this threshold is different for each individual. Some studies have

290   shown favorable outcomes to strength when training at a lower number of sets per session is

291   introduced (Amirthalingam et al., 2017). Amirthalingam et al. (2017) concluded that exercising at

292   4-6 sets per muscle group within a workout was optimal for muscular adaptations and increasing

293   the number of sets within a session to greater than this number did not appear to produce a greater

294   effect. An increase in total training volume (repetitions x set x intensity) in one session and,

295   therefore, nearer to failure has also been shown to significantly increase the recovery time needed

296   (Pareja-Blanco et al., 2018). In our study, a recovery time effect did not occur, since the total

297   training volume was at a medium level (Weekly sets were at 11) and the intra-session sets were

298   also low, with 5-6 sets per session for the SPLIT group and 2-3 for the FULLBODY group. This

299   effect could be the reason why the Norwegian Frequency Project showed positive effects of higher

300   training frequency (Raastad, 2012), because higher level/elite athletes need a higher weekly set

301   volume to get adaptations. However, this is speculation, because the methods of that study cannot

302   be verified or controlled. There is a possibility that frequency can have an effect when weekly sets

303   are very high, but further research is required to develop an understanding of this; as of this

304   publication, no studies have been conducted on very high weekly sets (i.e., more than 20 sets).

305   The present findings also contradict motor learning theory, i.e., that practicing an exercise more

306   frequently will induce higher strength gains due to higher improvement in neural efficiency (Shea

307   et al., 2000). Our findings follow the hypothesis of Sale (1988) that this effect is limited for trained

308   subjects. Our results demonstrate that practicing a strength exercise twice a week could be

309   proficient to increase neural efficiency for trained subjects.

310   Fatigue could influence strength gain and recovery of athletes due to the total training volume per

311   muscle group per session. To this end, the rating of perceived exertion can be an important tool

312   for resistance-trained subjects and coaches during exercise execution or training sessions (Foster

313   et al., 2001). We found that subjects reported RPE changes during the training period per week in

314   all three measurements (RPE after the training bout, barbell back squat, and bench press), which

315   is an indication that the intensity changed throughout the training period, especially around week

316   four and five. This follows previous studies that have shown a correlation between the reported

317   RPE and the intensity prescribed for 1RM under resistance training (Naclerio et al., 2011;

318   Pincivero et al., 2003). The main changes in RPE per week occurred after the barbell back squat

319   with the indication that the subjects reported higher RPE after the squat for the SPLIT group then

320   the FULLBODY group (Figure 3) throughout the training period. This difference between the

321   exercises RPE indicates that a higher number of sets with barbell back squats in one session can

322   induce higher fatigue; splitting the total sets of barbell back squat into two sessions can be

323   favorable for perceived exertion. This result could also be an effect of the number of sets done

324   with "support exercise" and single-joint exercises in the training protocol. The increased number

325   of sets done on the muscles that are used can increase the subjects' fatigue and increase the

326   recovery time needed after the training session.

327 This study had several limitations. First, the study only lasted 8 weeks. Although the duration was

328 sufficient to achieve a significant increase in strength for both barbell back squat and bench press,

329 over a longer training time, a differences between the groups could occur. Second, the small sample

330 size affected the statistical power, as most longitudinal studies in this field. Third, the results are

331 specific to resistance-trained men. Men and women could have a difference in fatigability (16). It

332 has been suggested that women have a quicker recovery rate on muscle fatigue than men after

333 resistance training (Judge & Burke, 2010), and therefore may experience better effects of higher

334 frequency than men. However, to our knowledge, there are no studies testing the effects of training

335 frequency on trained women. Fourth, this study did not control for the dietary intakes of the

336 subjects. The subjects may not have had an optimal nutritional intake during the training period,

337 which may affect the results; however, the randomization of the subjects should have prevented

338 such a bias.

339 Based on our findings, we conclude that training with a frequency of two and four sessions per

340 muscle group are both viable approaches to increase muscle strength in the barbell back squat and

341 bench press for trained males, as long as the total weekly training volume is equal. It is possible

342 that spreading the weekly volume to different days could be favorable for the rating of perceived

343 exertion, especially for exercising the muscles in the lower body. The group with a training

344 frequency of four reported a lower RPE for barbell back squat than the group training with a

345 frequency of two. This study corresponds with previous studies and with two meta-analyses on

346 frequency training; it seems that the effect of increasing the training frequency does not have an

347 equally important role as volume and load on strength gains (Grgic et al., 2018; Ralston et al.,

348 2018).

349

350 **CONCLUSION**

351 The results of this study suggest that both training with a frequency of two and four times per week

352 gives similar increases in maximal strength for trained subjects under the same total weekly

353 volume. The RPE result in this study suggests that it could be favorable to spread the total training

354 volume in several training bouts throughout the week, especially for training the muscles in the

355 lower body. This suggests that higher training frequencies could be used as a tool to counteract

356 perceived exertion for athletes. Both results give coaches and athletes greater variety in how to

357 structure a training program with different training frequencies without sacrificing an increase in

358 performance. Programs can then be periodized with different training frequencies to follow the

359 athlete's personal preferences, time constraints, or when the daily training volume is no longer

360 manageable.

361

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482

483

484   **Figure legend**

485   **Figure 1.**

486   Mean 1RM of A) squat and B) bench press (± SD) at pre- and posttest for each subject and the

487   average of SPLIT and FULLBODY training groups

488   * indicates a significant increase in 1RM from pretest for this group at $p < 0.05$.

489

490   **Figure 2.**

491   Absolute individual change from pretest to posttest in A) 1RM squat and B) bench press

492   performance with average per group (dotted line).

493

494   **Figure 3.**

495   Average (± SD) rating of perceived exertion for A) whole training bout, after B) barbell back squat,

496   and C) bench press per week.

497   * indicates a significant difference between the two groups for this week at $p < 0.05$.

498   → indicates a significant difference from this RPE with the next one at $p < 0.05$.

Table 1. Schematic overview of the training protocol.

Table 1. Schematic overview of the training protocol.

3   **Table 1.** Schematic overview of the training protocol for each group (SPLIT and FULLBODY).

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 curl	3			Triceps curl	3		
	Face pulls	3			Face pulls	3		
FULLBODY	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
	Face pulls	3	Calf raises	3	Face pulls	3	Lateral raises	3

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

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

1 **Table 2**. Schematic overview of the load and repetitions ranges per week. Both groups had a

2 predetermined program with preset weights, based on a percentage of 1RM. During one week,

3 both groups did the same total volume (sets x repetitions x intensity).

		Back Squat		Bench press	
Week	Weekly Sets	Rep range	Intensity (% of 1RM)	Rep range	Intensity (% of 1RM)
1	11	5-7	70-75 %	7-10	65-70 %
2	11	3-7	72.5-80 %	6-10	67-72.5 %
3	11	3-6	75-80 %	6-10	70-75 %
4	11	2-5	77.5-87.5 %	4-8	72.5-80 %
5	11	3-5	75-82.5 %	3-5	72.5-82.5 %
6	11	3-5	75-85 %	3-5	77.5-85 %
7	11	2-4	77.5-87.5 %	2-5	77.5-87.5 %
8	11	2-5	77.5-90 %	2-4	80-90 %

Figure 1

Mean 1RM of squat and bench press (± SD) at pre- and posttest for SPLIT and
FULLBODY training groups

Mean 1RM of A) squat and B) bench press (± SD) at pre- and posttest for each subject and
the average of SPLIT and FULLBODY training groups * indicates a significant increase in 1RM
from pretest for this group at p < 0.05.
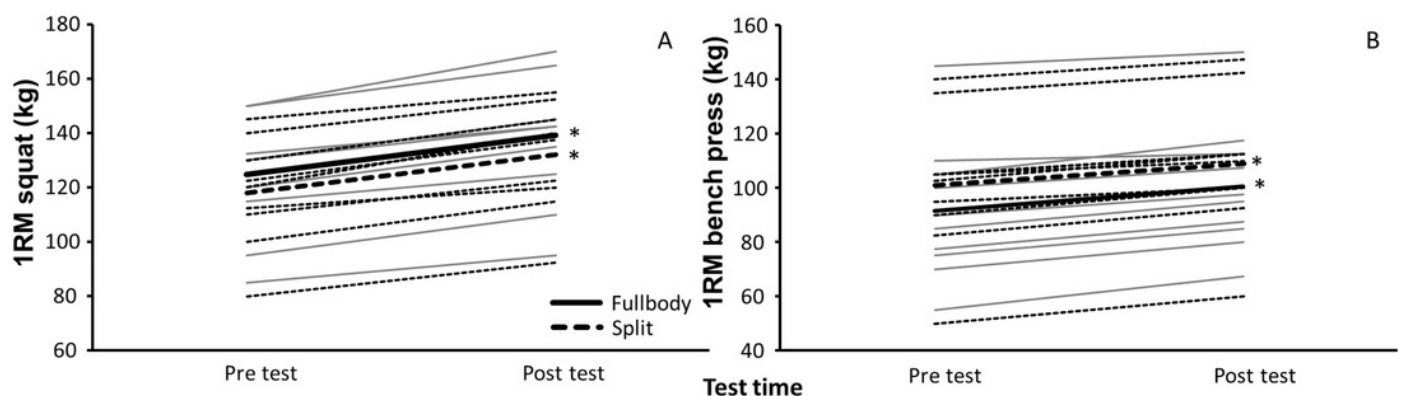
Figure 2

Absolute individual change from pretest to posttest in 1RM squat and bench press performance with average per group (dotted line).

Absolute individual change from pretest to posttest in A) 1RM squat and B) bench press performance with average per group (dotted line).
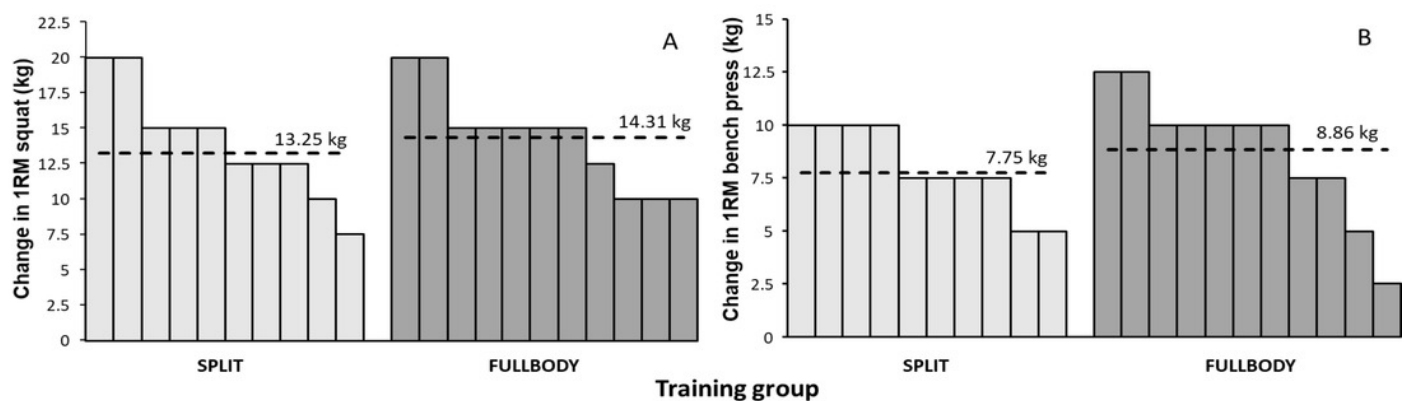
Figure 3

Average (± SD) rating of perceived exertion for whole training bout, after barbell back squat, and bench press per week.

Average (± SD) rating of perceived exertion for A) whole training bout, after B) barbell back squat, and C) bench press per week. * indicates a significant difference between the two groups for this week at $p < 0.05$. → indicates a significant difference from this RPE with the next one at $p < 0.05$.