A strength-oriented exercise session required more recovery time than a power-oriented exercise session with equal work

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The present randomized cross-over controlled study aimed to compare the rate of recovery from a strength-oriented exercise session vs. a power-oriented session with equal work. Sixteen strength-trained individuals conducted one strength-oriented session (5 repetitions maximum (RM)) and one power-oriented session (50% of 5RM) in randomized order. Squat jump (SJ), countermovement jump (CMJ), 20-m sprint, and squat and bench press peak power and estimated 1RMs were combined with measures of rate of perceived exertion (RPE) and perceived recovery status (PRS), before, immediately after and 24 and 48 hours after exercise. Both sessions induced trivial to moderate performance decrements in all variables. Small reductions in CMJ height were observed immediately after both the strength-oriented session (7±6%) and power-oriented session (5±5%). Between 24 and 48 hours after both sessions CMJ and SJ heights and 20 m sprint were back to baseline. However, in contrast to the power-oriented session, recovery was not complete 48 hours after the strength-oriented session, as indicated by greater impairments in CMJ eccentric and concentric peak forces, SJ rate of force development (RFD) and squat peak power. In agreement with the objective performance measurements, RPE and PRS ratings demonstrated that the strength-oriented session was experienced more strenuous than the power-oriented session. However, these subjective measurements agreed poorly with performance measurements at the individual level. In conclusion, we observed a larger degree of neuromuscular impairment and longer recovery times after a strength-oriented session than after a power-oriented session with equal total work, measured by both objective and subjective assessments. Nonetheless, most differences were small or trivial after either session. It appears necessary to combine several tests and within-test analyses (e.g., CMJ height, power and force) to reveal such differences. Objective and subjective assessments of fatigue and recovery cannot be used

interchangeably; rather they should be combined to give a meaningful status for an individual in the days after a resistance exercise session.

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Abstract

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21 strength-trained individuals conducted one strength-oriented session (5 repetitions maximum
22 (RM)) and one power-oriented session (50% of 5RM) in randomized order. Squat jump (SJ),
23 countermovement jump (CMJ), 20-m sprint, and squat and bench press peak power and
24 estimated 1RMs were combined with measures of rate of perceived exertion (RPE) and
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29 and SJ heights and 20 m sprint were back to baseline. However, in contrast to the power-oriented
30 session, recovery was not complete 48 hours after the strength-oriented session, as indicated by
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35 performance measurements at the individual level. In conclusion, we observed a larger degree of
36 neuromuscular impairment and longer recovery times after a strength-oriented session than after
37 a power-oriented session with equal total work, measured by both objective and subjective
38 assessments. Nonetheless, most differences were small or trivial after either session. It appears
39 necessary to combine several tests and within-test analyses (e.g., CMJ height, power and force)
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41 be used interchangeably; rather they should be combined to give a meaningful status for an
42 individual in the days after a resistance exercise session.

43

Introduction

44

45 Athletes use different forms of resistance exercise (training) to improve muscle power output and
46 sport performance, including heavy load strength-oriented exercises (e.g. ~80% of 1 Repetition
47 Maximum [1RM]) and low-to-moderate load power-oriented exercises (e.g. ~40% of 1RM;
48 (Newton and Kraemer, 1994)). In general, high-intensity resistance exercise challenges the
49 ability to generate high forces, and with a conventional volume of exercise (~5-15 sets per
50 muscle group) neuromuscular fatigue develops during the sessions. This resistance exercise-
51 induced fatigue typically requires 1-3 days of recovery (Vincent and Vincent, 1997;Raastad and
52 Hallen, 2000;Ahtiainen et al., 2003;2004).

53 The recovery process is obviously necessary for regaining full performance capacity, but it is
54 also intertwined with adaptation processes, such as hypertrophy and increased efficacy of the
55 metabolic pathways (Bishop et al., 2008;Paulsen et al., 2012;Cunanan et al., 2018). Recovery is
56 therefore vital for all who perform resistance exercise, whether recreationally trained individuals
57 or elite athletes. However, our knowledge of the recovery processes after resistance exercise is
58 still inadequate, and we cannot accurately predict recovery times from a given exercise session

59   (Bishop et al., 2008;Paulsen et al., 2012;Kellmann et al., 2018). The difficulty in predicting
60   recovery rates lies in the range of factors at play, including – but not restricted to – type of
61   muscle contractions, relative load (% of maximal strength) and volume of work performed (i.e.,
62   load times displacement times number of repetitions).

63   Contraction velocities and the transition from the eccentric to the concentric phase differentiate
64   the diverse forms of resistance exercise. Classical power-oriented exercise means using low to
65   moderate loads (e.g., 30-50% of 1RM) and the lifts are typically executed in a plyometric
66   fashion; i.e., a fast transition from eccentric to concentric phase, and high (maximal effort)
67   movement velocities (Newton and Kraemer, 1994;Suchomel et al., 2017). This contrasts with
68   strength-oriented exercise, in which the transition between the eccentric and concentric phase is
69   typically controlled and slow (due to the heavy loads used).

70   Surprisingly few studies have investigated the potential differences in recovery times between
71   different forms of resistance exercise, such as strength-oriented exercise (>80% of 1RM) with
72   slow velocities (mean velocity of the lifting bar <0.6 m/s) and power-oriented exercise with
73   low/moderate loads (<50% of 1RM) lifted with high velocities (mean velocity of the lifting bar
74   >1 m/s; (Banyard et al., 2018;Garcia-Ramos et al., 2018b)).

75   Linnamo et al. (1998) compared recovery rates after 40% of 10RM with 100% of 10RM (5 sets
76   and 2-minute rest periods) in the knee-extension exercise, applying a crossover design in non-
77   resistance trained individuals. Using an isometric strength test, the authors demonstrated less
78   acute fatigue and faster recovery from the power-orientated exercise compared to the heavy-load
79   exercise over 48 hours. Similarly, but studying elite track and field athletes, Howatson et al.
80   (2016) found a reduction in isometric strength 24 hours after heavy-load strength-oriented
81   session (4 x 5 repetitions; squat, split squat and push press), but not after power-orientated
82   session (30% of the heavy load; 4 x 5 repetitions; speed squat, split squat jump and power press).
83   However, with different exercise volumes (same total number of repetitions, but different loads),
84   it is not possible to tease out the true impact of the load. McCaulley et al. (2009) controlled for
85   exercise volume and reported greater acute neuromuscular fatigue after heavy-load squats than
86   after maximal power jump squats. However, there was no difference in the recovery between the
87   strength-oriented session and power-orientated session after 24 and 48 hours (McCaulley et al.,
88   2009). In a similar study, Hiscock et al. (2018) compared heavy loads (90% of 1RM; 3x3 reps)
89   against "power loads" (45% of 1RM; 3x6 reps) in squat and deadlift with equal volume between
90   exercise modes. No differences were found between experimental loads; however, recovery was
91   seemingly complete within 12 hours after the power-oriented session, while 24 hours were
92   required after the heavy-load session. In short, our knowledge of the impact of loads on recovery
93   after different modes of resistance exercise is limited and requires further study.

94   Recovery can be defined as normalisation of neuromuscular function (Bishop et al., 2008).
95   However, it is not always obvious which function(s) should be measured. In the McCaulley et al.
96   (2009) study, the participants conducted a dynamic squat exercise, but an isometric squat was
97   used to assess neuromuscular function. Hence, it seems reasonable to question whether a
98   dynamic test, such as squat jump (SJ) or countermovement jump (CMJ), would have displayed
99   similar recovery rates. Indeed, when a range of recovery tests have been applied, such as CMJ,

100 sprinting and single joint isokinetic torque, the tests do not demonstrate interchangeable recovery
101 courses (Andersson et al., 2008;Chatzinikolaou et al., 2010). Apparently, different recovery rates
102 may also be seen between variables extracted from the same test. For example, decrease in mean
103 power has been shown to recover faster than the increased duration of the concentric phase of the
104 CMJ (Gathercole et al., 2015a).

105 To confidently track the time course of recovery, dealing with the error of measurements is a
106 challenge. Impairments of muscle strength and power are typically observed in the range of ~5-
107 20% immediately after resistance exercise in trained individuals, but may be less than 5% below
108 baseline after 24 hours (Raastad and Hallen, 2000;Howatson et al., 2016;Hiscock et al., 2018).
109 Knowing that the typical error (coefficient of variation; CV) in day-to-day measurements of CMJ
110 and SJ height and power is at best ~3-5% (Raastad and Hallen, 2000;Hopkins et al.,
111 2001;Gathercole et al., 2015a), the sensitivity of vertical jump tests may be limited for
112 monitoring the final part of the recovery process. In the present study we address the typical
113 error of all tests applied and explore the sensitivity of different variables extracted from SJ and
114 CMJ (including jump height, peak power and peak force).

115 Exercise load and work, neuromuscular fatigue and recovery can be assessed not only with
116 objective performance measures (strength and power tests; as discussed above), but also
117 subjectively, using rate of perceived exertion (RPE) and perceived recovery status (PRS).
118 Perceived exertion has been used for years with endurance exercise (Borg, 1970), but also for
119 resistance exercise (Foster et al., 2017); while the PRS scale has a shorter history (Laurent et al.,
120 2011). Subjective measures are simple and convenient to use, but what do they tell us? The use
121 of and correlation between objective and subjective measures of recovery and performance
122 monitoring have been debated for years (Scott et al., 2016;Foster et al., 2017).

123 Interestingly, few investigations have compared subjective and objective recovery assessments
124 after different forms of resistance exercise. Sikorski et al. (2013) observed a relationship between
125 PRS and the muscle damage marker creatine kinase 48 hours after a conventional, high-volume
126 resistance exercise session; however, no measure of muscle function was included. Korak et al.
127 (2015) observed that recreationally strength-trained males experienced faster recovery, measured
128 with PRS, from single-joint compared to multi-joint exercises, which appeared to correspond to
129 changes in 10RM-tests (objective tests). Unfortunately, the study lacked appropriate objective
130 measures of recovery; i.e., tests of maximal force and power. In a case study of three
131 weightlifters/powerlifters, Zourdos et al. (2016) found that daily 1RM lifts consistently improved
132 performance over 37 days, but the improvement seemed inadequately reflected in RPE and PRS
133 scores. Although case studies of high-level athletes are interesting, such studies provide only
134 weak evidence. This leaves us with the conclusion that more research is needed to elucidate the
135 relationship between objective and subjective measures of recovery after different forms of
136 resistance exercise.

137 The aim of the present study was to compare the recovery rates from a power-oriented session
138 with a heavy-load strength-oriented session of similar work. A range of objective performance
139 tests of strength and power were combined with subjective tests (RPE and PRS) to acquire a
140 broad picture of the recovery processes in both upper and lower body muscles. We hypothesized

141 that the power-oriented session would induce less performance decrements than the strength-
142 oriented session at all time points; and, consequently, that complete recovery would occur within
143 48 hours for the power-oriented session but not the strength-oriented session.. Secondly,
144 compared to the strength-oriented session, we hypothesized that the participants would perceive
145 the power-oriented session as less strenuous and to experience a better recovery status after 24
146 and 48 hours. Finally, we hypothesized that changes in RPE and PRS would be numerically
147 related to changes in objective measures, such as the SJ and CMJ.

148

Materials & Methods

150 **Study design**
151 The present study was a randomized cross-over study where each participant completed a heavy-
152 load, strength-oriented session and a moderate-load, power-oriented session, in randomized order
153 (applying the Research Randomizer; Urbaniak and Plous (2013)). To achieve a counterbalanced
154 order, the participants were paired, so that one started with the strength-oriented session and one
155 with the power-orientated session. One to four weeks of rest were allowed between sessions
156 (16±10 days (mean±standard deviation)).

157 A test battery of physical performance tests and evaluation of perceived effort and recovery
158 status was applied before, immediately after, and 24 and 48 hours after the exercise sessions
159 (Figure 1). The concentric work (J) performed in the first session was recorded and replicated in
160 the second session, ensuring equal work in both sessions. The exercises were the same for both
161 sessions, but somewhat adapted to serve the purpose of the sessions (Table 1). The primary aim
162 of the study was to compare the recovery rates between sessions when all factors were equal
163 except the external load (50% lower in the power-oriented session than the strength-oriented
164 session).

165 *** Figure 1 and Table 1***

166 Three to seven days before the first exercise session, a familiarization session was conducted.
167 The participants were familiarized with all tests and exercises (see details below) and instructed
168 not to conduct any strenuous exercise 48 hours prior to the test days. The participants were also
169 instructed to standardize their breakfast before and their meals after the exercise sessions (for 48
170 hours). All supplements and medications were prohibited during the study period.

171 During the exercise sessions the participants were given a protein bar and a protein drink (both
172 supplements containing approximately 20 g protein, 30 g carbohydrates, and a total of ~1000 KJ
173 (Yt, Tine, Oslo, Norway), and an energy drink (30 g carbohydrates; 510 KJ; Yt, Tine, Oslo,
174 Norway) to ensure sufficient protein and energy intake (in total: 40 g protein and 90 g
175 carbohydrates; ~1500 KJ). Water was allowed ad libitum.

176 **Participants**
177 Nineteen young, resistance-trained individuals were recruited to this study. Sixteen participants,
178 eight males and eight females, completed all tests and both exercise sessions (21±4 years, 74±12
179 kg, 1.75±11 m; Table 2). Two participants dropped out due to muscle pains (hamstrings and

180   groin) during testing or the exercise sessions; and one was excluded due to technical problems
181   with the test equipment.

182   The participants were familiar with heavy-load strength training and had been training upper and
183   lower body strength exercises on a weekly basis during the last year (≥2 sessions/week). Of the
184   16 participants, three were competing at a national elite level (two volleyball and one beach
185   volleyball player), one was an international-level bike trial athlete, and the remaining 12
186   participants were students at the Norwegian School of Sport Sciences (Oslo, Norway) and
187   engaged in strength training at a recreational level.

188   The study was reviewed by the Norwegian Regional Ethical Committee of Medical and Health
189   Research (2016/1120). The participants gave written informed consent to take part in the study,
190   following the Declaration of Helsinki (World Medical Association).

191   **Testing and exercises**
192   The familiarization session consisted of all the tests (see below) and 1-3 sets of five repetitions of
193   all the exercises (for both sessions): squat, front squat, trap bar squat, bench press, narrow bench
194   press and push-ups (Figure 1). The loads were adjusted to get close to a 5-repetition maximum
195   (RM) during the last set. For the power exercises the loads were 50% of the estimated 5RM
196   loads. In both sessions, the exercises were executed with maximal effort in the concentric phase
197   in all repetitions. In the strength-oriented session, the eccentric phase was conducted with a
198   controlled, slow movement (>1 second). In contrast, in the power-oriented session the eccentric
199   phase was faster (<1 second) in order to maximize the power output in the concentric phase. The
200   movement velocity was measured using a linear encoder (see description below).

201   On the days of the exercise sessions, the participants rated their perceived recovery status (PRS
202   scale; 0-10; (Laurent et al., 2011)) prior to a warm-up. The warm-up consisted of a 10-minute
203   easy run with increasing velocity (not more than moderate effort) preceding 2 minutes of
204   individually selected dynamic stretching of both upper and lower body muscles. Thus, each
205   participant followed a warm-up procedure that they were accustomed to, and the procedure was
206   similar before each session (including the familiarization session).

207   The tests were then conducted in the following order: CMJ, SJ, 10 consecutive multiple jumps
208   (MJ), 20-meter sprint running, maximal push-up force, and power profiles and estimated 1RMs
209   in bench press and squat. Tests were performed before and immediately after the sessions, and
210   again after 24 and 48 hours. The power profile tests and 1RM estimation in the bench press and
211   squat were, however, not conducted immediately after the sessions in order to prevent additional
212   fatigue. Finally, 30 minutes after the sessions the participants rated the perceived exertion
213   (session RPE; 0-10; (Foster et al., 2001)). The participants were introduced to the ratings and
214   descriptors of both the RPE and the PRS scales at the familiarization session.

215   *Tests*
216   The countermovement jump (CMJ), squat jump (SJ), and multi-jump (MJ) were conducted on an
217   AMTI force platform (sampling rate: 2000 Hz; OR6-5-1; AMTI, Watertown, MA, USA). Before
218   every test session (for each participant), offset values were acquired and the body weight of the
219   participant was measured and averaged over a 2.3 s period (as recommended by Street et al.

220 (2001)). The body weight measured before each jump was confirmed against the initial weigh-in
221 value (less than 5% discrepancy was considered valid). All force data were filtered with a low
222 pass filter (second order Butterworth bi-directional low pass filter; cut-off frequency of 120 Hz).

223 All jump-tests were performed with the hands fixed on the hips (akimbo). Based on jump height,
224 the average of each individual's two best attempts of 3-6 jumps was used for subsequent
225 statistical analyses – except for MJ, where only one attempt was made (due to the development
226 of fatigue). The inter-test coefficients of variation (CVs) for the jump tests are listed in Table 2.

227 All data collected from the AMTI force plate were analysed using a custom-made software
228 (Matlab, The Mathworks, Inc., MA, USA; Biomekanikk AS, Oslo, Norway). From the SJ,
229 duration, concentric peak force, peak and mean power, RFDmax, and jump height were
230 calculated. From the CMJ, duration, eccentric time, peak and mean eccentric and concentric
231 force, RFDmax, and jump depth (lowering of the center of mass (COM)) and jump height were
232 calculated. From the MJ, jump height, vertical stiffness, and reactive strength index (RSI) were
233 calculated.

234 Jump height was calculated as the squared take-off velocity divided by 2 g for all jumps (SJ,
235 CMJ, and MJ). Take-off velocity was calculated by the impulse–momentum method described
236 by Linthorne (2001) and Street et al. (2001), with the impulse-integral starting from the time
237 point when vertical force exceeded (or fell below for CMJ) 100% of body weight and ending
238 when force fell below 2 N (take-off).

239 The jump's phases were calculated as follows: Duration (s) of the SJ was found by backtracking
240 force data from take-off (force < 2 N) to the point where the force was 101.5% of body weight.
241 CMJ was divided into an eccentric phase and a concentric phase (Figure 2), defined by the phase
242 where the COM was descending and ascending, respectively. The initiation of the CMJ
243 (eccentric phase) was found by backtracking the force data from the point of zero velocity, i.e.,
244 the deepest position of the COM, to the point where the force was 98.5% of body weight.
245 Eccentric peak force was the highest force measured within the eccentric phase, and eccentric
246 time was defined as the duration of the eccentric phase where the force was greater than that of
247 the body weight (Figure 2). Peak concentric force was the highest force measured from the point
248 of zero velocity of the COM to the point of take-off.

249 ***Figure 2***

250 The maximal rate of force development (RFD) was defined as the largest increase in force over a
251 5 ms time window during the jump (both for SJ and CMJ; Figure 2). Specifically, the RFD
252 values (N/s) were calculated from numerical differentiation of the low-pass filtered force
253 measurements using a 4-point method, and the derivative was averaged over 5 ms (10 samples).
254 In the MJ test, the participants were instructed to jump ten consecutive CMJs as high as possible.
255 The vertical stiffness was calculated as the maximal force divided by the downward
256 displacement of the COM, while the reactive strength index (RSI) was calculated as jump-height
257 divided by the ground contact time. All variables are presented as the average of the ten jumps.

258 Two to three maximal 20-meter sprint runs were performed on a rubberized indoor track
259 (Mondo, Conshohocken, PA, USA) with 3-4 minutes' rest between trials. The sprints were
260 measured with an electric timing system (Biomekanikk AS, Oslo, Norway) with a timing trigger
261 (single-beamed timing gate 0.6 m after the start line and 0.4 m above ground level) and dual-
262 beamed timing gates placed every 5 m along the sprint track. Participants were instructed to
263 accelerate as fast as possible from a standing start with one foot in front of the other. The inter-
264 test CV for the sprint test is given in Table 2.

265 After a specific warm-up consisting of ten push-ups with gradually increasing effort and three
266 maximal singles, three single maximal push-ups were assessed on a force platform (sampling
267 rate: 2000 Hz; OR6-5-1; AMTI, Watertown, MA). One minute of rest was given between the
268 single push-up efforts. The participants were instructed to keep their body "straight" (minimize
269 any movement of the spine and pelvis) and to do a controlled slow eccentric phase to a position
270 where the chest was 2-3 cm above the floor, and then do a push as fast as possible. The hands
271 were allowed to leave the platform if the push-force was large enough to lift the upper body off
272 the ground (the feet were always in contact with the ground). Hand and foot placements were
273 standardized for each participant. If the participants failed to conduct the push as described, the
274 attempt was discarded and repeated (this was, however, a subjective decision by the test leader).
275 The inter-test CV for the push-up test is given in Table 2.

276 Bench press and squat performance were assessed using a linear encoder (Musclelab Linear
277 Encoder; Ergotest Innovation, Langesund, Norway). The string of the encoder was attached to
278 the bar, with the device measuring displacement (d) and time of the concentric phase (200 Hz
279 sampling rate; 0.019 mm resolution). The start and end of the concentric phase were detected as
280 a 5 ms period of no movement (<0.004 m/s) or immediately by a change in direction (within 5
281 ms). The calculations of velocity and force from each load were based on the entire concentric
282 phase (i.e., average/mean velocity and force; $v = d/t$; acceleration $[a] = v/t$, force $[F] = mg + ma$).

283 In both the bench press and squat the participants completed sets of three maximal repetitions at
284 four different loads, with ~5 seconds between each lift and 2-4 minutes between sets. All
285 repetitions were conducted with maximal effort in the concentric phase. The external loads were
286 25, 50, 75 and 90% of estimated 1RM (estimated during the familiarization session). The
287 attempts with the highest velocity from each load were selected for further analysis. A concentric
288 force-velocity relationship (linear regression) and a power-velocity relationship (parabolic curve)
289 were established and peak power and 1RM were estimated (software from Ergotest Innovation,
290 Langesund, Norway). Peak power was calculated as the apex of the parabolic power-velocity
291 relationship. The 1RM was calculated from the intercept of the load (mg) - velocity relationship
292 and the force (mg + ma) - velocity relationship.

293 For the squat, the participants were instructed to squat down to a position where the femur was
294 parallel with the floor, in a slow, controlled manner, and then extend as rapidly and powerfully
295 as possible. For the squat we estimated force from the system mass (90% of body mass and the
296 external mass), while for the bench press, only the external mass was used. We used 90% of the
297 body weight for the squat calculations, as suggested by the manufacturer (Ergotest Innovation,
298 Langesund, Norway). This is very close to the 88% of body weight suggested by others using a

299   similar linear encoder device (Cormie et al., 2007). The inter-test CVs for the bench press and
300   squat tests are given in Table 2.

301   *Exercise sessions*
302   The strength-oriented session consisted of three exercises for the lower body, in the following
303   order: squat, front squat, trap bar squat; and three exercises for the upper body, performed in the
304   following order: normal bench press, narrow bench press and weighted push-ups (Table 1). A
305   warm-up set of 8 repetitions at 60-80% of 5RM before each exercise preceded 5 sets of 5RM.
306   The 5RM loads were estimated from the familiarization session for each exercise. The inter-set
307   rest period was 3-4 minutes. The loads were adjusted between sets, if necessary. All exercises
308   were conducted at the same tempo with a controlled slow eccentric phase and a fast as possible
309   concentric phase. The leg exercises were performed with free weights (Eleiko, Halmstad,
310   Sweden), while both normal and narrow bench press exercises were performed in a Smith rack
311   (Multipower, Technogym, Cesena FC, Italy). Weighted push-ups were performed on three 30 cm
312   custom-made boxes, and loads were applied by a weight-vest (1-9 kg; Reebok, Boston, Ma, US)
313   and (if needed) weight discs (5-20 kg) placed on the participant's back, positioned over the
314   scapulae.

315   The power-oriented session was conducted with loads corresponding to 50% of the external load
316   used in the strength-oriented session. Loaded CMJ, front squat with overhead push, trap bar
317   CMJ, normal bench press throw (Smith rack), narrow bench press throw (Smith rack), and
318   explosive push-ups were performed with a continuous high velocity tempo in the concentric
319   phase (Table 1).

320   We measured the concentric displacement for all the exercises in both sessions with a linear
321   encoder (see above). The encoder's string was attached to the bar in all cases except for both
322   push-up variations, where the string was attached to a light chest belt at the distal part of the
323   sternum.

324   The total work was calculated by summarizing the products of repetitions, load and displacement
325   for each set of each exercise. Only the displacement of the concentric phase was used; i.e., the
326   distance from the vertically lowest to the vertically highest position of the bar in the squat
327   exercise. For the lower body exercises we assumed the load to be the sum of 90% of the body
328   weight and the external load (see above). For the front squat push, the squat part was calculated
329   as a regular squat, but for the final overhead push only the external load was used; thus, the squat
330   work and push work were calculated separately and then added together. For the bench press
331   exercises, only the external load was used, while for the push-ups the weight of the upper body
332   (measured with the force plate during testing) was added to the external load.

333   The first session (randomly strength or power) was used as a template for the second session for
334   each participant. Hence, we adjusted the number of sets per exercise so that the concentric work
335   performed in each exercise was similar between sessions. The amount of work per exercise was
336   fine-tuned by adjusting the number of repetitions in the final set (e.g., performing only two
337   repetitions in order to reach the required amount of work).

338 **Statistics**
339 The data were analysed in spreadsheets that enabled adjustment of one or two predictor variables
340 in the changes within or difference between sessions (Hopkins, 2007). The spreadsheet is
341 fundamentally based on the T-test but gives the opportunity to adjust for baseline to control for
342 the regression to the mean effect. All data were log-transformed, and changes are reported as
343 percentages with their associated 95% confidence interval (CI).

344 The reliability of the tests was based on the familiarisation session and the two pre-tests (before
345 each session). The coefficient of variation (CV) was calculated as described by Hopkins (2000).
346 The smallest worthwhile change was calculated as the baseline between subjects' standard
347 deviation (SD) multiplied by 0.2 (Hopkins, 2004).

348 Effects were evaluated using clinical magnitude-based inferences (MBD) (Hopkins et al.,
349 2009;Hopkins, 2019)), a method appropriate for small samples. The magnitude of changes
350 within and difference in mean between sessions were assessed by standardization (mean
351 change/difference divided by baseline SD of all subjects), and the resulting standardized effect
352 evaluated with a modification of Cohen's (1992) scale: <0.2, trivial; 0.2-0.6, small; 0.6-1.2,
353 moderate; >1.2, large (Hopkins et al., 2009). The subjective variables (RPE and PRS) were
354 evaluated with the following scale: <10% trivial, 10-30% small, 30-50% moderate, 50-70%
355 large, 70-90% very large, and 90-100% extremely large (Hopkins, 2010).The initial RPE and
356 PRS values were therefore factored by 10 (0-100).

357 To make clinical inferences about true values of effects in the population studied, the effects
358 were expressed as probabilities of harm or benefit in relation to the smallest worthwhile change
359 (0.2 of SD; (Hopkins et al., 2009)). A clear change within or difference between the two exercise
360 modalities corresponds to the case of an effect that is almost certainly not harmful (<0.5% risk of
361 harm) and possibly beneficial (>25% chance of benefit). The effect is shown as the difference or
362 change with the greatest probability, and it is shown qualitatively using the following scale: 25-
363 75%, possibly; 75-95%, likely; 95-99.5%, very likely; > 99.5%, most likely (Hopkins et al.,
364 2009). In addition, p-values were included, and effects were considered significant at p<0.05 if
365 the 95% CI did not overlap zero (p<0.01 with 99% CI).

366 Correlations between variables were obtained using Pearson's r (and 95% CI). We restricted the
367 correlation analyses to testing between objective and subjective variables that showed a
368 difference between sessions, in order to minimize the risk of observing random correlations.

369 An order-effect is a potential risk with a crossover design (Woods et al., 1989). Hence, we tested
370 the session-order effect by including session order as a covariate. The effects were trivial (0.0-
371 0.5%), so we did not further include the order effect to avoid too many covariates with the
372 relatively low sample size (baseline value was already included).

373

374 **Results**
375 Baseline values for the 16 participants are presented in Table 2. The differences between the two
376 modalities at baseline were all trivial; nevertheless, baseline values were included as a covariate

377   in all analyses of within-session changes and between session differences, and thereby controlled
378   for.

379   ***Table 2***

380   The smallest worthwhile change (SWC) and the CV for each variable are presented as relative
381   values (Table 2). Note that the CV was larger than the SWC for most variables (e.g., CMJ and SJ
382   RFDmax), but equal or lower for some variables (e.g., eccentric peak force).

383   Within-session changes immediately after (0 hours), and 24 and 48 hours after the sessions are
384   shown in Figure 3 and Table 3. Immediately after the sessions the changes were generally
385   negative: both sessions showed small clear negative changes for most CMJ variables (height,
386   mean power, concentric peak force, eccentric peak force; Figure 3) and SJ mean power (Table
387   3). The CMJ RFDmax and the subjective variables (RPE and PRS) had a clear moderate negative
388   change after both sessions. In addition, the strength-oriented session gave clear small negative
389   changes in CMJ depth, SJ height, SJ RFDmax, SJ duration and MJ RSI, while these were trivial
390   after the power-oriented session (Table 3 and Figure 3).

391   ***Table 3 & Figure 3***

392   At 24 hours similar trends emerged, with the strength-oriented session showing clear small
393   negative effects on CMJ peak concentric force (Figure 3), SJ RFDmax, SJ duration and squat
394   peak power; while these changes were trivial after the power-oriented session (Table 3). In
395   addition, the strength-oriented session showed a clear moderate negative effect on CMJ eccentric
396   time (Figure 3) and total and lower body PRS, compared to a small negative effect after the
397   power-oriented session. In contrast, the power-oriented session gave a small possibly beneficial
398   effect on MJ height. MJ vertical stiffness had a small increase after the strength-oriented session,
399   while it had a clear decrease after the power-oriented session.

400   At 48 hours, most clear negative changes were small and only evident after the strength-oriented
401   session (Table 3 and Figure 3). Further, CMJ RFDmax and CMJ eccentric time displayed clear
402   moderate negative changes after the strength-oriented session (Figure 3); this was also reflected
403   in a small increase in total duration of the CMJ (5.3 ± 3.5%) 48 hours after the strength-oriented
404   session. In contrast to the strength-oriented session, the power-oriented session resulted in a
405   small possibly beneficial change in squat peak power at 48 hours (Table 3).

406   A few clear differences were observed between sessions (Figure 3 and Table 4). Compared to the
407   power-oriented session, the strength-oriented session showed small negative effects on CMJ
408   depth, SJ duration and MJ height immediately after the session. Moreover, the strength-oriented
409   session was rated higher on the sRPE scale than the power-oriented session (small effect). At 24
410   hours, the strength-oriented session showed small clear negative effects on CMJ depth and
411   eccentric peak force, SJ RFDmax, MJ height, squat peak power, and total, upper and lower body
412   PRS compared to the power-oriented session. On the other hand, the strength-oriented session
413   had a small and likely beneficial effect on MJ vertical stiffness compared to the power-oriented
414   session.***Table 4***

415 At 48 hours, the strength-oriented session still demonstrated small and possibly to likely negative
416 effects compared to the power-oriented session for CMJ concentric and eccentric peak forces, SJ
417 RFDmax, push-up peak force and upper body PRS. The differences between sessions in CMJ
418 depth and squat peak power were partly due to improvements over baseline after the power-
419 oriented session.

420 To investigate the relationship between subjective and objective tests, we selected the objective
421 tests that demonstrated the greatest difference between the sessions. Hence, we correlated the
422 CMJ eccentric peak force against PRS at 24 and 48 hours after exercise; and, for the upper body,
423 push-up peak force against PRS at 24 and 48 hours after exercise (Figure 4). There were no clear
424 positive or systematic correlations between these variables. There was a clear negative
425 correlation between push-up peak force and PRS at 24 hours after the power-oriented session
426 (but not after 48 hours), indicating a counterintuitive relationship between high force (i.e.,
427 indicating a high degree of recovery) and a low degree of perceived recovery.

428 ***Figure 4***

429

Discussion

431 In this study, we aimed to compare the recovery rates after a heavy-load, strength-oriented
432 session and a moderate-load, power-oriented session of similar concentric work. Our main
433 findings were: 1) The strength-oriented session had, overall, the largest detrimental effects on the
434 neuromuscular system, impairing both the eccentric and concentric phases of jumping. However,
435 the differences in performance assessments between the sessions were generally of small or
436 trivial magnitudes. 2) The most sensitive recovery-markers for demonstrating reduced capacity
437 and a difference between the strength-oriented session and the power-oriented session were CMJ
438 eccentric and concentric peak forces, SJ RFDmax and squat peak power; these variables
439 displayed small, but likely clear differences between sessions after 24 and 48 hours of recovery.
440 3) In contrast to the strength-oriented session, the power-oriented session seemed to potentiate
441 performance, as we observed small increases in MJ height after 24 hours and in squat peak
442 power after 48 hours. 4) Finally, the strength-oriented session was perceived as more strenuous
443 and the rate of recovery as slower compared to the power-oriented session; however, subjective
444 and objective measurements correlated poorly at the individual level.

Previous studies
446 Small to trivial impairments of neuromuscular performance were observed after both the exercise
447 sessions. More specifically, measures of CMJ and SJ heights and sprint times were reduced by 1-
448 8%, which are at the low end compared to previous studies (~2-20%; (Raastad and Hallen,
449 2000;Howatson et al., 2016;Raeder et al., 2016;Davies et al., 2018;Hiscock et al., 2018)). We
450 believe that this discrepancy is because our participants were well trained, and more importantly,
451 they were familiarized with the exercises and tests.

452 In line with the existing literature (Linnamo et al., 1998;Brandon et al., 2015;Howatson et al.,
453 2016), a heavy-load strength-oriented session attenuated the neuromuscular system more than a

454   low or moderate load power-oriented session. However, in previous studies where the exercise
455   work was controlled for, the differences between strength- and power-oriented sessions were
456   close to eliminated (McCaulley et al., 2009;Hiscock et al., 2018). Our observations confirm these
457   findings, but add some nuances to this picture, as we observed some clear differences between
458   the strength-oriented session and the power-oriented session, such as for CMJ eccentric peak
459   force. Nevertheless, the differences in recovery rates between resistance exercise sessions of
460   different modes (strength- and power-oriented) with similar exercise work must be expected to
461   be rather subtle in magnitude, but these differences may still be relevant information and
462   important for athlete monitoring and training planning. When small differences are of
463   importance, we must, however, ensure that we have adequate measurement methods.

464   **Methodological issues: Reliability and fatigue sensitivity**
465   To discriminate between the recovery rates of closely related exercise modalities such as
466   strength- and power-oriented sessions, highly reliable (day-to-day) tests must be applied. Based
467   on our familiarization session, and two pre-session tests, we observed very high reliability for the
468   sprint test (CV: ~1%). CMJ and SJ height and estimation of 1RMs had good reliability (CV: 3-
469   5%), while peak power in the squat and bench press and MJ height had acceptable reliability
470   (CV: ~9-10%). Push-up peak force reached near acceptable reliability (CV: ~11%). Overall, the
471   reliability of tests applied in this study is in line with those of others (Raastad and Hallen,
472   2000;Hopkins et al., 2001;Byrne and Eston, 2002;Cronin et al., 2004;Cormack et al.,
473   2008;Taylor et al., 2010;Gathercole et al., 2015a;Gathercole et al., 2015b). One exception among
474   our tests was the RFDmax gleaned from CMJ and SJ, which demonstrated poor reliability (CV
475   >20%). Previous studies confirm a moderate to poor reliability for RFD measurements in single
476   joint knee-extension (CV = 7-17%) (Buckthorpe et al., 2012), and for CMJ and SJ (CV = 16-
477   18%) (McLellan et al., 2011;Gathercole et al., 2015a). The low reliability for RFD is probably
478   related to the complexity of the task (Maffiuletti et al., 2016), meaning that it is more difficult to
479   achieve a true maximal RFD than a maximal force. This seems to be reflected in studies showing
480   larger increases in RFD than in maximal force within a session (rehearsal) and as an effect of
481   training (Holtermann et al., 2007). That said, better reliability of RFD measures might be
482   achieved by other types of tests than the jump tests applied here; indeed, the isometric mid-thigh
483   pull test appears to be a preferable choice to assess RFD in the lower body (Haff et al.,
484   2015;Hornsby et al., 2017).

485   Performance tests may also be evaluated by comparing the "smallest worthwhile change" (SWC)
486   with the typical error (Cormack et al., 2008): If the SWC is larger than the typical error, the test
487   should allegedly be able to (confidently) detect relevant and meaningful changes. Among our
488   tests, jump height and measures of force (concentric and eccentric peak force) demonstrated CVs
489   equal to or lower than the SWCs (see Table 2). Nevertheless, an evaluation of tests must be
490   applied in practice. Gathercole et al. (2015a) used the term "fatigue sensitivity", which refers to a
491   test's ability to detect impairments in neuromuscular function after exercise. As the conditions of
492   the neuromuscular system change, due to different forms of central and peripheral fatigue (Enoka
493   et al., 2011), high reliability measured in the rested state is not necessarily valid for the fatigued
494   state. In fact, tests of isolated joints, such as isokinetic knee-extension assessments, appear to
495   demonstrate larger changes than multi-joint tests, such as sprint and jump tests after different

496   multi-joint activities (Byrne and Eston, 2002;Andersson et al., 2008;Howatson et al., 2016). To
497   this end, we suggest that tests enabling subtle changes in the movement pattern, such as sprint
498   and CMJ, may be highly reliable, but may lack fatigue sensitivity. Subtle movement/technique
499   compensations that optimize the conditions for the current state of the neuromuscular system
500   may indeed "mask" fatigue if only jump height in a CMJ is considered (Van Ingen Schenau et
501   al., 1995;Gathercole et al., 2015b).

502   As indicated above, there were trivial changes in CMJ height and peak power 24 and 48 hours
503   after both sessions, but clear changes in CMJ eccentric time and CMJ eccentric peak force.
504   Similar findings have recently been reported by others (Gathercole et al., 2015a). These
505   observations indicate that the participants' ability to use the eccentric phase was impaired in the
506   recovery phase, but some compensations in the execution of the jump apparently minimized the
507   reductions in jump height and power production. After the strength-oriented session the
508   reduction in eccentric peak force seemed related to a slower eccentric phase during the CMJ; i.e.,
509   increased eccentric time, since the lowering the of centre of mass was not changed. On the
510   contrary, the participants appeared to lower their centre of mass more after the power-oriented
511   session than at pre-test, especially at 48 hours. Future studies should investigate changes in the
512   kinetics and kinematics (movement strategies) of a CMJ in the recovery phase compared to the
513   rested state. However, we suggest the eccentric peak force is a more sensitive marker of fatigue
514   and neuromuscular impairments than jump height and maximal power.

515   We found no clear meaningful differences between sessions or in the recovery rates between
516   sessions for CMJ and SJ heights. This contrasts with observations by Byrne and Eston (2002),
517   who reported that SJ height was reduced more and recovered slower than CMJ (and drop jump)
518   height after a squat exercise session (10 x 10 repetitions at 70% of body weight). The
519   discrepancy between findings may be related to more muscle damage in the study by Byrne and
520   Eston (2002) than the present study – as indicated by a larger drop in performance (Paulsen et
521   al., 2012). Moreover, studies have investigated various measures of RFD and observed that the
522   impairment and recovery of RFD differ from maximal force (Penaillilo et al., 2015;Farup et al.,
523   2016). In our study, we extracted RFDmax from CMJ and SJ, and despite low reliability, we
524   report small unclear and possibly clear differences between sessions at 24 and 48 hours – in
525   accordance with previous observations (Gathercole et al., 2015a). Thus, we recognize RFDmax
526   values from jump tests as possibly fatigue sensitive, but we warn about high day-to-day test
527   variability (as discussed above). Moreover, the reader should be aware that sampling frequency
528   and the methods used for (concentric/eccentric) phase identification may affect the outcomes of
529   SJ and CMJ analyses (Owen et al., 2014;Eagles et al., 2015). Hence, comparisons across studies
530   must be made with caution.

531   From the force-velocity tests in bench press and squat we calculated peak power and estimated
532   1RM. The 1RM values had allegedly good reliability (CV<5% and CV<SWC), but contrary to
533   the peak power, the 1RM values showed trivial changes after both exercise sessions. Although it
534   has been suggested to be worth using (Jovanovic and Flanagan, 2014;Scott et al., 2016), force-
535   velocity estimated 1RM appears to have limited value for monitoring small changes in recovery
536   status; i.e., estimated (or predicted) 1RM tests appear to have low fatigue sensitivity. We applied

537 ~90% of 1RM as the heaviest load, which may have been too low to get an accurate estimation
538 of 1RM in the squat, as observed by some (Banyard et al., 2017). For the bench press, however,
539 ~90% of 1RM should be adequate for precise 1RM estimations – at least in an unfatigued state
540 (Jidovtseff et al., 2011;Garcia-Ramos et al., 2018a).

541 **Mechanisms for neuromuscular recovery**
542 Exercise-induced impairment of neuromuscular function and the following recovery phase are
543 multifaceted (Lieber and Friden, 2002;Enoka et al., 2011;Paulsen et al., 2012). However, if we
544 consider a particular exercise, such as the squat, and assume a constant range of motion (muscle
545 lengthening/strain) and a given total exercise volume (sets x repetitions), the determining factors
546 would be narrowed down to contraction/lengthening velocity and force. With the criterion of
547 maximal effort (intention to move) in the concentric phase, velocity will be high and force low
548 during light or moderate load power exercises, and vice-versa for heavy load strength exercises
549 (cf. the force-velocity relationship (Huijing, 1998)). Higher concentric forces during the heavy
550 load strength exercises will logically put more mechanical stress on the muscle tissue. However,
551 high-force concentric contractions result in minimal muscle damage and a swift recovery of
552 muscle function within 24 hours (Jones et al., 1989;Lee et al., 1999;Carson et al., 2002). Thus,
553 concentric work can probably only explain perturbations in neuromuscular function shortly after
554 exercise (i.e., minutes to a few hours, as a result of metabolic factors; (Allen et al., 2008)). This
555 led us to suggest that the eccentric phase was probably of greatest importance in the differences
556 in neuromuscular impairment and recovery rates between sessions (Paulsen et al., 2012). In other
557 words, the higher eccentric forces – simply due to higher loads – during the strength-oriented
558 session likely explain the slower recovery compared to the power-oriented session (Faulkner et
559 al., 1992;Black et al., 2007). On the other hand, the between-session differences displayed by the
560 recovery markers were generally small and trivial compared to the significant difference in loads
561 (the loads in the power session were 50% of those in the strength session). Therefore, we propose
562 that the higher eccentric velocity during the power-orientated (compared to the strength-
563 orientated session) caused a substantial mechanical stress on the muscles, despite the moderate
564 loads: Stretch-shortening cycle exercises have, indeed, been shown to induce muscle damage and
565 require days of recovery (Nicol et al., 2006). Future research should investigate this, but we
566 suggest that how the eccentric phase during power-orientated exercise is performed and the
567 utilization of the stretch-shortening cycle could have a major impact on recovery times.

568 **Lower and upper body exercise**
569 In the present study, both upper body and lower body exercises were applied. Studies exploring
570 muscle damage and recovery after eccentric exercise have reported that upper body muscles
571 sustain more damage and require longer recovery times than lower body muscles (Jamurtas et al.,
572 2005;Chen et al., 2011;Chen et al., 2019). However, recovery rates after traditional strength
573 training do not appear to be different between upper and lower body exercises, such as the bench
574 press and squat (McLester et al., 2003;Korak et al., 2015;Moran-Navarro et al., 2017). In line
575 with these studies, our data demonstrate a similar recovery rate for upper and lower body
576 exercises. Moreover, as for the lower body, the strength-oriented session seemed to induce
577 somewhat more fatigue and longer recovery times than the power-oriented session for the upper
578 body. In contrast to most studies that have investigated recovery after eccentric exercise (as cited

579   above), we recruited well-trained individuals, which points to training status as an important
580   parameter for recovery times – rather than an inherent difference between upper or lower body
581   muscles. Nevertheless, great care should be taken when comparing recovery from different
582   exercises/sessions, because variables such as muscle strain, force and work are very difficult to
583   control for.

584   **Fatigue vs. potentiation and supercompensation**
585   Neuromuscular function can be altered through adaptation to training over weeks and months
586   (Goldspink, 1985), but the neuromuscular system is also history-dependent for shorter time
587   periods. In fact, both fatigue and potentiation are possible outcomes of muscle contractions (Sale,
588   2002). While heavy loads and large exercise volumes may induce long-lasting neuromuscular
589   fatigue (hours and days), exercises conducted with low volume and high/maximal effort can
590   result in potentiation and enhanced neuromuscular function that lasts for minutes to several hours
591   (Cook et al., 2014;Russell et al., 2016). Interestingly, in the present study the power-oriented
592   session appeared to enhance MJ height at 24 hours and squat peak power and push-up peak force
593   48 hours after exercise (note that the push-up peak force at 48 hours was trivial and unclear
594   compare to baseline, but clearly different between sessions). This is in line with Tsoukos et al.
595   (2018), who observed increased CMJ height and RFDmax 24 and 48 hours after loaded jump
596   squats (40% of 1RM; 5 x 4 repetitions). In contrast to squat peak power, we observed no such
597   "supercompensation" in CMJ, SJ or 20 m sprint (which were all back to baseline at 48 hours).
598   Notably, our participants executed a large exercise volume, about three times that of Tsoukos et
599   al. (2018), and fatigue mechanisms may have overshadowed most of the supercompensation
600   effects of power exercises. Moreover, we only followed the participants for 48 hours, which
601   means that we do not know whether the supercompensation occurred later after the strength-
602   oriented session (e.g. after 72 hours). As final note, potentiation effects (or supercompensation)
603   is indeed relevant for athletes, as it is common practice for "power athletes", e.g., rugby players,
604   track and field throwers and sprinters, to perform a power-oriented session close to competitions
605   (~4-48 hours; (Russell et al., 2016); and own observations from the Norwegian Olympic Center,
606   Oslo, Norway).

607   **Objective vs subjective measures of recovery**
608   Session RPE (sRPE) for resistance exercise was reviewed by McGuigan (2004) and validated for
609   "intensity"; i.e. load in % of 1RM, by Sweet et al. (2004). Later studies have found the sRPE to
610   be related to both volume and work rate during strength training (Scott et al., 2016;Hiscock et al.,
611   2018). The present study ensured equal concentric work, but different loads – i.e., the power-
612   oriented session was performed with 50% of the loads used in the strength-oriented session.
613   Nevertheless, because the power-oriented session lasted ~12% (~13 minutes) longer than the
614   strength-oriented session, the work rate was highest during the strength-oriented session. As the
615   difference in loads (% of 1RM) between sessions was much larger than the difference in work
616   rate, we suggest that the higher loads (% of 1RM) were the dominant factor influencing the sRPE
617   scores (although we acknowledge that this cannot be ascertained with the present study design).
618   Notably, it has been proposed that exercise intensity/load (% of 1RM) influences RPE scores via
619   a positive relationship with the central motor control discharge (Gearhart et al., 2002), cf. the
620   "corollary discharge model" (Pageaux, 2016). However, our participants in both sessions were

621 strongly encouraged to execute every repetition with the intention to move as fast as possible in
622 the concentric phase. Indeed, both the motor-related cortical potentials (MRCP; (Slobounov et
623 al., 2004)) and the electromyographic (EMG) amplitude seem independent of load (% of 1RM) if
624 the intention to move is maximal – at least for lower body exercises (Bosco et al.,
625 1982;Hakkinen et al., 1986;Kawamori and Haff, 2004;McBride et al., 2010). If we assume that
626 our participants moved maximally in all repetitions, the corollary discharge model seems unable
627 to explain a higher sRPE after the strength-oriented session than the power-oriented session.
628 Consequently, we suggest that the sRPE scores in the present study were influenced by afferent
629 feedback from the muscles; supporting a "combined model" (Pageaux, 2016). The afferent
630 feedback may be a combination of different sensors including tendon organs ("force sensors")
631 and nociceptor receptors responding to metabolic perturbations. Metabolic perturbations, such as
632 elevated extracellular levels of adenosine, lactate and protons (Allen et al., 2008), stimulate
633 capsaicin fibres (Aδ and C-nerves; (Pollak et al., 2014)); and accordingly, muscular fatigue may
634 be an important underlying mechanism behind the RPE scores (Hardee et al., 2012;Vasquez et
635 al., 2013). When working at maximal intensity, fatigue will start to develop within seconds
636 (Allen et al., 2008), and probably to a larger degree during the strength-oriented session than the
637 power-oriented session due to more time under tension (i.e., a longer acceleration phase during
638 the lifts and/or less deacceleration). We cannot exclude the possibility that the participants used
639 elastic energy storage and release (the stretch shortening cycle) during the power-oriented
640 session, and thereby had better energy economy during the power-oriented session than the
641 strength-oriented session (Bosco et al., 1982). Higher energy expenditure and more fatigue in
642 combination with the heavier loads could explain the higher sRPE after the strength-oriented
643 session than the power-oriented session. Finally, it is noteworthy that the "contents"/definition of
644 the RPE concept, i.e., effort vs. force, pain and discomfort, and the mechanisms behind RPE, are
645 debatable (Pageaux, 2016). Moreover, the timing of reporting RPE, e.g. during or immediately
646 after an exercise vs. 30 minutes after a session (i.e., sRPE), may be important for the decisive
647 mechanisms of the RPE scores; thus, more scientific work is needed to better understand the use
648 of sRPE in relation to different modes of resistance exercise.

649 While sRPE scores are collected after a session, PRS is obtained before an exercise session. PRS
650 is supposed to give an evaluation of the athletes' readiness and performance status in the
651 upcoming session (Laurent et al., 2011). In the present study, recovery status 24 and 48 hours
652 after the strength-oriented session were reported lower compared to the power-oriented session.
653 Indeed, as for sRPE, PRS pointed in the same direction as the objective tests. However, no
654 consistent correlations were found between the PRS and objective variables, such as CMJ
655 eccentric peak force and push-up peak force. Interestingly, the state of recovery was perceived as
656 incomplete both 24 and 48 hours after the power-oriented session although performance was
657 back to baseline, or even above (squat peak power and MJ). Recent studies support a partly
658 dissociated time course between objective and subjective recovery status – for both upper and
659 lower body muscles – indicating a slower recovery when assessed subjectively (Zourdos et al.,
660 2016;Ferreira et al., 2017a;Ferreira et al., 2017b;Marshall et al., 2018). In summary, this
661 advocates for caution in interpreting subjective and objective measures of recovery. In our case
662 (and perhaps most cases), it is conceivable that neither the subjective nor the objective measures
663 revealed the true recovery status. On the objective side we merely measured some properties of

664   the neuromuscular system, leaving the possibility that unassessed properties were not recovered.
665   Interstingly, Zourdos et al. (2016) observed a difference in the PRS when assessed before and
666   after warm-up (higher PRS after warm-up). We assessed PRS only before warm-up, leaving the
667   possibility for higher coherence between objective measurements and PRS if evaluated after
668   warm-up.

669   **Limitations**
670   The present study has limitations. First, we applied a series of tests and we cannot exclude the
671   possibility that the tests themselves induced fatigue that affected the results; e.g., reduced the test
672   reliability. Moreover, we had no control trial in which the participants simply conducted the four
673   test-sessions without participating in an exercise session (see Figure 1). Consequently, we must
674   be careful interpreting the changes in relation to time after each session (within-session changes);
675   it is possible that the recovery was prolonged due to all the tests.

676   Second, we calculated the work done based on concentric work; thus, we excluded eccentric
677   work, and we cannot rule out that some differences between sessions could have been explained
678   by this fact.

679   Third, each participant completed two sessions. Due to the repeated bout effect, a faster recovery
680   must be expected after the second session (McHugh, 2003). Moreover, since the loads (in % of
681   1RM) were higher in the strength-oriented session, the adaptative processes may have been
682   better stimulated after the strength- than the power-oriented session (i.e., strengthening of the
683   myofiber cytoskeleton (Paulsen et al., 2009)). If true, this may have created a bias toward faster
684   recovery after the power-oriented session. Furthermore, the time between sessions (the washout
685   period) varied between the participants (1-4 weeks), which means that their training status may
686   have changed slightly. This effect does appear small as the pre-values before each session were
687   very similar, with low to moderate CV for all variables (Table 2). To this end, the order of
688   sessions was randomized, and the impact of session-order was trivial when controlled for.
689   Additionally, we recruited both females and males. The participants had different training
690   backgrounds and we did not control their training in the washout period (except during the 48
691   hours before each session). We did not fully control the diets of the participants. We
692   acknowledge that these factors may have induced biases and variability in our results.

693   Fourth, we did not include tests that allowed us to distinguish between central and peripheral
694   fatigue, nor did we measure systemic markers of recovery (such as creatine kinase, testosterone
695   and cortisol; (Buckthorpe et al., 2014;Hiscock et al., 2018;Tsoukos et al., 2018)). This could
696   have given us valuable information about the subtle impairments of neuromuscular performance
697   and recovery between sessions.

698   Fifth, we acknowledge that the definition of the different variables gleaned from the SJ and CMJ
699   tests are open for debate. Particularly, we want to make the reader aware of the fact that CMJ
700   peak eccentric and concentric force are reached within a very narrow time window in the lowest
701   position of the jump. Thus, collecting only the force in the lowest squat position could yield the
702   necessary information, with the advantage that the point/position is clearly defined (easily
703   reproducible).

704   Finally, one should be careful about extrapolating the results of this study to other training
705   interventions/programs due the many combinations/possibilities within a strength/power training
706   program that may be important in the recovery process, such as exercises, load, volume, work
707   and interest-rest periods.

708   **Practical applications**
709   Knowledge of recovery from exercise sessions is needed to make qualified assumptions when
710   designing training programs, particularly for elite athletes who must handle large training
711   volumes and avoid overtraining. The present and previous studies have shown that to monitor
712   recovery one must consider a combination of tests and be aware of the error of measurements. In
713   our study, the eccentric peak force during a CMJ and the peak power calculated from a squat
714   force-velocity test were the variables that seemingly best differentiated between a strength-
715   oriented session and a power-oriented session. Further research is warranted to see whether these
716   tests are valid for other modes of resistance exercise and with participants of different
717   performance levels (training status).

718   In our hands, RFD from CMJ and SJ seem to have too large a day-to-day variability to be
719   recommended for monitoring recovery. Improved standardizations and instructions to the athlete
720   may be worth exploring. Similarly, for the upper body our applied tests were not fully
721   satisfactory in terms of reliability and fatigue sensitivity, implying that more work is needed.

722   The power-oriented session tended to improve performance in certain tests at 24 and/or 48 hours
723   after exercise. Potentiation or a fast supercompensation from power-oriented sessions is highly
724   relevant for athletes preparing for competitions.

725   Objective and subjective tests of recovery may not correlate. Consequently, both test modalities
726   should be used and interpreted together to ensure a holistic approach (Kiely, 2012). Because the
727   recovery process is so complex, it is important to acknowledge that there is much we do not
728   know or understand; thus, relying on only objective or only subjective measurers could prove
729   inadequate for most athletes.

730   It appears that the best tests for assessing recovery will differ significantly according to the
731   exercises that have been conducted. Consequently, we cannot expect a "gold standard" test
732   battery. Rather, we need to use a selected number of tests for each specific athlete or group of
733   athletes, and a combination of subjective and objective tests appears advisable.

734

Conclusion

736   We hypothesized that a heavy-load, strength-oriented exercise session would require a longer
737   recovery period than a moderate-load, power-oriented session with equal concentric work. Our
738   hypothesis was confirmed as the power-oriented session required less than 48 hours of recovery,
739   while the strength-oriented session required more than 48 hours. The strength-oriented session
740   induced an overall larger detrimental effect on the neuromuscular system than the power-
741   oriented session at all time points (0, 24 and 48 hours), reducing both power and strength
742   properties. However, differences in the performance assessments between the exercise sessions

743 were generally small or trivial. The apparently best markers for detecting differences between the
744 strength-oriented session and power-oriented session were the CMJ derivate eccentric peak force
745 and squat peak power. Considering the good reliability (lower than the SWC), the CMJ eccentric
746 peak force seemed to be the most sensitive parameter. For the upper body, the push-up peak
747 force seemed more sensitive as a recovery marker than bench press peak power and 1RM, but
748 the push-up had only acceptable reliability. In contrast to the strength-oriented session, the
749 power-oriented session seemed to potentiate multi-jump performance and squat peak power.
750 Furthermore, the strength-oriented session was experienced as more strenuous (higher sRPE) and
751 more recovery was perceived to be required (lower PRS) compared to the power-oriented
752 session, which were in accordance with our secondary hypothesis. However, our third hypothesis
753 was falsified as the subjective measurements correlated poorly (inconsistently) with the objective
754 measurements; indicating the need for both objective and subjective measurements in practice.

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759

Data availability statement

761 The raw data set is available.

762

Author contributions statement

764 CH, DSO, LH and GP conceived and designed the study. CH, MM, FS, LH, DSO, and GP
765 carried out the study and collected the data. CH, DSO, PS, and GP performed statistical analyses
766 and interpreted the data. CH, PS and GP wrote the manuscript. All authors read and approved the
767 final manuscript.

768

Conflicts of interest

770 Author Daniela Schäfer Olstad was employed by the company Polar Electro Oy. Of note, the
771 present study does not contain any data collected by Polar Electro Oy equipment/devices. The
772 remaining authors declare that the research was conducted in the absence of any commercial or
773 financial relationships that could be construed as a potential conflict of interest.

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Figure 1

Overview of the study design

Overview of the study design. The session that was performed first, either the strength-oriented session or the power-oriented session, was randomized.

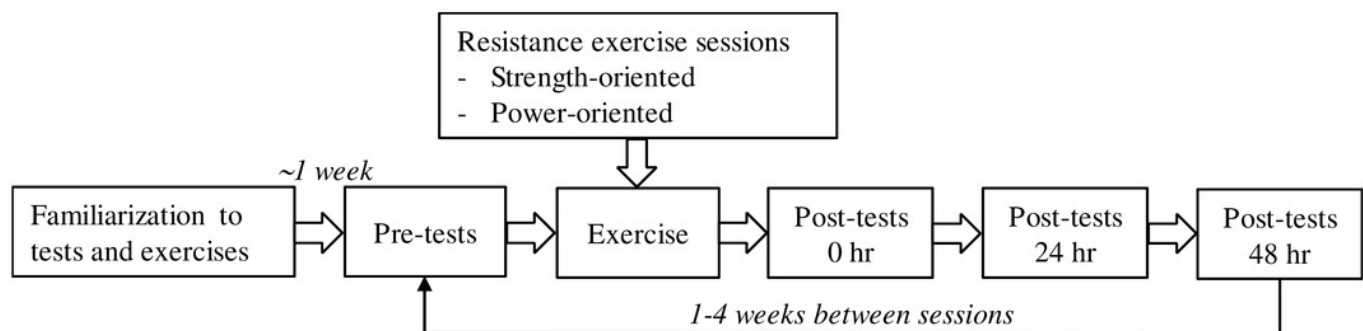



Figure 2

Force-time curve of a countermovement jump

An example of a force-time curve of a countermovement jump (CMJ). The eccentric and concentric phase are displayed.

RFD: Rate of Force Development

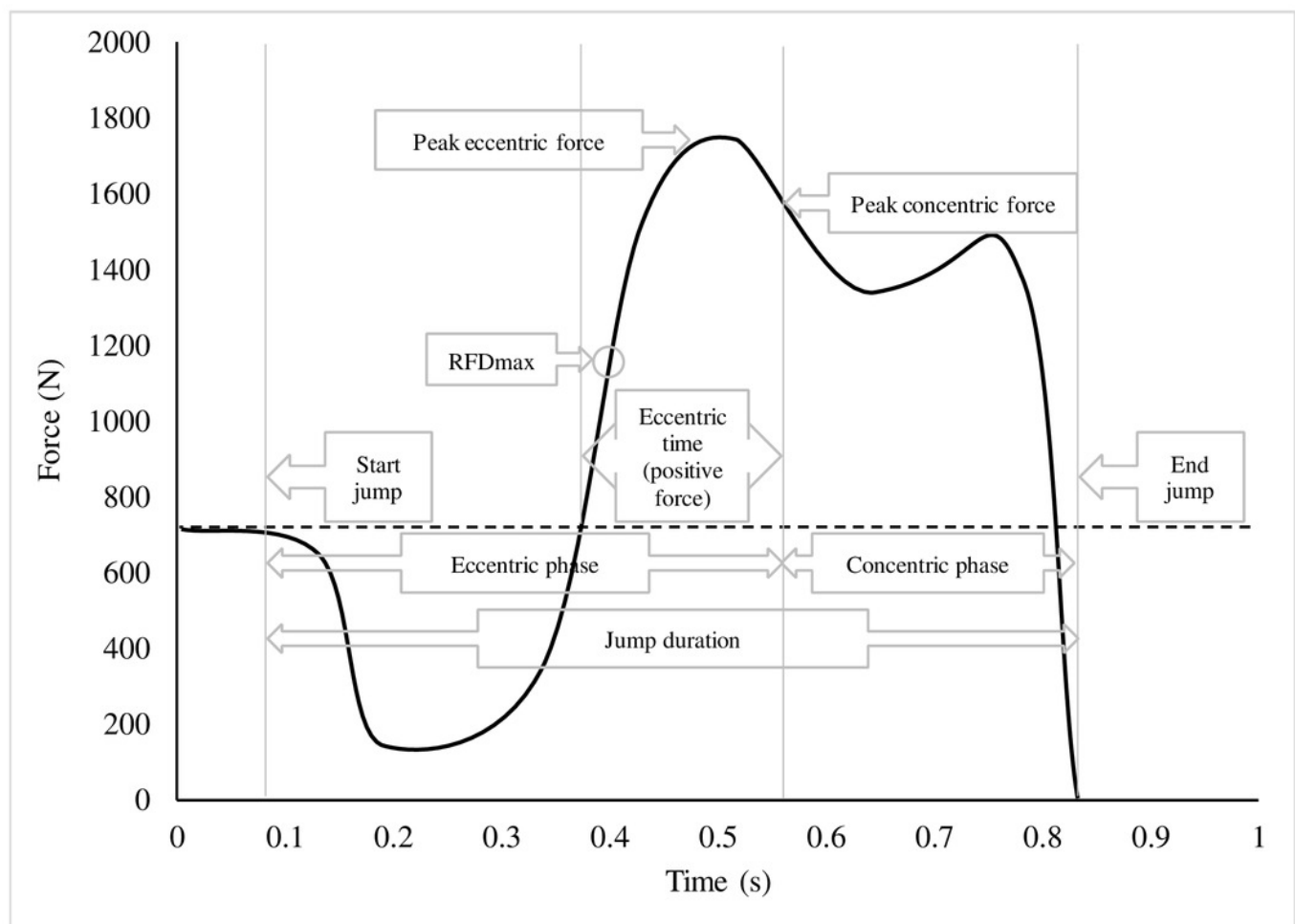



Figure 3

Variables derived from the countermovement jump (CMJ) test

Variables derived from the countermovement jump (CMJ) test obtained before, immediately after (0 hours) and 24 and 48 hours after the strength-oriented session and the power-oriented session. Values are means and 95% CIs of percentage changes from pre-values. Changes within sessions and differences (Diff) between sessions are marked with effect sizes and p-values. Grey areas represent the smallest worthwhile change. A: Jump height, B: Peak power, C: Mean power, D: Peak concentric force, E: RFDmax, F: Eccentric time, G: Eccentric peak force, H: Depth (lowering of centre of mass).

RFDmax: Maximal Rate of Force Development. Trivial (Triv): <0.2, Small: 0.2-0.6; Moderate (Mod): 0.6-1.2; Large: 1.2-2.0; Very large: 2.0-4.0; Extremely large: <4.0 *: Possibly beneficial, **: Likely beneficial, ***: Very likely beneficial +: Possibly harmful, ++: Likely harmful, +++: Very likely harmful, ++++: Most likely harmful ^{0}: Possibly trivial, ^{00}: Likely trivial, ^{000}: Very likely trivial, ^{0000}: Most likely trivial ^{Uncl}: Unclear a: p<0.05 b: p<0.01

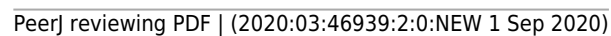
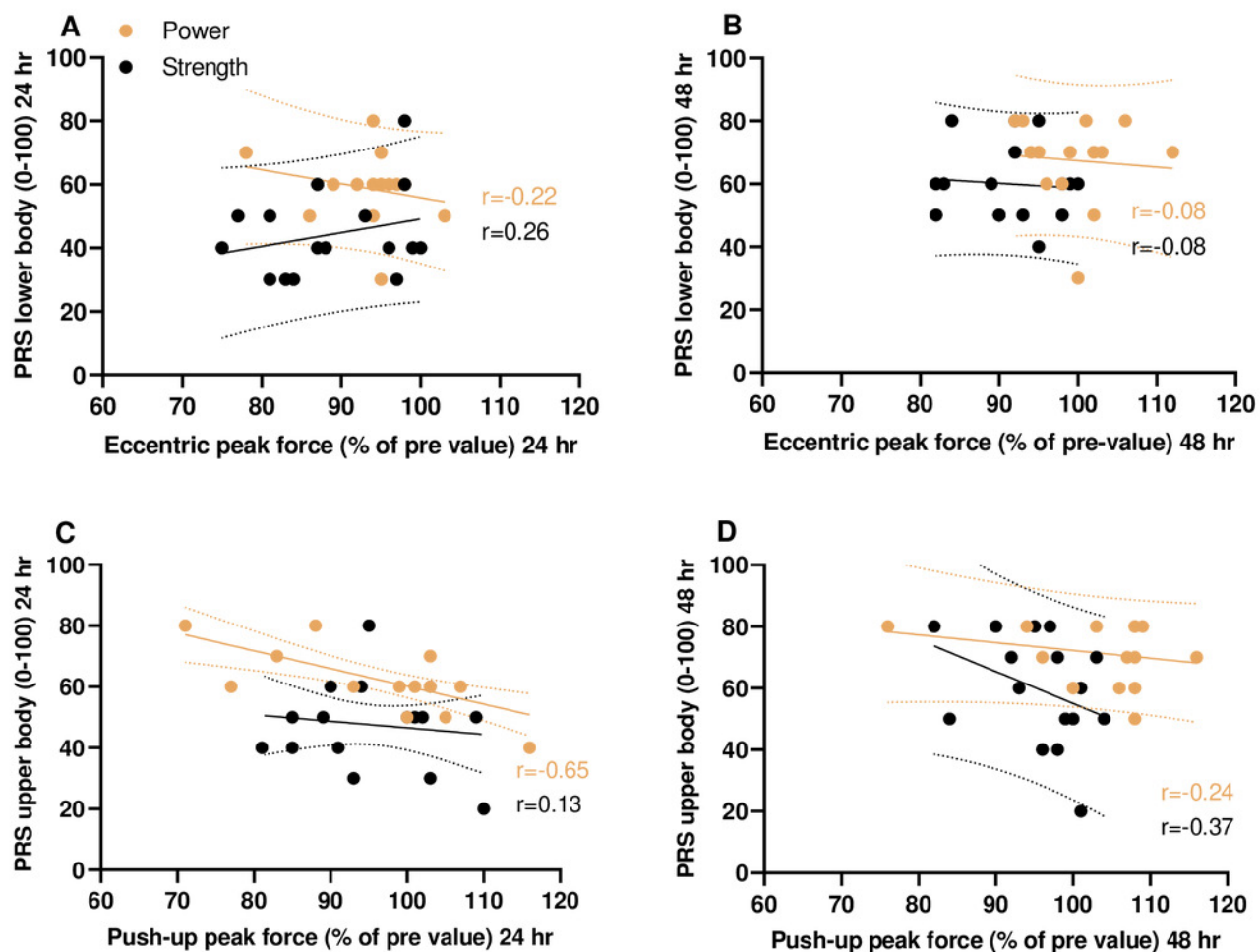



Figure 4

Objective vs. subjective measures

Figure 4. X-y-plots of individual values for the strength-oriented session and the power-oriented session; regression lines are given with 95% confidence bands. A and B display the relationship between eccentric peak force and perceived recovery status (PRS; lower body) 24 and 48 hours after the sessions. C and D display the relationship between peak push-up force and PRS (upper body) 24 and 48 hours after the sessions. PRS values are given in the range 0-100, where 100 is fully recovered

The exercises applied

Exercises for each of the two sessions

Power session	Heavy strength session	Comment
Loaded CMJ	Squat	Same depth in the eccentric phase
Front squat with overhead push	Front squat	Same depth in the eccentric phase
Trap bar CMJ	Trap bar squat	Same depth in the eccentric phase
Bench press throw	Bench press	Conducted in a Smith rack
Narrow bench press throw	Narrow bench press	Conducted in a Smith rack
Explosive push-ups	Weighted push-ups	Load by weight-vest (1-9 kg) and discs (5-20 kg). Boxes (25 cm) were placed under feet and hands.

Baseline values

Baseline values for the strength-oriented session and the power-oriented session.

Variable	Power Mean ± SD	Strength Mean ± SD	SD used for standardizing (adjusted)	Smallest worthwhile change % (0.2 SD)	Coefficient of Variation % (CV)
CMJ (cm)	34.8 ± 8.7	34.7 ± 9.0	8.9	5.0	5.1
CMJ peak power (W)	1905 ± 670	1869 ± 722	703	7.5	6.5
CMJ mean power (W)	316 ± 116	317 ± 128	123	8.0	8.7
CMJ concentric peak force (N)	1788 ± 406	1774 ± 348	381	4.3	4.0
CMJ RFDmax (N/s)	13169 ± 5317	12843 ± 5895	5663	8.8	21.2
CMJ duration (s)	0.84 ± 0.08	0.84 ± 0.09	0.09	2.1	7.4
CMJ eccentric peak force (N)	1793 ± 410	1787 ± 357	378	4.4	4.2
CMJ eccentric time (s)	0.18 ± 0.04	0.19 ± 0.03	0.04	3.8	9.9
CMJ depth (cm)	-39.2 ± 6.0	40.1 ± 6.4	6.3	3.2	8.3
SJ (cm)	32.0 ± 8.0	32.3 ± 8.2	8.2	5.0	5.7
SJ peak power (W)	1980 ± 672	2003 ± 748	717	7.3	6.3
SJ mean power (W)	586 ± 220	606 ± 254	240	8.2	9.8
SJ peak force (N)	1630 ± 326	1637 ± 361	347	4.3	4.3
SJ RFDmax (N/s)	7155 ± 2090	7675 ± 3210	2744	6.9	21.0
SJ duration (s)	0.40 ± 0.03	0.40 ± 0.05	0.04	2.1	8.6
MJ (cm)	27.6 ± 6.8	29.6 ± 8.2	7.7	5.2	9.1
MJ RSI	45.2 ± 12.0	47.4 ± 15.6	14.1	6.0	14.9
MJ vertical stiffness (N/m)	6.0 ± 1.9	5.9 ± 1.7	1.8	6.0	19.9
20 m (s)	3.08 ± 0.22	3.08 ± 0.23	0.23	1.5	1.3
Push-up peak force (N)	1071 ± 421	1105 ± 422	425	7.1	11.2
Squat peak power (W)	1380 ± 332	1438 ± 314	327	4.8	7.2
Bench press peak power (W)	433 ± 180	450 ± 184	184	9.4	9.3
Squat estimated 1RM (kg)	121 ± 39	120 ± 41	39.9	6.6	4.6
Bench press estimated 1RM (kg)	80 ± 29	81 ± 30	30.0	7.5	3.3
PRS (%)	83.1 ± 9.5	76.9 ± 10.1	10.4	10	14.5
sRPE upper body (0-10)	5.1 ± 1.5	6.8 ± 1.5	--	10	--
sRPE lower body (0-10)	5.3 ± 1.1	7.4 ± 1.3	--	10	--
Total work upper body (kJ)	12 ± 7	11 ± 7	--	--	--
Total work lower body (kJ)	57 ± 14	57 ± 14	--	--	--

1RM = 1 Repetition Maximum, CMJ = Countermovement Jump, MJ = Multi Jump, PRS = Perceived Recovery Status, RSI = Reactive Strength Index, RFDmax = Maximal Rate of Force Development, SJ = Squat Jump, sRPE = session RPE

Changes and recovery over time

Percent changes from baseline within the strength-oriented session and the power-oriented session, with 95% CIs and associated effect sizes and inferences (adjusted for baseline values).

Variable		Post 0 0 hours Mean ± SD; ±95%CI	Inference	Post 1 24 hours Mean ± SD; ±95%CI	Inference	Post 2 48 hours Mean ± SD; ±95%CI	Inference
SJ height	Power Strength	-4.2 ± 3.8; ±1.9 -8.2 ± 5.8; ±2.8	Triv^{00} (p<.05) Small^{+++} (p<.05/01)	-1.2 ± 3.9; ±2.1 -3.7 ± 6.5; ±3.3	Triv^{0000} Triv^{00} (p<.05)	0.7 ± 4.4; ±2.4 -2.1 ± 6.7; ±3.4	Triv^{0000} Triv^{000}
SJ peak power	Power Strength	-2.9 ± 4.3; ±2.2 -4.3 ± 4.8; ±2.4	Triv^{000} (p<.05) Triv^{+} (p<.05/01)	-1.5 ± 5.6; ±2.9 -2.6 ±9.4; ±4.7	Triv^{000} Triv^{00}	-1.1 ± 7.0; ±3.7 -3.8 ± 8.6; ±4.3	Triv^{000} Triv^{+}
SJ mean power	Power Strength	-5.9 ± 7.9; ±3.8 -11.5 ± 12.9; ±5.8	Small^{+} (p<.05/01) Small^{+++} (p<.05/01)	-5.4 ± 11.8; ±5.7 -7.8 ± 14.1; ±6.5	Small^{+} Small^{++} (p<.05	-1.5 ± 12.9; ±6.7 -6.3 ± 15.1; ±7.1	Triv^{uncl} Small^{+}
SJ peak force	Power Strength	-0.7 ± 3.2; ±1.7 -0.6 ± 3.0; ±1.6	Triv^{0000} Triv^{0000}	-0.9 ± 3.7; ±1.9 -1.2 ± 5.8; ±3.0	Triv^{0000} Triv^{000}	-1.4 ± 4.3; ±2.3 -2.7 ± 4.6; ±2.4	Triv^{0000} Triv^{000} ($^{(}$p<.05)
SJ RFDmaks	Power Strength	-4.4 ± 15.3; ±7.3 -7.0 ± 17.3; ±8.0	Triv^{+} Small^{+}	0.0 ± 16.0; ±7.9 -11.5 ± 28.1; ±11.8	Triv^{00} Small^{++}	4.2 ± 17.5; ±9.4 -7.3 ± 32.9; ±14.2	Triv^{uncl} Small^{+}
SJ duration	Power Strength	1.9 ± 6.8; ±3.6 5.3 ± 8.8; ±4.8	Triv^{000} Small+ (p<.05)	4.1 ± 9.8; ±5.2 5.5 ± 9.8; ±5.3	Triv^{+} Small+ (p<.05)	1.7 ± 9.5; ±5.1 4.4 ± 9.8; ±5.2	Triv^{00} Triv^{+}
MJ heigth	Power Strength	2.4 ± 12.4; ±6.4 -3.2 ± 10.0; ±4.1	Triv^{uncl} Triv^{00}	6.4 ± 9.3; ±5.3 -0.5 ± 8.4; ±3.5	Small* (p<.05) Triv^{000}	4.4 ± 10.7; ±5.7 1.4 ± 4.8; ±2.1	Triv* Triv^{0000}
MJ RSI	Power Strength	-2.5 ± 14.7; ±7.2 -6.3 ± 11.4; ±5.4	Triv^{00} Small^{+} (p<.05)	4.1 ± 11.3; ±6.2 -0.7 ± 7.3; ±3.8	Small^{uncl} Triv^{000}	1.1 ± 11.3; ±5.8 1.6 ± 8.3; ±4.4	Triv^{00} Triv^{000}
MJ vertical stiffness	Power Strength	2.8 ± 19.9; ±10.4 0.4 ± 11.6; ±6.2	Triv^{uncl} Triv^{00}	-5.3 ± 18.0; ±9.1 5.3 ± 10.5; ±5.8	Small^{+} Small*	-5.2 ± 24.4; ±11.6 -1.1 ± 15.2; ±7.8	Small^{+} Triv^{00}
20 m	Power Strength	0.0 ± 1.8; ±1.0 1.5 ± 1.8; ±1.0	Triv^{0000} Triv^{+} (p<.05)	0.7 ± 1.6; ±0.8 1.2 ±1.9; ±1.1	Triv^{000} Triv^{+} (p<.05)	0.6 ± 1.7; ±0.9 0.5 ± 1.7; ±1.0	Triv^{000} Triv^{000}
Push-up peak force	Power Strength	-0.6 ± 12.0; ±6.1 -1.0 ± 7.3; ±3.1	Triv^{000} Triv^{0000}	-4.8 ± 14.4; ±7.5 -4.7 ± 9.6; ±3.9	Triv^{+} Triv^{00}	5.2 ± 14.4; ±8.6 -4.3 ± 7.1; ±2.9	Triv^{uncl} Triv^{00}
Squat peak power	Power Strength	-- --	-- --	2.9 ± 9.0; ±4.7 -6.4 ± 7.6; ±3.7	Triv^{00} Small^{++} (p<.05/01)	5.8 ± 6.7; ±3.8 -3.7 ± 8.3; ±4.7	Small* (p<.05) Triv^{+}
Bench press peak power	Power Strength	-- --	-- --	-0.1 ± 5.3; ±3.0 -5.6 ± 6.3; ±3.4	Triv^{0000} Triv^{000} (p<.05/01)	3.5 ± 8.9; ±5.2 -2.6 ± 10.7; ±6.4	Triv^{000} Triv^{000}
Squat estimated 1RM	Power Strength	-- --	-- --	-1.6 ± 6.2; ±3.2 -0.5 ± 5.7; ±3.0	Triv^{0000} Triv^{0000}	-1.3 ± 5.5; ±2.9 -2.5 ± 4.8; ±2.8	Triv^{0000} Triv^{0000}
Bench press estimated 1RM	Power Strength	-- --	-- --	-1.6 ± 4.8; ±2.7 -3.2 ± 5.4; ±3.0	Triv^{0000} Triv^{000} (p<.05)	-1.1 ± 3.9; ±2.2 -2.8 ± 5.0; ±3.1	Triv^{0000} Triv^{0000}
PRS total	Power Strength	-36.9 ±16.5; ±8.9 -44.1 ± 15.6; ±8.4	Mod^{++++} (p<.05/01) Mod^{++++} (p<.05/01)	-23.8 ± 8.7; ±4.7 (p<.05/01) -30.0 ± 11.9; ±6.4 (p<.05/01)	Small^{++++} Mod^{++++}	-13.6 ± 9.1; ±4.7 (p<.05/01) -16.3 ± 14.7; ±7.9 (p<.05/01)	Small^{++} Small^{+++}
PRS upper body	Power Strength	-38.1 ± 17.5; ±9.4 -43.8 ± 11.7; ±6.2	Mod^{++++} (p<.05/01) Mod^{++++} (p<.05/01)	-21.3 ± 10.4; ±5.6 (p<.05/01 -29.4 ± 10.3; ±5.5 (p<.05/01)	Small^{++++} Small^{++++}	-11.3 ± 8.8; ±4.7 (p<.05/01 -17.5 ± 18.1; ±9.7 (p<.05/01)	Small^{+} Small^{++}
PRS lower body	Power Strength	-40.6 ± 14.5; ±7.8 -45.0 ± 13.6; ±7.3	Mod^{++++} (p<.05/01) Mod^{++++} (p<.05/01)	-24.4 ± 11.3; ±6.0 (p<.05/01) -32.5 ± 13.3; ±7.1 (p<.05/01)	Small^{++++} Mod^{++++}	-15.6 ± 13.0; ±7.0 (p<.05/01) -16.9 ± 12.5; ±6.7 (p<.05/01)	Small^{++} Small^{+++}

1RM = 1 Repetition Maximum, CI: Confidence Interval, MJ = Multi Jump, PRS = Perceived Recovery Status, RSI = Reactive Strength Index, RFDmax = Maximal Rate of Force Development, SD: Standard Deviation, SJ = Squat Jump, sRPE = session RPE

Trivial (Triv): <0.2, Small: 0.2-0.6, Moderate (Mod): 0.6-1.2, Large: 1.2-2.0; Very large: 2.0-4.0; Extremely large: <4.0

*: Possibly beneficial, **: Likely beneficial, ***: Very likely beneficial

$^{+}$: Possibly harmful, $^{++}$: Likely harmful, $^{+++}$: Very likely harmful, $^{++++}$: most likely harmful

^{0}: Possibly trivial, ^{00}: Likely trivial, ^{000}: Very likely trivial, ^{0000}: Most likely trivial

^{uncl}: Unclear (need more data)

p<.05: The 95% CI do not overlap with zero

p<.01: The 99% CI do not overlap with zero

Differences between sessions

Percent differences between the strength-oriented session and the power-oriented session at 0, 24 and 48 hours, with 95% CIs and associated effect sizes and inferences (strength minus power; adjusted for baseline values).

Variable	Post 0 0 hours Mean; ±95%CI	Inference	Post 1 24 hours Mean; ±95%CI	Inference	Post 2 48 hours Mean; ±95%CI	Inference
SJ height	-4.1; ±3.4	Triv[+] ($p<.05$)	-2.5; ±3.8	Triv[00]	-2.8; ±3.6	Triv[00]
SJ peak power	-1.4; ±3.5	Triv[0000]	-1.1; ±5.2	Triv[000]	-2.7; ±5.3	Triv[000]
SJ mean power	-6.0; ±5.7	Triv[00] ($p<.05$)	-2.5; ±8.4	Triv[00]	-4.8; ±9.9	Triv[+]
SJ peak force	0.1; ±2.4	Triv[0000]	-0.3; ±3.4	Triv[000]	-1.3; ±3.1	Triv[000]
SJ RFD max	-1.8; ±11.4	Triv[0]	-11.3; ±13.7	Small[++]	-10.5; ±15.0	Small[+]
SJ duration	2.9; ±5.3	Small[+]	0.4; ±6.8	Triv[uncl]	1.7; ±7.5	Triv[uncl]
MJ height	-5.1; ±8.5	Small[+]	-6.0; ±6.3	Small[+]	-1.7; ±5.3	Triv[00]
MJ RSI	-3.5; ±9.0	Triv[+]	-4.2; ±6.5	Triv[+]	1.2; ±5.6	Triv[000]
MJ vertical stiffness	-2.7; ±9.7	Triv[+]	10.8; ±12.4	Small[**]	4.0; ±10.7	Triv[uncl]
20 m	1.4; ±1.0	Triv[+]	0.5; ±1.2	Triv[00]	-0.1; ±1.1	Triv[000]
Push-up peak force	-0.3; ±7.8	Triv[uncl]	0.4; ±9.3	Triv[00]	-9.0; ±8.9	Small[+] ($p<.05$)
Squat peak power	--	--	-9.1; ±5.6	Small[++] ($p<.05/01$)	-8.8; ±5.5	Small[++] ($p<.05/01$)
Bench press peak power	--	--	-5.3; ±4.7	Triv[00] ($p<.05$)	-5.7; ±7.7	Triv[+]
Squat estimated 1RM	--	--	1.1; ±3.1	Triv[0000]	-1.2; ±4.2	Triv[000]
Bench press estimated 1RM	--	--	-1.6; ±3.4	Triv[0000]	-1.7; ±4.5	Triv[000]
sRPE total	-20.6; ±10.1	Small[+++] ($p<.05/01$)	--	--	--	--
sRPE upper body	-16.9; ±10.7	Small[++] ($p<.05/01$)	--	--	--	--
sRPE lower body	-21.9; ±8.8	Small[+++] ($p<.05/01$)	--	--	--	--
PRS total	-11.1; ±7.0	Small[+] ($p<.05/01$)	-10.1; ±9.2	Small[+] ($p<.05$)	-6.8; ±10.4	Triv[+]
PRS upper body	-9.4; ±4.8	Triv[+] ($p<.05/01$)	-10.2; ±8.8	Small[+] ($p<.05$)	-10.1; ±10.9	Small[+]
PRS lower body	-8.5; ±6.6	Triv[+] ($p<.05$)	-12.8; ±11.2	Small[+] ($p<.05$)	-6.1; ±10.8	Triv[00]

1RM = 1 Repetition Maximum, CI: Confidence Interval, MJ = Multi Jump, PRS = Perceived Recovery Status, RSI = Reactive Strength Index, RFDmax = Maximal Rate of Force Development, SD: Standard Deviation, SJ = Squat Jump, sRPE = session RPE
Trivial (Triv): <0.2, Small: 0.2-0.6; Moderate (Mod): 0.6-1.2; Large: 1.2-2.0; Very large: 2.0-4.0; Extremely large: <4.0
*: Possibly beneficial, **: Likely beneficial, ***: Very likely beneficial
[+]: Possibly harmful, [++]: Likely harmful, [+++]: Very likely harmful, [++++]: Most likely harmful
[0]: Possibly trivial, [00]: Likely trivial, [000]: Very likely trivial, [0000]: Most likely trivial
[uncl]: Unclar (need more data)
$p<.05$: The 95% CI do not overlap with zero
$p<.01$: The 99% CI do not overlap with zero