

Effects of two contrast training programs on jump performance in rugby union players during a competition phase

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2 during a competition phase.

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4 Original investigation.

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6 **Running head:** Strength-power vs. speed-power training.

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ABSTRACT

Purpose: There is little literature comparing contrast training programs typically performed by team sport athletes within a competitive phase. We compared the effects of two contrast training programs on a range of lower-body measures in high-level rugby union players during the competition phase of their season. **Methods:** The programs consisted of a higher volume-load (strength-power) or lower volume-load (speed-power) resistance training; each included a tapering of loading (higher force early in the week, higher velocity later in the week) and was performed twice a week for four weeks. Eighteen players were assessed for peak power during a bodyweight countermovement jump (BWCMJ), bodyweight squat jump (BWSJ), 50-kg countermovement jump (50CMJ), 50-kg squat jump (50SJ), and broad jump (BJ). Reactive strength index (RSI) was determined by dividing jump height by contact time during a depth jump. Players were then randomized to either the strength-power or speed-power training group and were reassessed following the intervention. Inferences were based on uncertainty in outcomes relative to thresholds for standardized changes. **Results:** There were small between-group differences in favor of strength-power training for mean changes in the 50CMJ (8%; 90% confidence limits, $\pm 8\%$), 50SJ (8%; $\pm 10\%$), and BJ (2%; $\pm 3\%$). Differences between groups for BWCMJ, BWSJ and reactive strength index were unclear. For most measures there were smaller individual differences in changes with strength-power training. **Conclusion:** Our findings suggest that high-level rugby union athletes should be exposed to higher volume-load contrast training for larger and more uniform adaptation to occur in explosive power throughout a competitive phase of the season. **Key words:** Athlete, power, resistance, strength.

49

50 Introduction

51 The level of power an athlete possesses has been shown to distinguish between different levels of
52 athletic ability and as such, increasing an athlete's ability to produce power may improve
53 sporting performance.¹ Improving power in well trained team sport athletes, especially during the
54 competition phase of the season can be difficult to achieve. Baker² reported a 1% decrease in
55 lower body mean power throughout a 29 week competition phase in professional and college
56 aged rugby league players. While more recently, a 3% decrease in lower body peak power was
57 observed during a 13 week competition phase in professional rugby union players.³
58 Consequently, training methods that improve power in already well trained athletes during the
59 competitive phase of the season need to be identified.

60

61 Programming methods consisting of the combination of strength training (lower velocity / higher
62 force) and power training (higher velocity / lower force) have been regularly reported to be
63 superior to strength or power training in isolation.^{4,5} Combined resistance training is commonly
64 referred to as either compound training (heavy resistance day alternated with a lighter resistance
65 day), complex training (several sets of a heavy resistance exercise that are followed by sets of a
66 lighter resistance exercise) or contrast training (alternating heavy and lighter exercises set for
67 set).⁶ Previous authors have reported larger improvements following combined training when
68 compared to high strength or high power training alone.^{4,5} It has been postulated that combined
69 training provides broader neuromuscular adaptations resulting in greater transfer to a wider
70 variety of performance variables.⁴

71

72 Although, combined training methods consisting of heavy loads (>80% 1RM) in conjunction
73 with lighter loads performed ballistically have been reported to improve power;⁴ authors have
74 also investigated the acute effects of combined training with lighter loads. Smilios and
75 colleagues⁷ investigated the effect of contrast training with 30% 1RM half squat on bodyweight
76 jump performance in trained regional-level team sport athletes. It was reported that loaded jump
77 squats of 30% 1RM produced significant improvements (4%) in a subsequent bodyweight jump.⁷
78 Additionally, Baker⁸ reported similar improvements (5%) in a jump squat that was preceded by a
79 ~60 %1RM jump squat in professional rugby league players. However, the chronic effect of
80 heavier vs. lighter contrast training in elite athletes has not been established. Previous research
81 has determined the training effects of heavy vs. light ballistic training (not contrast training).
82 McBride and colleagues⁹ investigated the effects of eight weeks of heavy or light jump squat
83 training on strength and power development. It was reported that the velocity of the movement,
84 as controlled by the load plays a key role in velocity-specific training adaptations i.e. the heavy
85 group produced greater improvements in force output, while the light group had greater
86 improvements in velocity. Interestingly, both groups significantly increased lower body strength.
87 Whether chronic improvements can be made with lighter contrast training loads over a longer
88 training period needs to be established.

89 Many professional athletes, including those playing rugby union taper training load during each
90 competition week in an attempt to optimize physical preparation. This taper allows athletes to
91 express themselves in a non-fatigued and primed state during the weekly competition/game.
92 High force, lower velocity training is normally performed at the beginning of each training week,
93 while lighter, higher velocity training is performed in the latter stages of the week (typical of
94 compound training). Additionally, in an attempt to maximize training quality, athletes may also

95 perform complex and contrast training as part of their resistance training programs. Although the
96 effects of combined training have been relatively well established; the effects of combined
97 training methods with different intensities (heavy vs. light contrast training) performed with a
98 weekly taper (heavy day and lighter day) requires further attention. Anecdotally, the current best
99 practice is to lift with heavier contrast training loads.

100 Professional rugby union players perform a variety of different training modes concurrently
101 within a training phase i.e. strength and power, speed, anaerobic and aerobic conditioning, along
102 with a variety of rugby specific training (skills, team plays, technical and tactical sessions).
103 However, much of the current literature does not address this; yet application of research results
104 is still applied to team sport athletes who perform concurrent training. Understanding the effects
105 of different resistance training methods within a competition phase will enhance programming
106 and subsequent training adaptation, enabling athletes to be better prepared for weekly
107 competition as occurs in many team sports. Therefore, the purpose of this investigation was to
108 compare the effects of two contrast training programs on a range of lower body performance
109 measures in high-level rugby union players during the competition phase of their season. Each
110 program included a tapering of loading (higher force early in the week, higher velocity later in
111 the week); with the major difference between the two programs being the loading. Either a heavy
112 (strength-power) or a lighter (speed-power) resistance program was performed, which therefore
113 affected the movement velocity that could be produced during each exercise set. It was
114 hypothesized that the strength-power program would result in greater improvements in
115 performance measures requiring higher force production (e.g. weighted jumps), whilst the speed-
116 power program would result in greater improvements in performance where high levels of
117 velocity were required (e.g. bodyweight jumps).

118

119 **Methods**

120 *Subjects*

121 Eighteen high-level rugby union players from a New Zealand provincial representative team
122 (semi-professional and professional players) volunteered to take part in this study (Table 1)
123 during the final two weeks of pre-season training and the first seven weeks of the competitive
124 phase of the season. The intervention period included a four week baseline training and
125 familiarization phase, during which time a lower-body maximal strength assessment (box squat)
126 took place using methods previously described^{3,10} in order to characterize the training level of the
127 subjects. Each player had at least two years of resistance training experience and was deemed
128 highly trained (see box squat strength, Table 1). Players were informed of the experimental risks
129 and signed an informed consent document prior to the investigation. The investigation was
130 approved by an Institutional Review Board for use of Human subjects.

131

132 Insert Table 1 here

133

134 *Design*

135 Following a four-week baseline training and familiarization phase consisting of three resistance
136 training sessions per week, players were assessed for peak power outputs during a bodyweight
137 countermovement jump (BWCMJ), bodyweight squat jump (BWSJ), 50-kg countermovement
138 jump (50CMJ), 50-kg squat jump (50SJ), depth jump (DJ) and broad jump (BJ). Players were
139 then matched on playing position and BWCMJ power and were randomly allocated to either the
140 strength-power or speed-power training group. Each group completed a four week training

141 intervention consisting of two training sessions per week and were then reassessed at the end of
142 the training intervention. Power was assessed using the countermovement jump, squat jump, DJ
143 and BJ exercises. These exercises were selected due to their common usage in power training
144 programs and research studies and their ability to represent lower-body power.^{3,11-13}
145 Additionally, these exercises were selected as they provide a ‘profile’ of the specific areas of
146 power production, i.e. loaded and unloaded, inclusion or exclusion of stretch shortening cycle,
147 vertical and horizontal axis, and tendon compliancy.¹⁴ Peak power was selected as the dependent
148 measure as it has been reported to have the greatest association with athletic performance.¹⁵

149

150 *Methodology*

151 In order to characterize the training level of the subject, each player was assessed for maximal
152 lower-body strength using the box squat exercise. Briefly, each player was required to perform
153 three sets (50%, 70%, 90% effort, two-six repetitions) of sub-maximal box squat followed by
154 one set to failure of one to four repetitions. During the box squat, players used a self-selected
155 foot position, and were required to lower themselves to a sitting position briefly on the box and
156 then return to a standing position. The box height was adjusted for each player to allow the top of
157 the thighs to be parallel to the floor while in the seated position.^{3,10} Three minutes rest was
158 allowed between each set. Each set to failure was used to predict the players’ one repetition
159 maximum (1RM).^{16,17}

160

161 Players performed two repetitions of BWCMJ, BWSJ, 50CMJ, 50SJ, DJ and BJ. Each jump was
162 performed on a commercially available portable force plate (400 Series Performance Force Plate,
163 Fitness Technology, Australia). For all jumps, no arm swing was allowed, the only exception
164 being the BJ in which an arm swing was permitted. A position transducer (PT5A, Fitness
165 Technology, Australia) was connected to a broomstick (vertical bodyweight jumps) or Olympic
166 weightlifting bar (vertical weighted jumps) and was held across the posterior deltoids at the base
167 of the neck. For the BWSJ and 50SJ players lowered themselves to approximately 90° flexion of
168 the knee, paused for three seconds and then jumped on the command “go”.¹⁴ BWCMJ and
169 50CMJ were performed in the same manner with no pause between eccentric and concentric
170 movements. The DJ consisted of participants standing on a box 30 cm above the force plate,
171 stepping off the box and attempting to jump as quickly and as high as possible after foot contact
172 (players were given the instructions to pretend that the force plate was “very hot” to minimize
173 contact time on the force plate). The DJ score was determined by dividing the jump height by the
174 contact time and will be referred to as the reactive strength index (RSI) from herein.^{18,19} The BJ
175 was performed without the use of the force plate, and players were permitted the use of arm
176 swing and were instructed to jump horizontally for maximal distance from a stationary position.
177 Broad jump distance was measured as the distance from the front of the toes prior to take off, to
178 the back off the heel on landing. The testing protocol was performed seven days prior to the
179 beginning of the first training session. All players had been familiarized with the testing battery
180 prior to testing.

181

182 Both the force plate and position transducer were interfaced with computer software (Ballistic
183 Measurement System, Fitness Technology, Australia) that allowed direct measurement of force-
184 time characteristics (force plate) and displacement-time and velocity-time (position transducer)
185 variables as outlined by Dugan and colleagues.¹⁵ The best value for each jump type was used for
186 analysis.

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Training

It has been previously reported that performance gains in a pre-season training phase may essentially be a return to prior fitness levels.¹⁰ Therefore, as this investigation commenced during the pre-season training phase, all players underwent a monitored four week base training phase to ensure that they were in a well-trained state prior to the beginning of the training intervention. The base training phase consisted of two 60 min rugby training sessions per week, three 45-60 min conditioning training sessions per week, one strength and plyometrics session (strength, 3-4 sets x 2-6 RM, 3 min rest for 4-6 exercises; plyometrics, 3 sets x 4 reps, 3 min rest for 3 exercises); one hypertrophy session (4 sets x 8-12 RM, 90 s rest for 5 exercises); and a circuit training session (6-12 reps, 30 s rest for 10 exercises, 30 min duration). On the final week of the base training phase, all players were assessed for the maximum load that could be lifted for 2-4 repetitions in all the training exercises used in the intervention (except for sled sprint whereby a standardized load was used during the intervention phase²⁰). The maximal 2-4 repetition testing allowed specific intensities and loads based on 1RM to be set for each individual during the intervention phase.

The intervention phase consisted of either a strength-power or speed-power resistance training performed twice a week for four weeks during the competition phase of the season (Table 2, Table 3). Each program included a tapering of loading (higher force early in the week, higher velocity later in the week). All the training sessions for the strength-power intervention were performed at a greater percent of 1RM than the speed-power intervention. For both interventions, exercises in the first training session were performed at a greater percent of 1RM, while exercises in the second training session were performed at a lower percent of 1RM. The exercises in each training group (i.e. strength-power and speed-power training) were matched for similar movement patterns e.g. concentric focus, bilateral exercise. Therefore the major difference between each group was the load used, which based on the force-velocity relationship influenced the muscular forces and movement velocity that could be produced during the exercises. Players were instructed to perform all exercises as explosively as possible, with maximal intent.

Insert Table 2 here

Insert Table 3 here

Additional Training

In addition to the training described above, players also performed three upper body resistance exercises (85-95% 1RM, three sets of four repetitions) during session 1. During session 2 players performed two upper body resistance exercises in a ballistic fashion (40-60% 1RM, three sets of four repetitions). Players also performed one speed development session with low resistance (20-30 min, including fast foot ladders, mini hurdles, maximal sprinting, over-speed sprinting), three team training sessions (30-75 min, including specific rugby skill, tactical, tackling, etc), one competitive match, and one recovery session (20-40 min, including light exercise, stretching, hot and cold baths) each week.

Statistical Analysis

232 All outcome measures i.e. peak power, reactive strength index and broad jump distance are
233 presented as mean \pm standard deviation. All data were log-transformed to reduce non-uniformity
234 of error, and the effects of the training phase were derived by back transformation as percent
235 changes.²¹ Standardized changes in the mean of each measure were used to assess magnitudes of
236 effects by dividing the changes by the between-player standard deviation. Standardized changes
237 of 0.00-0.19; 0.20-0.59; 0.60-1.19; and ≥ 1.20 were interpreted as trivial, small, moderate, and
238 large effects, respectively,²² a modification of Cohen's thresholds of 0.2, 0.5, and 0.8.²³ To make
239 inferences about true (large-sample) value of an effect, the uncertainty in the effect was
240 expressed as 90% confidence limits. The effect was deemed unclear if its confidence interval
241 overlapped the thresholds for small positive and negative effects.²³ To gain insight into the
242 relative influence of the force and velocity components to the improvements in jump power,
243 subsequent analysis of peak force and velocity data was then completed for measures that
244 responded favorably to the training. Finally, correlational analysis was performed to assess the
245 possibility of the difference in baseline strength affecting the magnitude of change in power. The
246 kinetic and kinematic variables measured in this investigation have been shown to have good
247 test-retest reliability ($R \leq 0.95$; $CV < 3.5\%$) when similar testing procedures were used with a
248 comparable population.^{14,24}

249

250 Results

251 Baseline data for all measures are presented in Table 4. Both training groups were reasonably
252 well matched for baseline scores with between-group differences reaching small magnitudes for
253 the BWSJ and 50SJ only.

254

255 Insert Table 4 here.

256

257 Inferences about the effect of each training program are shown separately (percent change) and
258 comparatively (percent effect) in Table 5. There were smaller mean changes and larger standard
259 deviations in the speed-power group for the 50CMJ, 50SJ, and RSI exercises which suggests that
260 there were negative responders. Relative to the changes in the speed-power group, the strength-
261 power group produced small increases in 50CMJ (410 W; 90% confidence limits, ± 380 W), 50SJ
262 (360; ± 480 W) and BJ (4; ± 7 cm). Alternatively, unclear between-group differences were
263 observed in BWCMJ, BWSJ and RSI (Table 5).

264

265

266 Insert Table 5 here

267

268 Next, changes in peak force and velocity data were assessed in measures that responded
269 favorably to training (i.e. 50CMJ, 50SJ). Following the strength-power training, peak force
270 improved by 12.1% ($\pm 19\%$; small) and 26% ($\pm 22\%$; large) in the 50CMJ and 50SJ,
271 respectively. Only trivial improvements in peak force were observed for any of the measures in
272 the speed-power group. A small increase in peak velocity was observed in the strength-power
273 group for the 50CMJ ($4.5 \pm 7.7\%$); whilst a small decrease in peak velocity occurred in the
274 speed-power group in the 50SJ ($-2.1 \pm 4.6\%$).

275

276 Correlations between baseline strength and the magnitude of the change in 50CMJ and 50SJ
277 power ranged from $r=0.17$ to $r=-0.16$ suggesting that up to 3% of the variation in the change in
power was due to differences in baseline strength. However, moderate correlations between

278 baseline squat strength and change in 50CMJ were observed for force ($r=-0.53$) and velocity
279 outputs during the 50CMJ ($r=-0.37$); suggesting that up to 29% and 14% of the change in force
280 and velocity outputs could be explained by differing baseline strength levels. Only trivial
281 correlations were observed between squat strength and change in 50SJ force and velocity.
282 Finally, the correlation between baseline strength and change in BJ distance was $r=-0.30$,
283 explaining up to 9% of the variation of the change in BJ.

284
285 In addition to maximal lower-body strength being assessed prior to the training program so that
286 training intensities could be set; lower-body strength was also assessed by the conditioning coach
287 in eight players from the strength-power program, and four players from the speed power
288 program following the four week training phase. A small increase of 4.8%; ($\pm 13\%$) was
289 observed in the 12 players assessed. Athletes in the strength-power program increased strength
290 by 3% ($\pm 17\%$), while speed-power program athletes improved by 8% ($\pm 3\%$).

291 292 **Discussion**

293 Findings from the current investigation suggested that the strength-power program was superior
294 to the speed-power program, resulting in larger and more uniform improvements in various
295 measures of lower body power. The strength-power program also successfully improved power
296 in a greater number of performance measures; whilst the speed-power program only resulted in a
297 small increase in a single measure. However, this single improvement for the speed-power
298 program was less than that in the strength-power program.

299
300 Previous investigations examining changes in lower body power during a competitive season in
301 the rugby codes have reported maintenance at best.^{2,3} Argus and colleagues³ reported a small
302 3.3% decrease, while Baker² reported a trivial 0.3% increase in weighted countermovement jump
303 power. However, attempting comparisons between the current and previous investigations^{2,3} has
304 several limitations. Firstly, the current investigation only consisted of a short phase at the start of
305 a competitive season. Secondly, the specific detail of the resistance training programs used in the
306 previous investigations was not fully reported. Future research should attempt to monitor
307 changes over a longer competitive phase of the season using similar programming strategies to
308 allow for more detailed comparisons. Nonetheless, the strength-power training program in the
309 current investigation resulted in moderate improvements in both weighted countermovement
310 jump power (12%) and weighted squat jump power (11%).

311
312 Strength-power training was superior to the speed-power training program resulting in larger
313 improvements in a greater number of measures of jump performance. In contrast, McBride and
314 colleagues⁹ who investigated the effects of training with heavy (80% 1RM) or light (30% 1RM)
315 jump squats reported that light jump squat training improved performance in a greater number of
316 measures than heavy jump squat training. Harris and colleagues⁴ reported improvements in a
317 greater number of performance measures following a high power training program when
318 compared to a high force program. Although in both investigations^{4,9} the higher load group
319 improved to a greater extent in high force output measures (1RM values), whereas the lower
320 load group showed the greatest improvement in higher velocity-related movements. Differences
321 in methodology, including the length of the intervention period and utilization of the contrast
322 training method may help to explain some of the variation between the current investigation and
323 previous literature.^{4,9} Additionally, the current investigation did not attempt to match training

324 volume. As such, unequal resistance training volume between the strength-power and speed-
325 power groups may be responsible for the differences observed. Although the resistance training
326 volume performed can not be accurately determined post training due to some of the exercises
327 performed (e.g. sled sprints and bodyweight exercises), and force outputs or repetition
328 contraction time not measured during training; it is likely that the strength-power group
329 performed a greater training volume. Indeed Crewther and colleagues²⁵ reported that when
330 repetitions are performed with maximal intent, as in the current study, an increase in load of 10%
331 results in a 14% increase in time under tension (TUT) and 15% increase in work done. The
332 participants in the strength power group performed on average 25% 1RM greater intensity than
333 the speed-power group during the four week intervention (although bodyweight exercises and
334 sled pulls could not be accounted for in this calculation). Therefore the greater intensity
335 performed in the strength-power group would have resulted in approximately 35% greater TUT
336 and 38% more work done and may be the differentiating factor between the two training
337 programs. In the investigation by McBride and colleagues⁹ discussed above, participants in the
338 light jump squat group performed an additional set of jumps in an attempt to equate overall
339 workloads over the training period. The equal-volume training load may help to explain the
340 performance improvements observed by McBride and colleagues⁹ in both the heavy and light
341 jump squat training groups.

342
343 The greatest improvement in performance measures for the present study were observed in the
344 weighted jumps. Tuomi and colleagues²⁶ suggested that initial performance adaptations during
345 combined training methods have a greater effect on higher force rather than lower force
346 producing activities. Additionally, previous authors have reported that heavier resistance training
347 results in greater improvements to the higher end of the force-velocity curve while lighter
348 resistance training result in improvements in the lower end.^{4,9} Training intensities for the
349 strength-power program in session one ranged from 80% to 98% 1RM which emphasizes the
350 higher end of the force-velocity curve. The strength-power program also trained with intensities
351 ranging from 45-55% 1RM during session two which was slightly heavier than the testing
352 weight. It is likely that the higher training load performed by the strength-power group resulted
353 in a greater adaptation in the weighted jumps due to the greater volume of training performed at
354 similar resistances. Attempting to move large external loads may induce a number of adaptations
355 including an increase in contractile force which may be realized through increased neural
356 activation, reduced co-activation as well as a number of muscle architectural or fiber size
357 adaptations.^{5,27-29} Therefore, training with greater resistance regularly, as in the strength-power
358 program, may have provided an increased neuromuscular stimulus resulting in greater
359 performance benefits. Likewise, the lack of improvement in the weighted jump measures in the
360 speed-power program may have been due to inadequate exposure to higher loads. The speed-
361 power program only trained with moderate to heavy loads (55% to 70% 1RM) once a week,
362 whilst the second session was performed using loads from bodyweight to 35% 1RM. As such,
363 training with only one heavier stimulus each week appears to be inadequate for performance
364 improvements in measures which require higher force production.

365
366 Similarly, the lack of improvement in the bodyweight jumps (excluding broad jump) in both
367 programs may have been due to the insufficient total volume or stimulus of the jump training
368 performed. It has been suggested that improvements in activities requiring greater velocity (i.e.
369 bodyweight or low resistance plyometrics) may need a longer training period or greater training

370 volume for adaptations to present.^{12,26} In a recent meta-analysis, de Villarreal and colleagues¹²
371 reported that training volumes of more than ten weeks maximize the probability of obtaining
372 significantly greater improvements in bodyweight vertical jump performance. De Villarreal and
373 colleagues¹² reported that for optimal improvements in bodyweight vertical jump performance,
374 training programs should include 50 contacts twice a week (100 total). In the current
375 investigation, neither program performed 100 contacts per week. The strength-power program
376 performed between 38-52 contacts each week while the speed-power program performed
377 between 49-56 contacts per week. It appears that the total volume of contacts may have been
378 inadequate to produce improvements in bodyweight vertical jump performance. The volume of
379 contacts performed in the current study was limited by the players' strength and conditioning
380 coach. The players were not accustomed to performing 100 jump contacts within their resistance
381 training sessions, and it was deemed that the increased jump volume may have had potential for
382 injury. All jump exercises had been regularly performed by the players in a contrast or complex
383 training method within their normal training programs for at least 12 months prior to the
384 investigation. As such, the continual performance of the bodyweight jump without any
385 significant increases in intensity or training stress would likely have only maintained
386 performance.

387
388 The athletes in the current investigation performed resistance training in addition to several
389 different training modes. Power development may be compromised by higher volumes of
390 training performed (i.e. during concurrent training); where as high force development may be
391 less affected^{2,30}. Indeed, in two separated investigations Argus and colleagues^{3,10} reported that
392 power development was more affected than strength (high force) development during a pre-
393 season and in-season training phase where concurrent training was performed. Although the
394 50kg jumps performed in the current investigation were not a strength task; jumping with
395 additional loads produces greater force output than with bodyweight alone (add reference which
396 im getting from library @\$@\$). Based on previous findings it may be speculated that the higher
397 force producing weighted jumps may have been less affected by the higher volume of concurrent
398 training performed. Therefore, the current investigations intervention period and contact volume
399 may not have been an adequate stimulus for improvements to be made in bodyweight vertical
400 jump measures. Additionally, the concurrent training performed by the participants may have
401 affected the higher velocity (bodyweight) jumps more so than the higher force producing
402 weighted jumps.

403
404 The speed-power program resulted in smaller mean changes with larger standard deviation for
405 the 50CMJ, 50SJ exercises and the RSI. These findings suggest that some individuals actually
406 had performance decrements over the four week training period. There were no similarities in
407 baseline characteristics (e.g. high power output) between the responders and non-responders to
408 explain the variability in the change of performance to the same training program. One
409 mechanism proposed by Beaven and colleagues³¹ suggested that players have differing
410 individual hormonal responses to a single resistance training session. Additionally, when players
411 trained using resistance training that elicited the greatest testosterone response, significant
412 improvements in strength occurred. Conversely, when players trained using resistance training
413 that produced the smallest testosterone response, 75% of players showed either no change or a
414 significant decline in 1RM performance.³² Further research is still required to determine
415 individual response to a training program.

416
417 Both programs produced small improvements in broad jump distance. Interestingly, neither of
418 the programs included any jumps in the horizontal plane, the only possible exceptions being the
419 weighted sled sprints. The players in the current investigation had traditionally performed
420 vertically dominated plyometric training, and thus minimal horizontal plyometric training prior
421 to this investigation. The small amount of horizontal training (weighted sled sprints) performed
422 by the two programs may have been adequate to elicit improvement in broad jump distance due
423 to the relatively unfamiliar stimulus. In conjunction with the weighted sled training, transference
424 of training adaptation from horizontal training performed during the players' additional rugby
425 trainings (e.g. scrimmaging, mauling) may have also provided stimulus for adaptation to occur.
426 Indeed, if there had been a greater focus on horizontal power within the program there may have
427 been greater increases in the broad jump for both groups and a potential between-group
428 difference in response.

429
430 Although it has been suggested that the ability to develop high levels of muscular power is
431 critical for successful performance in many sports;⁴ maximal strength is also important in most
432 contact sports.² For most athletes and conditioning coaches, improving maximal strength will be
433 one of the performance goal priorities of the program. As such it should be noted that maximal
434 box squat strength was assessed by the player's strength coach prior to and following the
435 intervention phase in a total of 12 of the players participating in this investigation (eight strength-
436 power, four speed-power). A small increase of 4.8%; ($\pm 13\%$) was observed in the 12 players
437 assessed. Athletes in the strength-power program increased strength by 3% ($\pm 17\%$), while
438 speed-power program athletes improved by 8% ($\pm 3\%$).

439 440 **Practical Applications**

441 Performing heavy combined training twice a week is an effective method for improving a range
442 of jump performance measures in high-level rugby union players over a four week competitive
443 phase. Our findings suggest that improvements in jump performance can be made in team sport
444 athletes during the competitive season when athletes are exposed to higher volume-load stimuli.
445 Indeed, the use of heavier resistance combined training (strength-power) produced larger
446 improvements in a greater number of performance measures than similar programming
447 performed with lighter resistances. For practitioners and athletes who regularly compete once a
448 week during the competition phase, the use of high force combined training consisting of
449 contrast training with a heavy day and lighter day is an effective way to make improvements in
450 performance over a short training phase during the competitive season. Finally, a greater volume
451 of lower resistance plyometric training may be required for athletes to enhance vertical
452 bodyweight jump performance.

453 454 455 **References**

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534 **Table 1.** Characteristics of high-level rugby union players in two separate training groups. Data
535 are mean \pm SD.

536
537 **Table 2.** Outline of lower body resistance training exercises in two separate lower body
538 resistance training programs (strength-power & speed power) in two groups of high-level rugby
539 union players during a competition training phase.

540
541 **Table 3.** Specific intensities and repetitions followed in two separate lower body resistance
542 training programs (strength-power & speed-power) in two groups of high-level rugby union
543 players during a competition training phase.

544
545 **Table 4.** Baseline values (mean \pm SD) produced during different jumps in two separate groups of
546 high-level rugby union players during a competition training phase.

547
548 **Table 5.** Percent change (mean \pm SD) and percent effect (difference; \pm 90% confidence limits)
549 produced during different jumps following four weeks of lower body resistance training in two
550 separate groups (strength-power & speed-power) of high-level rugby union players during a
551 competition training phase.

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Table 1. Characteristics of high-level rugby union players in two separate training groups. Data are mean \pm SD.

	Strength-power (n=9)	Speed-power (n=9)
Age (y)	23 \pm 2	25 \pm 2
Height (cm)	186 \pm 1	187 \pm 1
Weight (kg)	99 \pm 10	102 \pm 9
Box squat 1RM (kg)	160 \pm 27	176 \pm 17

RM, repetition maximum.

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Table 2. Outline of lower body resistance training exercises in two separate lower body resistance training programs (strength-power & speed power) in two groups of high-level rugby union players during a competition training phase.

Exercise	Strength-power		Speed-power	
	Session one	Session two	Session one	Session two
1	Box squat (heavy)	Jump squat (heavy)	Box squat (light)	Jump squat (light)
2	10-m sled sprint (120 kg) [#]	10-m sled sprint (30 kg) [#]	10-m sled sprint (30 kg) [#]	10-m sprint [#]
3	Deadlift	Power clean	½ Rack squat	90° Static jump*
4	20-kg box jump	High box depth jump*	Assisted jump*	Low box depth jump*

*bodyweight exercise (repetitions 4,4,4); [#] repetitions 1 x 10 m x 4 sets. Exercises 1 and 2, along with exercises 3 and 4 were performed using the contrast training method.

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Table 3. Specific intensities and repetitions followed in two separate lower body resistance training programs (strength-power & speed-power) in two groups of high-level rugby union players during a competition training phase.

Week	Repetitions	Strength-power		Speed-power	
		Session 1 (%1RM)	Session 2 (%1RM)	Session 1 (%1RM)	Session 2 (%1RM)
1	6, 6, 4, 4	80-90	40-45	55-60	20-25
2	4, 4, 3, 2	90-95	45-50	60-65	25-30
3	4, 3, 3, 2	95-98	50-55	65-70	30-35
4	4, 4, 3, 2	90-95	45-50	60-65	20-25

RM, repetition maximum.

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Table 4. Baseline values (mean \pm SD) produced during different jumps in two separate groups of high-level rugby union players during a competition training phase.

	Strength-power	Speed-power
BWCMJ (W)	6560 \pm 820	6740 \pm 930
BWSJ (W)	6650 \pm 840	6390 \pm 660
50CMJ (W)	5440 \pm 990	5530 \pm 660
50SJ (W)	5280 \pm 920	5050 \pm 490
RSI (m.s ⁻¹)	1.83 \pm 0.27	1.86 \pm 0.30
BJ (cm)	252 \pm 22	253 \pm 19

SD, standard deviation; BWCMJ, bodyweight countermovement jump; BWSJ, bodyweight static jump; 50CMJ, 50-kg countermovement jump; 50SJ, 50-kg static jump; RSI, reactive strength index; BJ, broad jump.

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Table 5. Percent change (mean \pm SD) and percent effect (difference; \pm 90% confidence limits) produced during different jumps following four weeks of lower body resistance training in two separate groups (strength-power & speed-power) of high-level rugby union players during a competition training phase.

	Strength-power (%)	Speed-power (%)	Strength-speed difference* (%)
BWCMJ	1.6 \pm 3.1 trivial	0.8 \pm 3.4 trivial	0.8; \pm 4.3 unclear
BWSJ	-1.4 \pm 4.2 trivial	0.4 \pm 4.0 unclear	-1.9; \pm 5.5 unclear
50CMJ	11.7 \pm 6.5 moderate	3.1 \pm 4.8 trivial	7.7; \pm 7.7 small
50SJ	11.2 \pm 5.6 moderate	4.4 \pm 9.6 unclear	6.9; \pm 9.7 small
RSI	0.8 \pm 5.8 unclear	3.4 \pm 19.1 unclear	-2.6; \pm 22.8 unclear
BJ	3.6 \pm 2.5 small	1.8 \pm 1.5 small	1.7; \pm 2.8 small

SD, standard deviation; BWCMJ, bodyweight countermovement jump; BWSJ, bodyweight static jump; 50CMJ, 50-kg countermovement jump; 50SJ, 50-kg static jump; RSI, reactive strength index; BJ, broad jump. *change in strength-power group compared to change in speed-power group.

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