The effects of superset configuration on kinetic, kinematic, and perceived exertion in the barbell bench press

Running Head: Superset configuration and kinetic, kinematic, and perceived exertion

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1 **ABSTRACT**

2 Training that is efficient and effective is of great importance to an athlete. One method of

3 improving efficiency is by incorporating supersets into resistance training routines. However,

4 the structuring of supersets is still unexplored. Therefore, the purpose of this study was to

5 assess the effects of agonist-antagonist (A-A), alternate peripheral (A-P), and similar

6 biomechanical (SB) superset configurations on rate of perceived exertion (RPE), kinetic and

7 kinematic changes during the bench press. 10 subjects performed resistance training protocols

8 in a randomized-crossover design, with magnitude-based inferences assessing

9 changes/differences within and between protocols. Changes in RPE were *very likely* and

10 *almost certainly* greater in the A-P and SB protocols when compared with the A-A, while all

11 superset protocols had *very likely* to *almost certain* reductions in mean velocity and power

12 from baseline. Reductions in mean velocity and power were almost certainly greater in the

13 SB protocol, with differences between the A-A and A-P protocols being *unclear*. Decreases

14 in peak force were *likely* and *almost certain* in the A-A and SB protocols respectively, with

15 changes in A-P being *unclear*. Differences between these protocols showed likely greater

16 decreases in SB peak forces when compared to A-A, with all other superset comparisons

17 being *unclear*. This study demonstrates the importance of exercise selection when

18 incorporating supersets into a training routine. It is suggested that the practitioner uses A-A

19 supersets when aiming to improve training efficiency and minimize reductions in kinetic and

20 kinematic output of the agonist musculature while completing the barbell bench press.

21

22 **Key words:** Perceived exertion; velocity; power; force

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24

INTRODUCTION

Resistance training is a well-established method of improving muscular strength, power, and hypertrophy (9, 28). Resistance training has been shown to be a safe method of training in athletes (14, 24), and can reduce the risk of injury when appropriately implemented (15). However, athletes are often unable to commit large periods of time to resistance training due to other training requirements (e.g. skill development, conditioning, team practice) and the large amount of variability within a training week (40). Therefore, it is important that training is time efficient. One method that has been shown to enhance resistance training efficiency while maintaining efficacy is the application of resistance training supersets (SS) (29). This method refers to the grouping of exercises so that two different exercises are completed consecutively, followed by a rest period (e.g. a squat and bench press followed by a rest interval). By strategically removing recovery between sets, reductions in training time have been shown to occur while training volume (e.g. total amount of weight lifted (Kg)) is maintained (30, 41).

Within the literature (31), three forms of SS configuration have been defined, with agonist-antagonist (A-A) pairings (e.g. bent-over row and bench press) being the most commonly investigated (4, 5). Nevertheless, alternate peripheral (A-P) (e.g. back squat and bench press) and similar biomechanical (SB) movements (e.g. dumbbell bench press and barbell bench press) have also been examined (7, 41). However, these different exercise groupings have not been compared despite evidence suggesting conflicting resistance training outcomes (e.g. in the bench press throw exercise, A-A pairings caused acute increases of 4.7% in mean power output (4), while SB demonstrated acute decreases in peak velocity of 10.7% (33)). Consequently, the effect of SS configuration on resistance training is still unknown.

1

2   While SS are known to improve training efficiency (41), neuromuscular function may be

3   impacted when using this method. Previous research (27, 28) has shown the importance of

4   maintaining high levels of kinetic (e.g. force) and kinematic (e.g. velocity and power) outputs

5   when aiming to develop muscle size, strength, and power. However, Weakley et al. (41) has

6   demonstrated that SS may cause greater losses in these variables when compared to

7   traditional (i.e. one exercise set followed by a rest) resistance training. It was shown that SS

8   can cause large reductions in lower body power (e.g. countermovement jump height) 24

9   hours post training (effect size (ES) ±90% confidence interval (90% CI); SS: -0.29 ± 0.19 vs.

10 traditional: 0.01 ± 0.19), with these changes attributed to increased metabolic perturbation

11 causing reduction in force-generating capabilities. Furthermore, these reductions in

12 neuromuscular function were also accompanied by increased rating of perceived exertion

13 (RPE) (41). These increases in RPE have shown near perfect relationships with metabolic

14 responses (41) and may provide additional insight into kinematic changes when resistance

15 training (34). However, it has previously been postulated that by manipulating SS exercise

16 order and exercise selection, kinetic, kinematic, and RPE outcomes may be positively

17 affected (4). These changes have been suggested to occur due to changes in motor unit

18 recruitment (3), varying rates of localized muscle fatigue (7), and / or alterations in the

19 triphasic neural pathways (4). Nevertheless, further research is still required to assess the

20 influence of varying SS configurations on neuromuscular outcomes.

21

22 Existing research has assessed the effects of differing forms of SS on bench press kinetic and

23 kinematic outputs (4, 30, 32), RPE (5, 41), and resistance training volume (5, 30). However,

24 no study has compared the effects of these different forms of SS configuration on bench press

25 outcomes when resistance training. Furthermore, it is unknown whether these different

1 arrangements of SS alter perceptions of perceived exertion. Therefore, due to the importance

2 of kinetic and kinematic outputs when training to develop muscle size, strength, and power

3 (27, 28), the aim of this study was to assess the effects of differing SS arrangement on

4 kinetic, kinematic, and RPE changes during the bench press exercise.

5

6 **METHODS**

7 **Experimental approach to the problem**

8 To assess the effects of three different forms of SS arrangement on kinetic, kinematic, and

9 RPE outcomes in the barbell bench press, 10 sub-elite adult rugby union players completed

10 four exercise protocols in a randomized-crossover design, with at least 7 days between each

11 testing session. The four resistance training protocols consisted of one set of the barbell

12 bench press followed by a five minute recovery period then either; 1) control (CON): three

13 further sets of the barbell bench press with a two minute recovery period between sets; 2) A-

14 A: three SS of the bent-over row and the barbell bench press with two minute rest periods; 3)

15 A-P: three SS of the back squat and the barbell bench press with two minute rest periods; 4)

16 SB: three SS of the dumbbell bench press and the barbell bench press with two minute rest

17 periods. All repetitions were completed without assistance. Exercises were completed at 65%

18 of three repetition maximum (3RM) as this intensity has been found to be near maximal when

19 performing SS (33) and has previously been utilized in literature investigating this training

20 method (41). A linear position transducer (GymAware, Kinetic Performance Technology,

21 Canberra, Australia) was used to record kinetic and kinematic outcomes due to their

22 importance while resistance training (28), while RPE was reported 15 minutes after the

23 completion of each protocol owing to its validity as an internal measure of training load and

24 relationship with metabolic outcomes (17, 41).

25

1

2 **Subjects**

3 10 male rugby players (mean ± standard deviation (SD); age: 20.9 ± 9.6 years; height: 183.2

4 ± 6.1 cm; body mass: 90.2 ± 9.6 kg; 3RM barbell bench press: 114.3 ± 10.3 kg; 3RM back

5 squat: 139.7 ± 27.9 kg; 3RM bent-over row: 101.1 ± 12.0 kg; 3RM dumbbell bench press:

6 87.5 ± 11.6 kg), who had at least two years resistance training experience (3.9 ± 1.2 years)

7 were recruited from a university rugby union team from the United Kingdom. Testing took

8 place in February (which is within the second half of the university rugby playing calendar).

9 All subjects confirmed that they did not have any current injuries, have not or do not

10 consume any medications or supplements that could influence performance, and that they

11 were not suffering from any diseases. Subjects were explained the design of the study,

12 provided an opportunity to ask questions and then provided informed written consent. All

13 experimental procedures were approved by Leeds Beckett University's ethics committee and

14 written assent was provided by all subjects.

15

16 **Experimental Procedures**

17 All testing was conducted at the same time of day one week apart, with subjects being asked

18 to refrain from physical activity for the 48 hours prior to all testing procedures. Subjects were

19 instructed to maintain normal dietary habits in the 24 hours prior to testing, with caffeine not

20 being consumed in the 12 hours before. All subjects were screened prior to acceptance into

21 the study (38), followed by anthropometric and 3RM strength assessment of the barbell bench

22 press, back squat, bent-over row, and dumbbell bench press. Subjects were randomized to

23 complete four testing sessions (i.e. CON, A-A, A-P, and SB) with session order designated

24 through computer-generated random numbering (37). All exercise protocols consisted of a

25 standardized warm-up, which consisted of dynamic movements and exercise specific

1 stretches, and a set of 10 repetitions of the bench press at 65% of 3RM performed as

2 explosively as possible prior to the experimental trials (i.e. CON, A-A, A-P, and SB). This

3 indicated the subject's baseline performance on that day. After a five-minute recovery period,

4 subjects then completed their scheduled protocol. During all repetitions and sets of the barbell

5 bench press, a linear position transducer (Kinetic Performance Technology, Canberra,

6 Australia) was attached which calculated peak force (i.e. the highest force value recorded

7 between two sampling points) and mean velocity and power (i.e. the overall velocity and

8 power output across the whole concentric range of motion) (19). These variables were used

9 due to their high level of reliability and validity (i.e. coefficient of variation <5% (6)) and

10 previous use in the barbell bench press (10). Following all exercise protocols RPE was

11 reported using a modified Borg category ratio-10 scale (16)

12

13 *3RM strength assessments testing*

14 The assessment of 3RM strength was completed as this is regularly used within similar

15 cohorts and has been used in the prescription of SS training methods (39-41). 3RM strength

16 testing of the barbell bench press, back squat, bent-over row, and dumbbell bench press was

17 completed during a familiarisation session after acceptance into the study. These exercises

18 were chosen due to the subjects' familiarity with these movements and their previous use in

19 rugby union research (11, 39, 40). 3RM strength of each exercise was assessed using the

20 following protocols which have previously been used to assess strength (39-41). The bench

21 press was completed with hand position at a self-selected width which was recorded and

22 replicated across conditions. The bar was lowered to the chest and returned to a locked-out

23 position to complete the repetition. The back squat was completed with the bar resting on the

24 upper trapezium with subjects required to lower themselves so that the top of the thigh was

25 parallel with the floor; as determined by the lead researcher. The bent-over row was

1 completed with an overhand grip which raised the bar to the lower sternum; while the torso

2 was maintained parallel to the ground. The dumbbell bench press begun with the subject

3 lying flat on a bench with the arms holding both dumbbells so that the elbow was at a 90-

4 degree angle. The arms were extended so that the dumbbells were directly over the subject's

5 chest and then returned to the start position.

6

7 *Superset and control protocols*

8 All protocols used the barbell bench press as an outcome measure, with SS protocols

9 requiring the completion of an exercise immediately prior, while the CON protocol

10 completed a single set of the bench press. All exercises (i.e. barbell bench press, back squat,

11 bent-over row, and dumbbell bench press) were loaded with a weight that was 65% of 3RM.

12 This intensity was selected for the protocols as it has previously been established that when

13 completing SS, intensities above this cause notable losses in repetition completion (i.e.

14 12.5%) (33). Furthermore, this is consistent with recent literature (41) which has investigated

15 the physiological responses of rugby union players. Each repetition required subjects to

16 complete a two second eccentric action, while the concentric portion of each exercise was

17 required to be as "forceful and as powerful as possible" (18, 28). Furthermore, each exercise

18 consisted of three sets of 10 repetitions, apart from the barbell bench press which had a fourth

19 set that was completed at baseline.

20

21 *Kinematic and Kinetic Assessment*

22 Assessment of mean velocity, mean power, and peak forces of the bench press were recorded

23 with a GymAware® optical encoder which sampled at 50Hz (Kinetic Performance

24 Technology, Canberra, Australia). The optical encoder, which was placed directly below the

25 barbell bench press exercise, contains a retractable cord that was attached to the barbell

1   during each set for each subject. Velocity and displacement are calculated from the rotation

2   of a pulley system within the optical encoder upon the movement of the barbell during the

3   exercise (2). The encoder, which has previously been assessed as highly valid for reporting of

4   velocity, power, and force (6), provides approximately one electrical impulse every three

5   millimetres of barbell displacement with each value time stamped with a one-millisecond

6   resolution. To assist in the calculation of the variables (i.e. power and force), barbell mass

7   and additional weight are inputted by the lead researcher before each trial (2, 12).

8

9   *RPE Measures*

10   Subjects were asked to rate their perceived exertion 15 minutes after each resistance training

11   protocol after being asked the question "How was your workout?". Subjects were supplied

12   the modified-Borg Scale and verbally indicated an answer which was recorded. This has

13   previously been shown to have a high level of reliability in differing resistance training

14   protocols (36).

15

16   **Statistical analyses**

17   Data are presented as either mean $\pm$ SD or percentage/effect size (ES) $\pm$ 90% confidence

18   intervals (90% CI) where specified. Prior to analysis, all data were log-transformed to reduce

19   bias arising from non-uniformity error, and then analysed for practical significance using

20   magnitude-based inferences (21). The chance of the RPE, mean concentric velocity, power,

21   or peak force being lower, similar, or greater than the smallest worthwhile change/difference

22   (SWC/D) (i.e. 0.2 x between subject difference) was calculated using an online spreadsheet

23   (23), with all between group comparisons of effects being further analysed using a separate

24   spreadsheet (22). The probability that the magnitude of change was greater than the SWC/D

25   was rated as <0.5%, *almost certainly* not; 0.5-5%, very un*likely*; 5-25%, un*likely*; 25-75%,

1   possibly; 75-95%, *likely*; 95-99.5%, *very likely*; >99.5%, *almost certainly* (21). Where the

2   90% Confidence Interval (CI) crossed both the upper and lower boundaries of the SWC

3   (ES±0.2), the magnitude of change was described as *unclear* (21). ES thresholds were set at

4   <0.2 (*trivial)*, 0.2-0.6 (*small*), 0.6-1.2 (*large)*, and 1.2-2.0 (*very large*) (21).

5

6   **RESULTS**

7

8   Data are presented for mean (±SD) concentric velocity, power, and concentric peak force

9   (Table 1) of the barbell bench press in the CON and three SS protocols. Also provided are the

10 ES (±90%CI), inference of change from baseline, and between condition comparison of ES

11 change from baseline to set three (ES ±90%CI and inference) across all conditions.

12

13   ***Insert table 1 here***

14

15 RPE (mean ± SD) in the CON (2.9 ± 0.8), A-A (4.0 ± 0.5), A-P (5.1 ± 0.8), SB (8.2 ± 0.7),

16 were found. All three SS protocols had *almost certainly* greater mean RPE values than the

17 CON, while the A-P condition had a *very likely* greater RPE when compared to the A-A

18 protocol. The SB protocol had an *almost certainly* greater RPE compared to both the A-A and

19 A-P protocols.

20

21

22

1   **DISCUSSION**

2   The purpose of the current study was to assess and compare the effects of three different SS

3   configurations on kinetic, kinematic, and RPE responses across 3 sets during the bench press

4   exercise. Of the three SS configurations, mean concentric velocity and power were reduced to

5   the greatest extent from baseline in the SB condition with *almost certainly* greater reductions

6   in this protocol when compared to the A-A and A-P pairings. Furthermore, when compared to

7   baseline, changes in peak force were *unclear* in the traditional and A-P condition, while *likely*

8   and *almost certain* reductions were reported in the A-A and SB complexes, respectively.

9   Comparisons between protocols demonstrated *likely* greater reductions in peak force in SB

10   when compared with A-A. However, differences between SB and A-P were *unclear*. Finally,

11   results revealed that the A-A pairing had *very likely* and *almost certainly* lower RPE than the

12   A-P and SB pairings, respectively.

13

14   The current study establishes the importance of SS configuration on resistance training

15   responses. Velocity loss from baseline to the final set occurred across all conditions, with

16   *moderate* changes in the CON (ES ± 90% CI; -0.62 ± 0.29) and A-A (ES ± 90% CI; -0.91 ±

17   0.41), and *large* (ES ± 90% CI; -1.45 ± 0.88) to *very large* (ES ± 90% CI; -6.17 ± 0.57)

18   reductions in the A-P and SB. While *possible* and *likely* differences were evident when CON

19   was compared with the A-A and A-P protocols, respectively, it is of note that *unclear*

20   differences were evident between the two latter conditions. This *unclear* result is partially

21   attributed to the large amount of uncertainty around the mean loss in velocity in the A-P

22   pairing. It is speculated that this uncertainty is due to varying tolerance of the large metabolic

23   cost of completing the back squat immediately followed by the bench press (40). With near

24   perfect relationships between measures of fatigue (e.g. lactate and ammonia accumulation) (*r*

25   = 0.95-0.97) and velocity loss in the barbell bench press (34), subjects with greater lower

1 body work capacity may have shown improved tolerance to this form of SS configuration.

2 Therefore, a high level of work capacity may be required to reduce loss of kinematic

3 outcomes in SS complexes that incorporate the lower body and its large component of lean

4 body mass.

5

6 The *very large* losses of velocity reported in the SB protocol were *almost certainly* greater

7 than reductions in all other protocols. Previous research (18) has shown that repeated high-

8 intensity muscle contractions can reduce substrate availability and increase metabolic

9 accumulation. These changes can cause acute reductions in muscle performance which have

10 been shown to impede moderate term (i.e. 8 weeks) strength and power development (28).

11 However, greater reductions in barbell velocity across these time frames have been related to

12 increased muscle hypertrophy (28). This promotes the idea that SS complexes that pair

13 exercises of a similar nature may not be ideal for the development of strength and power (8,

14 28, 31), yet may assist in the development of lean body mass due to responses related to

15 increased peripheral fatigue (31, 35). However, longitudinal research investigating this is still

16 required to elucidate these mechanisms and changes.

17

18 Accompanying the previously reported decreases in velocity, were almost identical losses in

19 power in the SS protocols (see table 1). However, the *moderate* (A-A), *large* (A-P), and *very*

20 *large* (SB) decreases in power from baseline do not mirror the much smaller changes in peak

21 force production. This suggests that the implementation of SS resistance training causes

22 reduction in power output primarily due to decreases in velocity rather than force, with these

23 changes in velocity most likely attributed to mitigated shortening speeds of muscle fibers and

24 the slowing of muscle relaxation (1). While reductions in peak forces do occur, albeit to a

25 lesser extent than mean velocity and power, these smaller changes may be due to an increase

1   in motor unit efficiency in the triceps brachii (3). Artur et al. (3) have demonstrated the

2   additional recruitment of higher threshold motor units when fatigue is induced prior to the

3   bench press exercise. However, it should be noted that this increased motor unit recruitment

4   may not promote long-term improvements in force and power (25, 26, 28). The practitioner

5   and sports scientist may therefore be cautious in the selection of SB pairings due to the large

6   amounts of localized fatigue, declines in kinetic and kinematic variables, and the mechanisms

7   that are utilized to maintain performance.

8

9   The current study also acknowledges the importance of SS configuration on perceived

10 intensity, with the A-A pairing reporting lower RPE when compared with A-P and SB. While

11 this study is not the first to assess SS configuration and RPE (5), it is the first to compare

12 supersets that extend beyond the agonist and antagonist format. It is speculated that the

13 greater range of movement and muscle mass utilized in the A-P SS (13), and the increased

14 localized muscle fatigue and subsequent substrate depletion in the SB protocol (8), increased

15 RPE and impacted performance. This indicates that perceived intensity may not only be

16 related to exercise choice or intensity, but total work completed (i.e. displacement of the

17 external load) and the total volume each muscle group completes (20). Therefore, when

18 implementing SS, consideration should be given to the movement pattern and range of

19 motion each exercise requires and how this can impact upon perceived measures of training

20 load.

21

22 While this study is the first to assess and compare the varying effects of different SS

23 configuration, it is not without its limitations that might reduce transferability to application.

24 First, while the definition of different forms of SS have been referred to in numerous

25 publications (3, 8, 31), the formulation of each SS complex within a defined category can

1 occur in a large variety of ways (41). This includes exercise selection (e.g. multi-

2 joint/isolated), order, intensity (as a percentage of 1RM), range of motion, and recovery

3 allotted between subsequent sets. It is therefore crucial that the practitioner and sport scientist

4 consider these training variables when designing relevant SS interventions. Secondly, due to

5 the nature of the research question, the outcomes of this study were being assessed within a

6 singular exercise (i.e. barbell bench press). Previous research has assessed neuromuscular and

7 metabolic responses across acute and short-term time periods (41). However, further research

8 is required to assess the outcomes of longitudinal research investigating varying

9 configurations of SS complexes. Finally, it is acknowledged that kinetic and kinematic

10 responses demonstrated in the current study may be exercise and loading specific. Complexes

11 of a similar nature may vary due to muscle mass utilized (34), terminal concentric velocity of

12 individual exercises (18), contribution of the stretch-shortening cycle (13), and the relative

13 "sticking region" of each exercise (34). These findings therefore need to be interpreted with

14 caution for exercises other than the barbell bench press.

15

16 In conclusion, the current study demonstrates the kinetic, kinematic and perceived exertion

17 responses to differing SS structures. The findings suggest that SS configuration can induce

18 varying levels of acute fatigue, with movements that are of a SB nature resulting in the

19 largest decline in performance. Additionally, resistance training that utilizes A-A and A-P

20 may demonstrate similar changes in performance outcomes. However, due to the large

21 amount of deviation in individual responses to A-P, as well as the *very likely* smaller change

22 in rate of perceived exertion in the A-A condition, protocols that integrate "*pull-push*" SS

23 complexes may be favourable in time constrained periods. Finally, TRAD training structures

24 that incorporate increased recovery may be most beneficial when training objectives are to

1 maximize movement velocity and power. Future research should endeavour to apply the

2 above findings and assess how these results can enhance training outcomes.

3

4 **Practical Application**

5 The ability to spend prolonged amounts of time training is often not feasible for an athlete.

6 Therefore, structures that enhance training efficiency by decreasing training time should be

7 considered. The implementation of SS is a unique training method that can enhance

8 resistance training efficiency, with A-A and A-P configurations both appearing to minimize

9 declines in kinetic and kinematic outcomes when compared with SB. Consequently, these

10 configurations should be utilized when aiming to reduce recovery interval frequency, or when

11 large amounts of training volume are required (e.g. muscular endurance/hypertrophy

12 mesocycles). Furthermore, the use of A-A SS may mitigate increases in perceived exertion

13 which may be beneficial during these training phases. However, the selection of SS

14 configuration may depend upon the desired training outcome and it should be noted that

15 traditional resistance training methods (i.e. singular sets) were superior in the maintenance of

16 velocity, power, and force. Therefore, when resistance training quality (i.e. high levels of

17 kinetic and kinematic outputs) is of the highest importance (e.g. during the development of

18 power) traditional methods may be of the greatest benefit.

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Table 1. Within and between condition comparison of barbell bench press mean velocity (m·s^{-1}), power (W), and peak force (N) across traditional and superset resistance training protocols

	Baseline M ± SD	Set 1 M ± SD	Baseline – Set 1 ES ± 90% CI Inference	Set 2 M ± SD	Baseline – Set 2 ES ± 90% CI Inference	Set 3 M ± SD	Baseline – Set 3 ES ± 90% CI Inference	Baseline – Set 3 Between condition comparison ES ± 90% CI / Inference
Mean Velocity (m·s⁻¹)								
Control	0.70 ± 0.10	0.70 ± 0.10	0.01 ± 0.21 *Likely trivial*	0.67 ± 0.10	-0.25 ± 0.24 *Possibly ↓*	0.64 ± 0.09	-0.62 ± 0.29 *Very likely ↓*	-0.29 ± 0.46 / A-A *possibly* greater ↓ -0.83 ± 0.90 / A-P *likely* greater ↓ -5.55 ± 0.94 / SB *almost certainly* greater ↓
Agonist-antagonist	0.70 ± 0.13	0.68 ± 0.15	-0.18 ± 0.19 *Possibly ↓*	0.64 ± 0.18	-0.51 ± 0.32 *Likely ↓*	0.59 ± 0.19	-0.91 ± 0.41 *Very likely ↓*	-0.54 ± 0.94 / A-A and A-P *Unclear* -5.26 ± 0.67 / SB *almost certainly* greater ↓
Alternate peripheral	0.70 ± 0.09	0.67 ± 0.13	-0.23 ± 0.39 *Possibly ↓*	0.61 ± 0.15	-0.89 ± 0.59 *Very likely ↓*	0.57 ± 0.16	-1.45 ± 0.88 *Very likely ↓*	-4.72 ± 1.00 / SB *almost certainly* greater ↓
Similar Biomechanical	0.74 ± 0.09	0.54 ± 0.15	-2.63 ± 0.74 *Almost certain ↓*	0.43 ± 0.15	4.66 ± 1.03 *Almost certain ↓*	0.36 ± 0.07	-6.17 ± 0.57 *Almost certain ↓*	
Mean Power (W)								
Control	509 ± 66	510 ± 68	-0.02 ± 0.22 *Unclear*	492 ± 62	-0.26 ± 0.26 *Possibly ↓*	485 ± 118	-0.36 ± 0.54 *Possibly ↓*	-0.63 ± 0.67 / A-A *possibly* greater ↓ -1.24 ± 1.14 / A-P *likely* greater ↓ -7.37 ± 0.89 / SB *almost certainly* greater ↓
Agonist-antagonist	507 ± 87	488 ± 101	-0.22 ± 0.21 *Possibly ↓*	458 ± 109	-0.59 ± 0.35 *Very likely ↓*	425 ± 121	-1.02 ± 0.45 *Almost certain ↓*	-0.61 ± 1.11 / A-A and A-P *Unclear* -6.74 ± 0.85 / SB *almost certainly* greater ↓
Alternate peripheral	501 ± 62	482 ± 92	-0.31 ± 0.52 *Unclear*	440 ± 100	-1.02 ± 0.73 *Very likely ↓*	407 ± 111	-1.63 ± 1.05 *Very likely ↓*	-6.13 ± 1.23 / SB *almost certainly* greater ↓
Similar Biomechanical	539 ± 51	398 ± 117	-3.08 ± 1.16 *Almost certain ↓*	303 ± 101	-5.83 ± 1.26 *Almost certain ↓*	250 ± 47	-7.76 ± 0.76 *Almost certain ↓*	
Peak Force (N)								
Control	1258 ± 126	1271 ± 146	0.10 ± 0.25 *Possibly trivial*	1295 ± 170	0.28 ± 0.33 *Possibly ↓*	1286 ± 170	0.21 ± 0.42 *Unclear*	-0.59 ± 0.83 / CON and A-A *unclear* -0.73 ± 0.85 / A-P *likely* greater ↓ -1.39 ± 0.59 / SB *almost certainly* greater ↓
Agonist-antagonist	1381 ± 191	1365 ± 225	-0.08 ± 0.13 *Likely trivial*	1341 ± 209	-0.21 ± 0.18 *Possibly ↓*	1309 ± 212	-0.38 ± 0.22 *Likely ↓*	-0.14 ± 1.03 / A-A and A-P *Unclear* -0.80 ± 0.85 / SB *likely* greater ↓
Alternate peripheral	1349 ± 225	1355 ± 215	0.02 ± 0.19 *Likely trivial*	1313 ± 215	-0.16 ± 0.22 *Possibly ↓*	1235 ± 211	-0.52 ± 0.77 *Unclear*	-0.66 ± 0.86 / A-P and SB *unclear*
Similar Biomechanical	1447 ± 139	1329 ± 193	-0.85 ± 0.38 *Very likely ↓*	1310 ± 145	-0.99 ± 0.33 *Almost certain ↓*	1286 ± 1285	-1.18 ± 0.46 *Almost certain ↓*	

M ± SD: Mean ± standard deviation. ES: Effect size. 90% CI: 90% confidence interval. ↑: increase. ↓: decrease. CON: control. A-A: agonist-antagonistic pairing; A-P: alternate peripheral pairing; S-B: similar biomechanical pairing.