

KINEMATICS AND KINETICS OF THE BENCH PRESS AND BENCH PULL EXERCISES IN A STRENGTH-TRAINED SPORTING POPULATION

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A comparison of kinematics and kinetics from the upper body musculature in shoulder flexion (bench press) and extension (bench pull) movements were performed across loads of 10-100%1RM. Twelve elite male sailors with extensive strength-training experience participated in the study. 1RM strength and force were greater in the bench press, while velocity and power output were greater for the bench pull across the range of loads. P_{max} for both mean and peak power occurred at a significantly ($p < 0.000$) higher relative load in the bench pull ($78.6 \pm 5.7\%$ and $70.4 \pm 5.4\%$ of 1RM) than the bench press ($53.3 \pm 1.7\%$ and $49.7 \pm 4.4\%$ of 1RM). Findings can most likely be attributed to differences in muscle architecture for shoulder extension/pull and flexion/push movements, which may have training implications for these muscles.

KEY WORDS: strength, power, performance, America's Cup, sailing.

INTRODUCTION:

Muscular power, as the combination between force and velocity, has been identified as an important factor in the performance of many sporting activities. Resistance training plays an important role in the development of muscular power, although there is still considerable conjecture in the literature as to the most efficient method of developing power (Cronin *et al.*, 2001). In order to understand how muscular power can best be developed, it is important to understand how load influences power output. The load that maximizes muscular power output (P_{max}) is one variable, which is considered important in improving the performance of various sporting movements. However, Cronin and Sleivert (2005) identified a number of issues within the current available research in this area and the generalization of results, given the variation in P_{max} load across populations and movements.

While extensive research on the power-load spectrum has been conducted with the bench press exercise using different populations, there has been very little examination of other upper body exercises/movements. Therefore, the aim of this study was to compare characteristics of the power-load spectrum of an upper body shoulder horizontal flexion/push movement (bench press) with an extension/pull movement (bench pull/prone row) in a strength trained, sporting population. Although it has received little research attention the bench pull is another key multi-articular exercise used in the conditioning of athletes across a wide variety of sports, and as such a better understanding of the kinetic and kinematic characteristics of this movement will be of benefit to the neuromuscular development of athletes.

METHODS:

Participants: Twelve elite-level sailors from the Emirates Team New Zealand America's Cup syndicate participated in this study. The sailor's mean (\pm SD) age, body mass, and height were 33.9 ± 5.5 years, 97.8 ± 12.5 kg, and 186.0 ± 7.1 cm. All participants had an extensive strength-training background (minimum of 3 years) and the bench press and bench pull exercises were commonly used as part of their training program. During routine strength testing performed in the week immediately prior to this study, mean (\pm SD) 1RM strength scores for the bench press and bench pull were calculated as 140.9 ± 26.6 kg and 120.6 ± 16.9 kg respectively, using the prediction equation of Mayhew *et al.* (1992).

Equipment: Testing was performed on a modified Smith machine (Figure 1). A linear transducer (Unimeasure, Oregon) was attached to the bar and measured bar displacement with an accuracy of 0.1 mm. These data were sampled at 500 Hz and relayed to a Labview based acquisition and analysis program.



Figure 1: Testing set-up for the power-load spectrum of the bench pull exercise.

Procedures: Each participant completed a 60-minute testing session involving both the bench press and bench pull exercises (Figure 2). Familiarisation was conducted through a self-determined, exercise-specific warm-up typically consisting of 3-4 warm-up sets of the particular exercise using progressively heavier loads. Following the warm-up the individuals' 1RM (Smith machine, concentric-only) was determined to the nearest 2.5 kg. Load for the power profile was then determined from 10-100% of 1RM at 10% intervals. Single repetitions of each load were performed in ascending order, with the instruction that each lift should be performed as explosively as possible. All lifts were separated by a rest period of 1-2 minutes and were concentric-only, with the bench press initiated from mechanical stops positioned ~3 cm off the sailor's chest, and the bench pull initiated from a supported supine position.

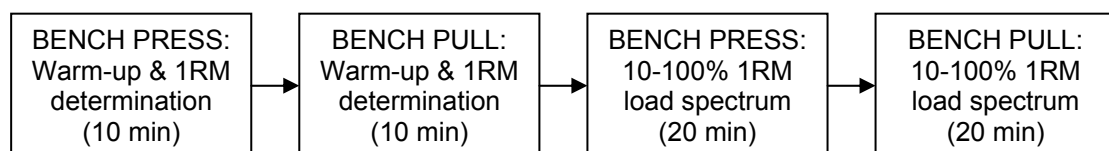


Figure 2: Structure of the testing session.

Data and Statistical Analyses: Displacement-time data were filtered using a low pass Butterworth filter with a cutoff frequency of 6 Hz, then differentiated to determine instantaneous velocity, acceleration, force and power output data over the range of motion for each load condition. Descriptive statistics for all variables are represented as mean and standard deviations. P_{max} values and power drop-off around P_{max} were calculated using the line estimation function (least squares method) in Microsoft Excel. Presence of significant systematic discrepancy between measures from the bench press and bench pull was determined using a two-tailed unpaired t -test (α level of $p \leq 0.01$).

RESULTS:

Set-up specific determination of 1RM performance resulted in mean 1RM scores of 119.7 ± 23.9 kg for the bench press and 99.4 ± 15.4 kg for the bench pull. Table 1 displays the force, velocity, and power output values for the bench press and bench pull across the range of relative loads. It is notable that force values were higher for the bench press/flexion movement while velocity values were greater for the bench pull/extension movement. In

addition, while both movements followed the typical force-velocity trade-off, the patterns of how these characteristics related to each other differed. Force values maintained a linear relationship throughout the range of loads; with force values for the bench pull approximately 17% lower relative to the comparative force values of the bench press. However, when bench pull velocity values were expressed relative to comparative bench press velocities they increased in an exponential manner as relative load increased (Table 1), with the mean velocity for the concentric phase of the bench pull over 500% greater than for the bench press at the 1RM load (100% 1RM).

Table 1. Kinematic and kinetic measures (mean±SD) for the bench press and bench pull exercises throughout a range of loads (%1RM).

Load (%1RM)	Bench Press			Bench Pull		
	Velocity (m/s)	Force (N)	Power (W)	Velocity (m/s)	Force (N)	Power (W)
10%	0.95±0.14	122±29	117±36	1.20±0.16	102±15	125±32
20%	0.85±0.15	234±49	199±61	1.17±0.14	198±31	235±63
30%	0.72±0.10	354±70	253±57	1.06±0.12	293±45	315±80
40%	0.61±0.10	473±96	286±65	0.99±0.07	389±64	387±82
50%	0.52±0.10	592±124	306±75	0.88±0.05	488±75	432±82
60%	0.44±0.09	708±146	303±64	0.79±0.06	573±87	454±89
70%	0.34±0.05	829±167	284±64	0.73±0.04	685±103	499±88
80%	0.24±0.05	942±187	225±55	0.65±0.05	779±119	506±86
90%	0.15±0.04	1049±216	153±50	0.53±0.04	878±131	468±80
100%	0.09±0.03	1176±232	105±38	0.47±0.03	984±147	462±78

Note: Measurements are the mean value of the sample for the concentric phase of a single repetition.

Power output was at a similar level for the two movements at low load (10% 1RM), but a substantially greater increase was observed with increased load for the bench pull in comparison to the bench press. It was also noticeable that mean power output was maximised at a significantly higher load ($p < 0.001$) for the bench pull (78.6±5.7%1RM) than the bench press (53.3±1.7%1RM). Similar values were found for the peak power, although the relative load at which maximum values occurred appeared to be slightly lower for both the bench pull (70.4±5.4%) and bench press (49.7±4.4%). In addition, reduction in power output either side of P_{max} was significantly lower ($p < 0.001$) for the bench pull at both 10% and 20% of load away from P_{max} , with a power output drop-off of 1.6% and 6.5% for the bench pull and 3.2% and 12.9% for the bench press.

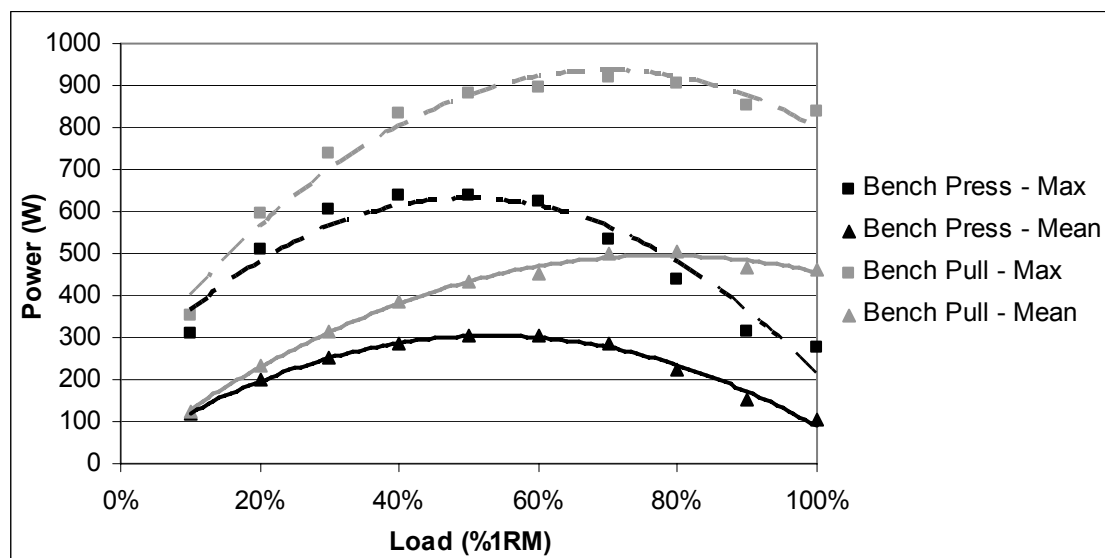


Figure 3: Comparison of the power-load spectrum for the bench press and bench pull. Curves are presented for both mean and maximum power from a single, averaged (all sailors), repetition.

DISCUSSION:

The most notable finding of this study was the divergent power-load spectrum profiles of the bench press and bench pull. Muscular power output was higher for the bench pull throughout the entire load range, and significantly ($p < 0.01$) so at loads of 40%1RM and greater which was interesting given the higher loads (~17%) being lifted in the bench press at the same relative load. Given that power is the product of force and velocity it would seem that the combination of these two variables is dependent on the muscles/movement used as evidenced in this agonist-antagonist pairing. That is, the greater velocities and subsequent power outputs observed in the bench pull movement may be attributed to the differing muscle architecture. The greater fibre lengths and longitudinal fibre arrangement of the primary movers in the bench pull exercise (latissimus dorsi, biceps brachii, brachialis) are characterised by faster shortening velocities, whereas the primary movers for the bench press (pectoralis major, triceps brachii) have shorter fibre lengths, greater pennation angles, and subsequently greater force capability. In terms of power output, it is evident that the benefits gained from the greater velocity-generating capability of the musculature used in the bench pull greatly out-weighed the corresponding deficit in force, especially as relative load increased.

These differences in muscular characteristics also resulted in a significant difference ($p < 0.001$) in the relative load at which P_{max} occurred. P_{max} loads for the bench press of around 50%1RM for both mean and peak power, along with a power output drop-off of ~3% for a 10% variation in load, means these findings were consistent with previous comparative research, which have reported P_{max} loads of 30-60%1RM (Baker, 2001; Cronin *et al.*, 2001). In contrast, P_{max} occurred at a much heavier load for the bench pull – 78.6%1RM for mean power and 70.4% for peak power. Similar findings have been reported in-situ for a single muscle fibre, with Edgerton *et al.* (1986) attributing the differences observed between power outputs and P_{max} loads in muscle groups of the lower limb to differences in muscle architecture (fibre length, type and arrangement). While Edgerton *et al.* (1986) reported flexor P_{max} to occur at a higher relative load (59%) than extensor P_{max} at the knee, the higher values again corresponded with the action involving more fusiform muscles with greater fibre length.

CONCLUSIONS:

The force, velocity, and power generating characteristics for the shoulder extensor muscles (bench pull) were substantially different from the shoulder flexors (bench press). The bench pull produced greater velocities and power outputs, along with exhibiting a higher relative load for P_{max} – findings which may be due to differences in muscle architecture. This may have implications in terms of the way different muscle groups or movement patterns are trained, depending on the requirements of the activity of interest

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