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The effect of enhanced maximal bench press strength on a 200m kayak ergometer sprint performance

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Abstract

While strong relationships between dynamic upper body strength and kayak sprint performance have been reported in several studies, information of the causal relationship is limited. Previously, maximal bench press and -pull has been proven strong predictors of kayak sprint performance, with bench press being of the highest importance. The aim of this study was to investigate the effect of two different strength training programs (bench press- and maintenance program) on a 200m kayak ergometer sprint performance. Twenty-six national elite junior A, U23 and senior kayak paddlers (sixteen men: age 18.6 ± 4.1 years, weight 79.1 ± 7.8 kg, height 179.0 ± 5.1 cm, and ten women: age 17.0 ± 1.4 years, weight 64.9 ± 4.6 kg, height 168.5 ± 6.6 cm) were divided into two groups, and tested (200m sprint performance, 1RM; bench press, bench pull, pull up, and maximal repetition pull ups) before and after six weeks of strength training, concurrent with their normal on-water kayak training. The purpose of the maintenance group was to maintain strength in all exercises, while the purpose of the bench press group was to increase maximal bench press strength. Significant differences were found in 200m sprint performance (difference = -1.15%; $p = 0.042$), 1RM bench press (difference = 7.53%; $p = 0.001$), and 1RM bench pull (difference = 2.31%; $p = 0.025$) in the bench press group. No significant differences were found for the maintenance group. In conclusion six weeks of heavy bench press training, improved the 200m kayak ergometer sprint performance, while six weeks of maintaining strength in press and pull resulted in no improvements for the 200m kayak ergometer sprint performance.

Introduction

In the Olympic Program in 2012 the K1 200m kayak sprint was added (1), which require different metabolic demands than the longer distances (2). 500 and 1000m require greater delivery from the aerobic system, while anaerobic capacity dominates the energy contribution (63%) during a 200m kayak sprint (3). The greater contribution from the anaerobic system results in higher demands for the anaerobic power, which can be expressed as the maximal power per stroke, and is thereby limited by muscle strength, more specifically upper body strength (4,5). Some of the most typical strength training exercises used in kayaking are bench pull and -press, as they replicate the involved muscles in the paddle stroke (6), which is commonly divided in a pull- and a push phase (7,8). The pull phase is when the paddle is immersed in the water until it exits, and the push phase is when the paddle is immersed in the water on the contralateral side of the kayak until it exits the water (8). The primary movers in the pull phase, found by Logan et al., are m. latissimus dorsi, m. teres major and minor, m. posterior deltoid and m. infraspinatus (8), which is in agreement with the primary muscles involved in bench pull (9). In the press phase, the primary movers are m. pectoralis major, m. anterior deltoid and m. triceps brachii (8), which are in agreement to the muscles involved in bench press (10,11).

Relationships between dynamic strength and 200m on-water kayak sprint performance has previously been reported in several studies (1,12–14). Pickett et al. revealed a strong negative relationship between 3RM bench press (r = -0.8), bench row (r = -0.76), and chin-up (r = -0.73) in relation to a 200m sprint performance, measured in seconds, indicating that athletes with greater muscle strength had the fastest sprint times. (12) Likewise, Akca et al. found a non-significant moderate negative relationship between 1RM bench press and a 200m sprint performance (r = -0.51) (13). Further, van Someren et al. reported a moderate negative relationship between dynamic strength, executed on a dynamometer positioned to simulate a paddle stroke, and a 200m sprint performance (r = -0.57; p = 0.013). (15) To the best of our knowledge, there are no studies showing contradicting results in the literature compared to the above-mentioned results, which indicates that the athletes with the greatest upper body strength show superior kayak sprint performance times. In general, maximal bench press and -pull strength has shown strong correlations to kayak sprint performance. However, there has been limited information concerning the importance of different strength qualities in relation to the prediction of a kayak sprint performance. Therefore, in an unpublished work by the present authors, the impact of different strength qualities (power (50% of 1RM), isometric, 1RM, and 40s maximal repetition (40% of 1RM)) of bench press and -pull in the prediction of a 30s on-water kayak sprint performance, was investigated on 33 national elite junior and U23 kayak paddlers. Partial least squares regression analysis showed, that 1RM bench press was the best predictor, and of highest importance for a 30s on-water kayak sprint performance, compared to the other strength qualities, where 1RM bench pull was second highest. (16) As above-mentioned studies are cross sectional studies, a causal relationship between upper body strength training and kayak sprint performance can therefore not be inferred. This has only been reported by Liow & Hopkins (17). They investigated the effect of slow and explosive strength training on a 15m kayak sprint, where the training program consisted of bench press and dumbbell pull. Both training groups improved 1RM strength (8-15%), while the slow strength training group had a greater improvement in 15m sprint time (3.4 ± 1.3%) than the explosive strength training group (2.3± 0.9%). No improvement was found in the control group (-0.2 ± 0.9%). (17) Even though a causal relationship was reported between improved strength and sprint performance, the main purpose was to investigate the difference in 15m sprint performance after the two strength training types, which may not be transferable to a 200m sprint performance. Further, both bench press and -pull were improved, which makes it challenging to tell if there is an effect on kayak sprint performance from enhanced bench press or -pull separately.

Causal relationships have previously been found between strength and performance in other sports disciplines. In a study by Styles et al., the effect of six weeks squat training (85-90% 1RM) on running sprint performance in elite soccer players was investigated. The strength training resulted in significant improvements in absolute and relative strength ($p \leq 0.001$) and an improvement on 20m running sprint performance (pre: 3.09 ± 0.07 s, post: 3.05 ± 0.05 s, $p \leq 0.001$). These results indicate that maximal squat strength enhanced running sprint performance in soccer players, highlighting the importance of developing maximal strength to improve short running sprint performance. (18) Veliz et al. investigated the effect of 18 weeks of heavy upper body strength training on a 20m swimming sprint, among other parameters, and found a significant decrease in sprint time for the training group, while both groups did the same in-water training. (19) Aspenes et al. investigated the effect of heavy upper body strength training on 100 and 400m crawl performance in swimmers, respectively. The strength training consisted of heavy cable straight-arm lat pull down. While no significant effect on the 100m sprint performance was found, the swimmers improved the 400m sprint performance approximately 1.3% ($p < 0.05$). (20) Strass studied the effect of maximal upper body strength training on crawl performance in competitive swimmers at 25 and 50m respectively. Improvements in performance where found (25m; 4.4 ±1.3% ($p < 0.001$), and 50m; 2.1 ± 0.4% ($p < 0.001$)) after only six weeks of training. (21) The above-mentioned results indicate causal relationships between improvements in strength and performance for athletes in their primary sport.

However, while several studies show high relationships between kayak sprint performance and maximal upper body strength (1,12,13,15), there is limited evidence regarding the causal relationship, in regard to kayak sprint. As mentioned above, previously unpublished research has found maximal bench press strength (1RM) as being of high importance for a 200m kayak sprint performance. Therefore, the aim of this study was to investigate the effect of two different strength training programs (a bench press- and a maintenance program) on a 200m kayak ergometer sprint performance. The purpose of the bench press program was to enhance the maximal bench press strength (1RM), while the purpose of the maintenance program was to maintain maximal strength. It was hypothesized that enhanced maximal bench press strength would improve a 200m kayak ergometer sprint performance.

Methods

Twenty-six national elite junior A, U23, and senior kayak paddlers (sixteen men: age 18.6 ± 4.1 years, weight 79.1 ± 7.8 kg, height 179.0 ± 5.1 cm, and ten women: age 17.0 ± 1.4 years, weight 64.9 ± 4.6 kg, height 168.5 ± 6.6 cm) from three regional kayak centers (Talentcenter Hovedstaden, Super Kraftcenter Silkeborg and Kano og Kajakklubben Limfjorden) with at least one year experience with free weight strength training, participated in this study. The participants were informed about the procedure of the study before providing their written informed consent. Parental or guardian consent was required for the participants under 18 years. The participants were tested (200m ergometer sprint, 1RM; bench press, bench pull, pull up, and maximal repetitions pull ups) before and after a six weeks strength training intervention. All tests were executed on the same day, in the same order for every participant at both pre- and post-testing. Participants were divided into two groups, a bench press group, and a maintenance group. Groups were stratified randomized, in relation to kayak center, gender, and maximal bench press strength, to make as homogeneous groups as possible. The purpose of the bench press group was to increase the maximal bench press strength and maintain the strength in the other exercises, while the purpose of the maintenance group was to maintain the strength in all exercises. This was done to analyze the differences in 200m ergometer sprint performance in a group with an increased maximal bench press strength compared with a similar group with no increase in maximal bench press strength. Both groups followed their normal kayak training routine, consecutively to the strength training.

Test protocol

Prior to the tests, a standardized ergometer warm-up was performed (table 1). Test protocol consisted of a 200m kayak ergometer sprint test, followed by a 40min rest after which strength tests were conducted, consisting of 1RM bench press, 1RM bench pull, 1RM pull up, and maximal repetitions pull ups.

Table 1: Standardized ergometer warm-up before the strength test. I2 = medium intensity. DS = double strokes

2 min Slow	2 min I2	2 min Slow	10 DS Flying start/95%	10 DS Flying start/100%	10 DS Regular start/100%	5 min Active rest

Ergometer sprint test: The ergometer sprint test was conducted on a Dansprint kayak ergometer (Dansprint PRO kayak ergometer, Dansprint ApS, Hvidovre, Denmark) and consisted of a 200m all out sprint. Drag was regulated in relation to sex and age and the same drag was used at both pre- and post-test. The participants were instructed to paddle all out from the start. A computer was connected to the ergometer and time (s) was recorded.

Strength tests: Prior to both bench press and –pull tests, participants performed four submaximal warm-up sets, consisting of 10, 8, 4, and 2 repetitions, respectively, with 50, 70, 80, and 90% of the participants' estimated 1RM, respectively. Each warm-up set was followed by a 2min rest. The estimated 1RM was calculated using a website-based calculator (22), which calculates an average estimation from several formulas (23). The test setup for the 1RM bench press consisted of a bench press rack and barbell. The press was accepted when head and buttock was kept in the bench throughout the press and the feet had contact to the floor. The barbell should be lowered down and touch the chest, without bouncing, and pressed up in fully extended arms. The test setup for the 1RM bench pull consisted of a prone pull bench and a barbell. The height of the bench was adjusted, so the participants could grab the barbell with extended elbows while the barbell laid on the ground. The pull was accepted when the barbell touched the underside of the bench and the head was held in the bench. The setup for the pull up tests consisted of a pull up bar. For the 1RM test, a weight belt and chalk were used. The participants grabbed the bar with shoulder width or slightly wider grip. A repetition was accepted if the chin was raised over the bar, and the participants did not kick or in other way created momentum with the legs. Further, the arms should be fully extended before the concentric phase. For the 1RM pull up test a specific warm-up protocol was performed, similar to the warm-up for 1RM bench press and -pull in proportion to repetitions, intensity, and rest between sets. If the participants estimated that they were able to perform more than 12 repetitions with bodyweight, they started the warm-up by performing 8-10 repetitions with only bodyweight, otherwise, they started the warm-up by performing cable lat pulldowns, similar to the intensity, reps, and rest as the other maximal tests. The intensity was increased, and repetitions decreased for every warm-up set. The participants had three trials to reach 1RM separated by 3min rest for every 1RM test. If the three trials succeeded with progression, the participants were given additional trials, until they were not able to progress anymore. Maximal repetitions pull ups test was executed 15min after the 1RM pull up test, and chalk was used. The aim was to perform as many repetitions as possible. Verbal encouragement was given during maximal attempts.

Training protocol

RPE: In the training programs, the intensity was indicated by a rate of perceived exertion (RPE) and refers to how high the intensity is in relation to the maximal capacity. The RPE indicates the number of repetitions the participants should be able to lift additionally after a set was done when RPE is subtracted from 10. I.e. an RPE at 8 would give 2 repetitions extra capacity when the set is done (10-8=2).

Bench press group: Participants in the bench press group had three strength training sessions a week besides their normal on-water kayak training. The main focus was the bench press, and every training session consisted of 6 to 9 sets of 1 to 6 repetitions of heavy bench press (RPE = 7-9), with at least 3 to 4min rest between sets. Progression was made by increasing the weight and decreasing the repetitions throughout the weeks. Additionally, the strength training consisted of 3 to 4 sets of 8 to 10 repetitions (RPE = 7-8) of split squats and reverse flyers or bench pull and one arm shoulder press (table 2).

Maintenance group: Participants in the maintenance group had two similar strength trainings a week besides their normal on-water kayak training. Every strength training consisted of 3 to 4 sets of 8 to 12 repetitions (RPE = 6-7). The strength training program consisted of split squats, bench pull, bench press, reverse flyers, one arm shoulder press, and one arm lateral pull down (table 3).

Table 2: Strength training program for the bench press group, for all six weeks of training

Week	One	Two	Three	Four	Five	Six
Day 1 and 3						
Bench press						
Number of sets	7	8	8	8	9	9
Reps	10,8,6,5,5,6,6	10,8,6,5,5,5,6,6	10,8,6,5,4,5,5,6	10,8,5,4,3,3,4,5	8,6,4,3,2,2,3,3,4	8,6,4,2,1,1,2,2,3
RPE	5,6,7,8,8,8,8	5,6,7,8,8,8,8,8	5,6,7,8,8,8,9,9	5,6,8,8,8,8,9,9	5,6,8,8,8,9,9,9,9	5,6,8,8,8,9,9,9,9
Pause	2,2,3,3,3,3	2,2,3,3,3,3,3	2,2,3,3,3,4,4	2,2,3,3,3,>4,>4	2,2,3,3,>4,>4,>4,>4	2,2,3,3,>4,>4,>4,>4
Split squat						
Number of sets	4	4	4	4	4	4
Reps	12,12,12,12	12,10,10,10	12,10,10,10	12,10,10,10	12,10,10,10	12,10,10,10
RPE	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8
Pause	2,2,3	2,2,3	2,2,3	2,2,3	2,2,3	2,2,3
Reverse flyers						
Number of sets	4	4	4	4	4	4
Reps	12,12,12,12	12,10,10,10	12,10,10,10	12,10,10,10	12,10,10,10	12,10,10,10
RPE	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8
Pause	2,2,3	2,2,3	2,2,3	2,2,3	2,2,3	2,2,3
Day 2						
Bench press						
Number of sets	7	8	8	8	9	9
Reps	10,8,6,5,5,6,6	10,8,6,5,5,5,6,6	10,8,6,5,4,5,5,6	10,8,5,4,3,3,4,5	8,6,4,3,2,2,3,3,4	8,6,4,2,1,1,2,2,3
RPE	5,6,7,8,8,8,8	5,6,7,8,8,8,8,8	5,6,7,8,8,8,9,9	5,6,8,8,8,8,9,9	5,6,8,8,8,9,9,9,9	5,6,8,8,8,9,9,9,9
Pause	2,2,3,3,3,3	2,2,3,3,3,3,3	2,2,3,3,3,4,4	2,2,3,3,3,>4,>4	2,2,3,3,>4,>4,>4,>4	2,2,3,3,>4,>4,>4,>4
Bench pull						
Number of sets	4	4	4	4	4	4
Reps	12,12,12,12	12,10,10,10	12,10,10,10	12,10,10,10	12,10,10,10	12,10,10,10
RPE	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8
Pause	2,2,3	2,2,3	2,2,3	2,2,3	2,2,3	2,2,3
One arm shoulder press						
Number of sets	4	4	4	4	4	4
Reps	12,12,12,12	12,10,10,10	12,10,10,10	12,10,10,10	12,10,10,10	12,10,10,10
RPE	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8	5,7,7,8
Pause	2,2,3	2,2,3	2,2,3	2,2,3	2,2,3	2,2,3

Table 3: Strength training program for the maintenance group, for all six weeks of training, performed two times per week.

Week	One	Two	Three	Four	Five	Six
Split squat						
Number of sets	4	4	4	4	5	5
Reps	12, 12, 12, 12	12, 12, 12, 12	12, 12, 10, 10	12, 10, 10, 10	12, 10, 10, 10, 8	12, 10, 10, 8, 8
RPE	5, 6, 6, 7	5, 7, 7, 8	5, 6, 6, 7	5, 7, 7, 8	5, 7, 7, 8, 8	5, 7, 7, 8, 8
Pause	2, 2, 2	2, 2, 3	2, 2, 2	2, 2, 3	2, 2, 3, 3	2, 2, 3, 3
Bench pull						
Number of sets	3	3	3	3	3	3
Reps	12, 12, 12	12, 12, 12	12, 12, 10	12, 10, 10	12, 10, 10	12, 10, 10
RPE	5, 6, 6	5, 7, 7	5, 6, 6	5, 7, 7	5, 7, 7	5, 7, 7
Pause	2, 2	2, 2	2, 2	2, 2	2, 2	2, 2
Bench press						
Number of sets	3	3	3	3	3	3
Reps	12, 12, 12	12, 12, 12	12, 12, 10	12, 10, 10	12, 10, 10	12, 10, 10
RPE	5, 6, 6	5, 6, 7	5, 5, 6	5, 7, 7	5, 7, 7	5, 7, 7
Pause	2, 2	2, 2	2, 2	2, 2	2, 2	2, 2
Reverse flyers						
Number of sets	4	4	4	4	4	4
Reps	12, 12, 12, 12	12, 12, 12, 12	12, 12, 10, 10	12, 10, 10, 10	12, 10, 10, 10	12, 10, 10, 8
RPE	5, 6, 6, 7	5, 7, 7, 8	5, 6, 6, 7	5, 7, 7, 8	5, 7, 7, 8	5, 7, 7, 8
Pause	2, 2, 2	2, 2, 3	2, 2, 2	2, 2, 3	2, 2, 3	2, 2, 3
One arm dumbbell shoulder press						
Number of sets	4	4	4	4	5	5
Reps	12, 12, 12, 12	12, 12, 12, 12	2, 12, 10, 10	12, 10, 10, 10	12, 10, 10, 10, 8	12, 10, 10, 8, 8
RPE	5, 6, 6, 7	5, 7, 7, 8	5, 6, 6, 7	5, 7, 7, 8	5, 7, 7, 8, 8	5, 7, 7, 8, 8
Pause	2, 2, 2	2, 2, 3	2, 2, 2	2, 2, 3	2, 2, 3, 3	2, 2, 3, 3,
One arm lat pulldown						
Number of sets	4	4	4	4	5	5
Reps	12, 12, 12, 12	12, 12, 12, 12	12, 12, 10, 10	12, 10, 10, 10	12, 10, 10, 10, 8	12, 10, 10, 8, 8
RPE	5, 6, 6, 7	5, 7, 7, 8	5, 6, 6, 7	5, 7, 7, 8	5, 7, 7, 8, 8	5, 7, 7, 8, 8
Pause	2, 2, 2	2, 2, 3	2, 2, 2	2, 2, 3	2, 2, 3, 3	2, 2, 3, 3,

Strength training was supervised two times a week to ensure correct technique and compliance to the training program, and the participants were encouraged to use a handed-out logbook to note kg for every set, to use during training sessions. Further, an illustration and description of every exercise was available in all three kayak centers. The total weekly volume in bench press and -pull training for both groups is illustrated in figure 1.

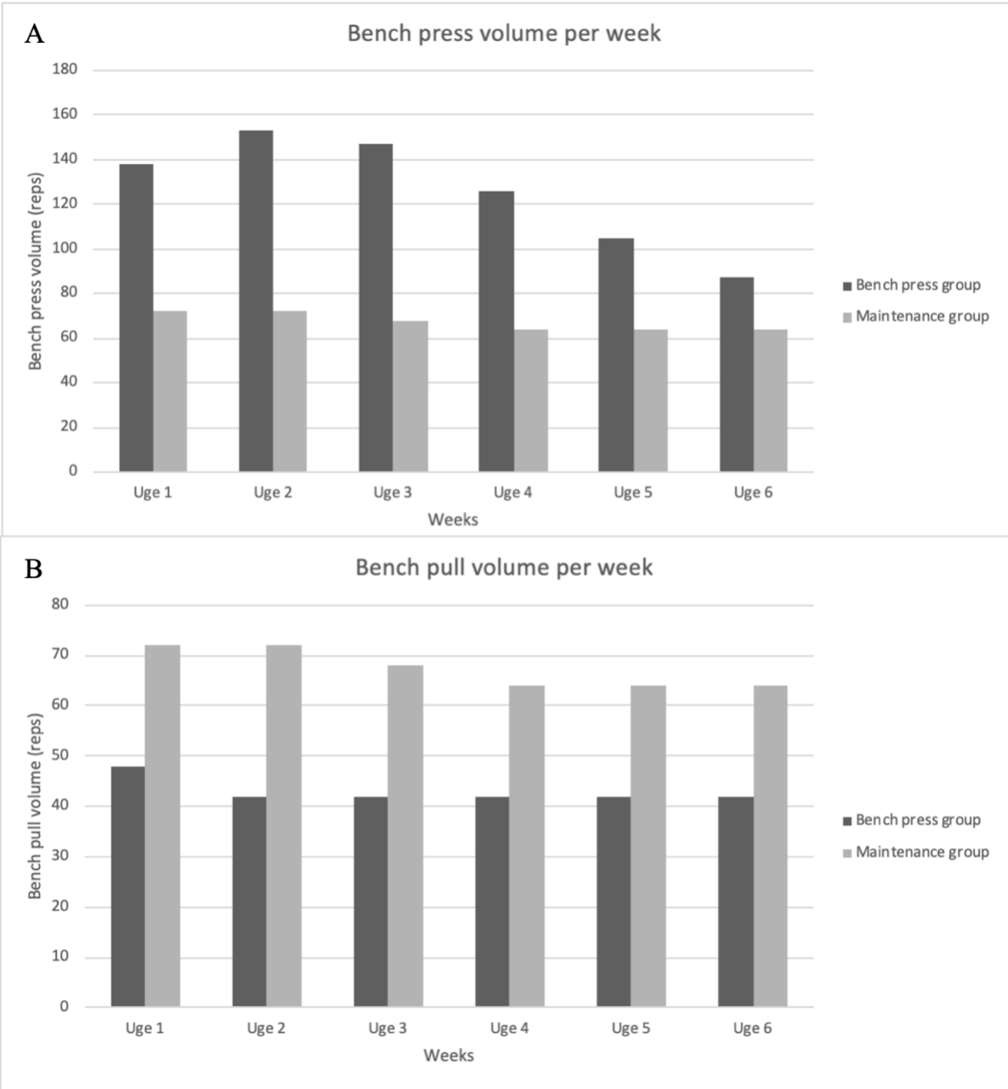

Figure 1: Total training volume per week in (A) bench press and (B) bench pull, for both the bench press group and the maintenance group, throughout the six week of training.

Statistical analysis

Statistical analysis was executed in SPSS (version 25). Shapiro-Wilk test was used to test for normal distribution. Mann-Whitney U Test (Independent Samples) was used to test if the groups were statistically different from each other for all five variables (200m sprint performance, 1RM bench press, 1RM bench pull, 1RM pull up, and maximal repetition pull ups) pre- and post-testing. Paired-Samples T-test was used to detect the difference between pre and post-test for the normally distributed variables and a Wilcoxon test (Related Samples) was used to test the difference between pre and post-test for the variables that were not normally distributed. Spearman correlations were made for bench press and -pull, in relation to 200m ergometer sprint performance. Effect size and achieved power for bench press and -pull, in relation to 200m ergometer sprint performance were calculated using G*power (version 3.1.9.3). Alpha-level was set to 0.05, beta-level was set at 0.2.

Results

Five participants were excluded because of personal issues unrelated to the study, and one participant was excluded due to equipment difficulties at the post test. 20 participants were used in the statistical analysis.
Mean and standard deviations (SD) prior to the intervention for the two groups are shown in table 4. Mann-Whitney U test showed no significant differences between groups in any variable prior to the intervention.

Table 4: Mean, standard deviation (SD), and p-value for the difference between groups in all the variables, prior to the intervention.

	Bench press group		Maintenance group		p-value
	Mean	SD	Mean	SD	
200m sprint (s)	44.83	4.25	46.23	5.15	0.527
1RM bench press (kg)	89.06	22.82	90.75	26.06	0.895
1RM bench pull (kg)	85.63	17.81	81.5	21.09	0.597
1RM pull ups (kg)	31.8	12.2	29.7	16.13	0.71
Max reps pull ups (reps)	18.44	6.23	16.5	9.06	0.523

Descriptive data, differences from pre to post test in percent and p-values of the differences within- and between groups are presented in table 5, for all five tests, for both groups (mean ±SD). For the maintenance group, no significant differences were found in any of the five variables; 200m sprint performance (difference = -0.15%; p = 0.893), 1RM bench press (difference = 1.34%; p = 0.408), 1RM bench pull (difference = 1.37%; p = 0.349), 1RM pull ups (difference = 4.76%; p = 0.442), and maximal repetitions pull ups (difference = 6.31%; p = 0.416). For the bench press group significant differences were found in 200m sprint performance (difference = -1.15%; p = 0.042), 1RM bench press (difference = 7.53%; p = 0.001), and 1RM bench pull (difference = 2.31%; p = 0.025). No significant differences were found in 1RM pull ups (difference = 1.14%; p = 0.667) and maximal repetitions pull ups (difference = 1.98%; p = 0.591). No significant differences were seen between groups in any variable post-testing.

*Table 5: Mean, SD, difference in percent from pre to post, and p-values of the differences within- and between groups, for all the variables * = significant difference between pre- and post-test.*

	Bench press group		Maintenance group		p-value between-groups
	Mean	SD	Mean	SD	Post
200m Ergometer sprint (s)					0.536
Pre	44.66	4.14	45.67	4.39	
Post	44.15	4.18	45.60	5.29	
Diff (%)	-1.15		-0.15		
p-value	0.042*		0.89		
1RM bench press (kg)					1.000
Pre	87.32	21.16	93.33	26.54	
Post	93.89	21.31	94.58	28.70	
Diff (%)	7.53		1.34		
p-value	0.001*		0.41		
1RM bench pull (kg)					0.817
Pre	85.00	14.97	85.42	21.18	
Post	86.96	14.98	86.58	20.18	
Diff (%)	2.31		1.37		
p-value	0.025*		0.35		
1RM pull ups (kg)					0.817
Pre	31.34	10.95	32.42	14.83	
Post	31.70	10.53	33.96	15.46	
Diff (%)	1.14		4.76		
p-value	0.67		0.44		
Max reps pull ups (reps)					0.938
Pre	18.07	5.58	18.50	9.31	
Post	18.43	5.27	19.67	7.69	
Diff (%)	1.98		6.31		
p-value	0.54		0.42		

Individual values in sprint performance (A), 1RM bench press (B), and 1RM bench pull (C) for the bench press group are illustrated in figure 2, as this was the only variables showing significant differences after the intervention.

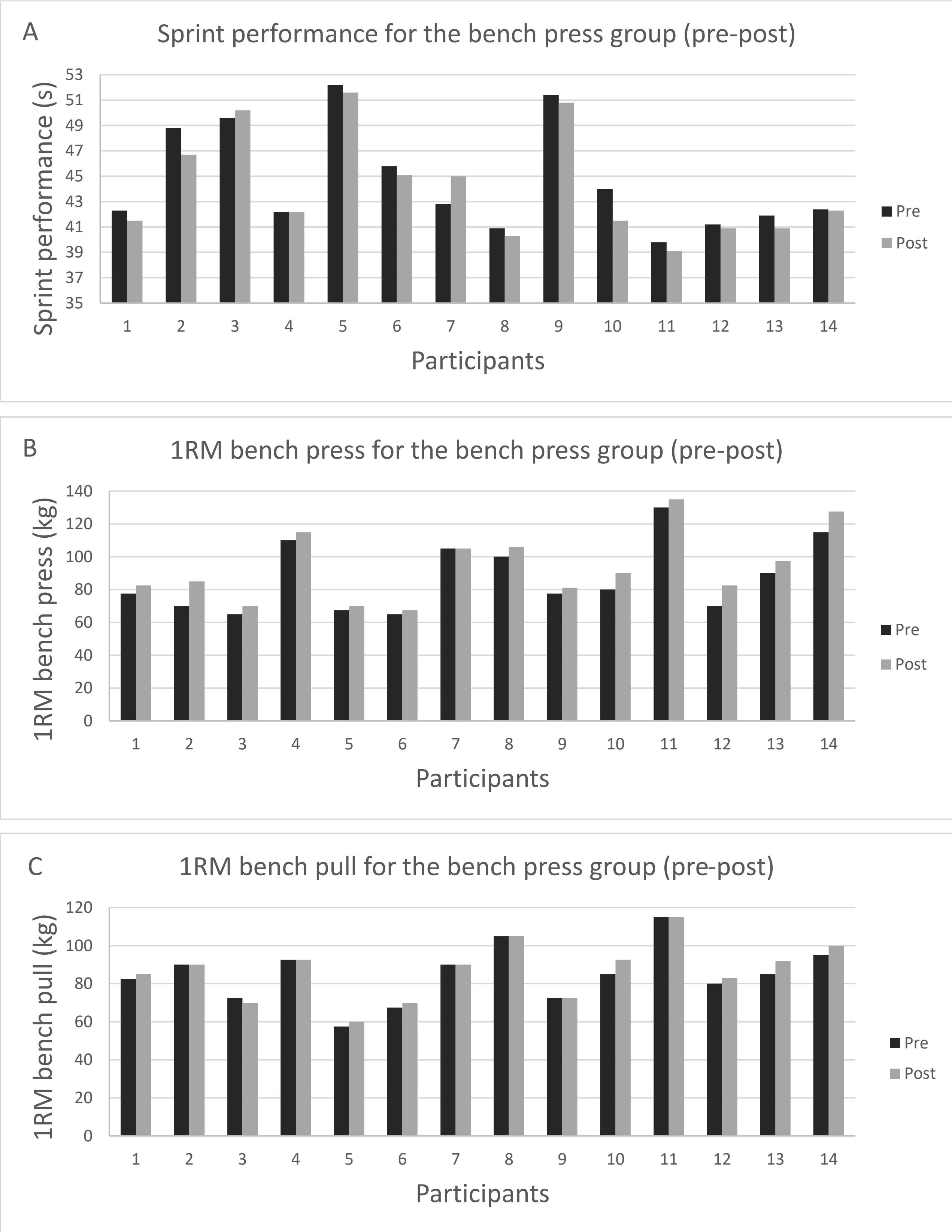

Figure 2: Individual values for 200m kayak ergometer sprint (A), 1RM bench press (B), and 1RM bench pull (C) at pre- and post-testing for the bench press group.

Effect size and power is presented in table 6. For the bench press group, small effect sizes (effect size < 0.30) were seen for 1RM pull ups and maximal repetitions pull ups, medium effect sizes (effect size = 0.3 – 0.5) were seen for 200m kayak ergometer sprint performance (effect size = 0.46) and 1RM bench pull (effect size = 0.43), and large effect size was seen for 1RM bench press (effect size = 1.09). For the maintenance group, small effect size was seen for 200m kayak ergometer sprint (effect size = 0.06) and medium effect sizes where seen for 1RM bench press (effect size = 0.36), 1RM bench pull (effect size = 0.41), 1RM pull ups (effect size = 0.30) and maximal repetitions pull ups (effect size = 0.35).

A strong power value was seen for 1RM bench press (power = 0.96), while all other variables showed low power values (bench press group: 200m kayak ergometer sprint performance; power = 0.36, 1RM bench pull; power = 0.31, 1RM pull ups; power = 0.07, maximal repetitions pull ups; power = 0.06, maintenance group: 200m kayak ergometer sprint performance; power = 0.05, 1RM bench press; power = 0.11, 1RM bench pull; power = 0.13, 1RM pull ups; power = 0.09, maximal repetitions pull ups; power = 0.11).

Table 6: Effect size and power for 200m kayak sprint, 1RM bench press, 1RM bench pull, 1RM pull ups and maximal repetitions pull ups for bench press- and maintenance group.

	200m sprint	1RM bench press	1RM bench pull	1RM pull ups	Max reps pull ups
Bench press group					
Effect size	0.46	1.09	0.43	0.12	0.08
Power (1-B err prob)	0.36	0.96	0.31	0.07	0.06
Maintenance group					
Effect size	0.06	0.36	0.41	0.30	0.35
Power (1-B err prob)	0.05	0.11	0.13	0.09	0.11

Spearman correlation coefficients for the differences in pre and post values, measured in percent, for both 1RM bench press and -pull in relation to 200m kayak ergometer sprint performance for the bench press group are presented in table 8. Significant moderate correlation of the differences in percent was found for 1RM bench press in relation to 200m kayak ergometer sprint performance (-0.467; p = 0.019) while a non-significant moderate correlation was found for 1RM bench pull in relation to 200m kayak ergometer sprint performance (-0.360; p = 0.060).

Table 7: Correlation coefficients of 1RM bench press and 1RM bench pull in relation to 200m kayak sprint for the bench press group

	Correlation coefficients	p-value
1RM bench press	-0.467	0.019
1RM bench pull	-0.360	0.060

Discussion

The aim of this study was to investigate the effect of two different strength training programs on a 200m kayak ergometer sprint performance. The purpose of the training intervention was to increase the maximal bench press strength in the bench press group and maintaining the strength in the other strength tests, while the purpose of the maintenance group was to maintain the strength in all the strength tests. This was done to investigate the effect of increased maximal bench press strength on a 200m kayak ergometer sprint performance, isolated from other strength variables. Results showed significant improvements for the bench press group in 200m kayak ergometer sprint performance, 1RM bench press and 1RM bench pull, with no significant differences in the 1RM pull up or maximal repetitions pull ups tests. No significant changes occurred in any of the tests in the maintenance group (table 5).

Results are in agreement with recent research showing relationships between maximal strength and kayak sprint performance (1,12–14). In previous research, the causal relationship between enhanced strength and kayak sprint performance has only been investigated by Liow & Hopkins, who found similar improvements in a 15m kayak sprint performance, in addition to enhanced maximal upper body strength. As the kayak is accelerating during the paddle stroke, an increase in maximal strength will allow the athlete to overcome greater resistance, which may lead to an enhanced rate of force development (12). Rate of force development is described as the ability to rapidly develop muscular force and is defined as the Δforce per Δtime. It has been suggested, that explosive movements with different time spans are influenced by different physiological parameters, e.g. muscle fiber type, maximal muscle strength, and neural drive to the muscle. (24) In a study by Andersen & Aagaard the relationship between the voluntary contractile rate of force development in different time intervals, from the onset of contraction in relation to maximal muscle strength, was investigated on m. vastus lateralis. The primary findings were that explosive muscle strength became increasingly more dependent on maximal strength, as the time from the onset of contraction increased. (24) In a review by McDonnell et al., the relationships between kayak velocity and different kinematic variables were investigated. where a stroke was defined from the start of the pull phase, to the start of the pull phase on the contralateral side of the kayak paddler. Stroke time is divided into a water phase time, where the paddle is immersed in water, and an aerial phase time, when the paddle is not in contact with the water. Relative water phase time varied from 50% to 65% of the total stroke time, and while a strong negative relationship was found between average water phase time and average kayak velocity ($r = -0.83$, $p < 0.05$), longer relative water phase time has been suggested to be associated with better performance. (25) In the present study, the average stroke rate during the 200m kayak ergometer sprint was 138±13 strokes per minute (post-testing), resulting in an average stroke time at ~440ms per stroke. According to McDonnel et al., the relative water phase time of the stroke during a 200m kayak performance for elite kayak paddlers is in average 55%, calculated from several studies in the review. This means it will take ~240ms to drag the paddle trough the water. In addition to Andersen & Aagaard, this is in agreement with maximal strength being of high importance in the stroke, because of the long contraction time. Furthermore, this supports the findings from unpublish work by the authors, who found that maximal strength, measured on 1RM, had the highest influence on a 30s on-water kayak sprint performance compared to other strength qualities (16).

Effect size describes the effectiveness of the strength training program and is a way to quantify the magnitude of the difference between pre and post for the kayak ergometer sprint and strength tests. The highest effect size was found for 1RM bench press (effect size = 1.09), demonstrating the greatest improvement in bench press (table 6). Further, the power describes the probability of making a type 2 error. The highest power was likewise found for 1RM bench press (Power = 0.96) and explains that there was a 4% probability for a type 2 error, with 69% for bench pull, being the second highest. In the present study, a low power in bench pull is expected, as the purpose for both groups were to maintain maximal strength in bench pull. Further, the power for the sprint test was small, which might be due to the relatively small changes in sprint time and a larger sample size might provide a stronger power for the data. Values for effect size and power suggests that the bench press have had the highest influence on the improvement in sprint performance for the bench press group, in the present study. Further, a moderate association between relative changes in 1RM bench press and 200m kayak ergometer sprint performance was found ($r = -0.467$; $p = 0.019$), while a non-significant moderate association was found between relative changes in bench pull and 200m kayak ergometer sprint performance ($r = -0.360$; $p = 0.060$), which further support enhanced bench press being of higher importance in the improvements in sprint performance (table 7). This is in agreement with an unpublished study by the present authors, where partial least squares regression analysis showed the highest regression coefficient for 1RM bench press, meaning 1RM bench press was the best predictor of the kayak sprint performance. (16) It is suggested by Mann & Kearney, that the most horizontal acceleration of the kayak, is when the paddle is in a vertical position (7). As a consequence, rapidly entering the paddle in this position, after immersion in water, and hold this for as long as possible in the paddle stroke, would be most effective (7). Though, this may not apply to ergometer sprint, due to biomechanical differences as the ergometer might not be affected by the angle of the paddle during the pull. In a study by Fleming et al. EMG, stroke force and 2D kinematic data during on-water and on-ergometer kayaking where compared. For both tasks, time to peak of the stroke was found to occur at the same time as the shaft entered a vertical position, though this happened earlier on the ergometer, than in the paddle stroke on-water. However, it was found that kayak ergometer does not fully replicate the biomechanical demands for on-water performance, as muscle activity and force generation significantly differs between on-ergometer and on-water (26). A strong press segment in the stroke, which involves the same muscles as the bench press (10,11), is needed to quickly reach a vertical position of the paddle (7). It could be argued that a strong press segment would further affect the paddle with more force, which will create a greater moment over the draw hand, as the formula for moment is moment = force * distance from the pivot. In kayaking, the distance will be from the press hand to the draw hand. As this distance is greater than the distance from the draw hand to the water, an increase in bench press might have a greater impact on the moment over the draw hand and thus affecting the water with greater force in the stroke, as force is multiplied by a greater factor. In a study by Timofeev et al., EMG analysis was made on m. latissimus dorsi, m. pectoralis major and m. biceps brachii of Olympic and World championship kayakers on a 1000m on-water kayak distance. The results showed strong intermuscular coordination of the contralateral musculature during both the press- and pull phase. (27) This intermuscular coordination allows the kayak paddler to stabilize the upper-body and thereby transfer force from leg, hip, core, and shoulder girdle rotation, to the paddle, and enhance the propulsive force of the kayak (12). In heavy bench press, the ability to produce force through intermuscular coordination is necessary to keep the intra-abdominal tension (28), and may therefore be transferable to the kayak sprint. Above-mentioned may be in agreement with bench press being of high importance to the paddle stroke, as it results in a stronger press phase, and because of the great intra-abdominal tension.

As seen in figure 1B, the maintenance group had a greater volume of bench pull training throughout the week than the bench press group. However, while the maintenance group did not significantly improve 1RM bench pull, a significant improvement of 2.31% was seen for the bench press group, which might indicate some transferability between the two exercises. It has been shown, that the acute hormonal response from strength training is dependent on the total trained muscle mass, intensity and volume (29,30). As bench press is an exercise that involves a great amount of muscle mass, the high volume and intensity might have contributed to a greater hormonal response for the bench press group, than the maintenance group. Further, m. latissimus dorsi, which is one of the main muscles involved in bench pull (8), is suggested to play an important role in bench press, as a stabilizer (31). These factors may have played a role in the increased 1RM bench pull strength for the bench press group, even though this was not the intention of the strength training program.

After the intervention, inter-individual differences in maximal strength gain was found, even though participants in each group followed the same strength training program. The strength gain in maximal bench press for the bench press group ranged between 0 - 21.4% (mean: 8.0% ± 5.9%), which indicate that they had different responses to the strength training. In other studies, inter-individual differences following strength training have also been found (32,33). Marshall et al. investigated the effect of six weeks of squat exercise (80% of 1RM) with either one, four, or eight sets of repetition to failure performed twice a week, on three groups of strength trained participants. The group with eight sets, improved the 1RM squat strength more than the other groups ($p < 0.05$). After the intervention, participants were sub-divided as either high, medium, or low strength responders (%increase in bodyweight-normalized squat strength), with all sub-groups present in both the one-, four-, and eight sets training group. No differences were seen in training experience, age, body weight, lean body mass, relative body fat, thigh and leg length, squat strength, muscle activation, rate of force development, and energy intake between the sub-groups at baseline test, suggesting that other factors contributed to the individual strength gains. (32) Results from Balshaw et al. showed a moderate negative correlation ($r = -0.429$, $p = 0.023$) between pre-training strength and the percentage change in maximal voluntary isometric contraction in knee extension after 12 weeks of strength training. This means that the participants with lower pre-training strength increased maximal voluntary contraction relatively more than the participants with greater pre-training strength, and it is pointed that pre-training strength plays a role in the strength responses after a training period. (33) Other factors that could have contributed to the inter-individual differences, is the intensity of which the individual training was executed. The intensity for each set throughout the intervention was the same for all participants, but the perception of how many repetitions each participant had in reserve could be different. During the supervision of the strength training, the participants were encouraged to notice the specific RPE, and adjust the weight on the barbell accordingly, to secure the correct intensity.

When evaluating sprint performance in sports, time or distance is often used as measurements. In the present study, the kayak performance was measured on a 200m sprint, as this is now an Olympic distance. According to Gastin, who reviewed the anaerobic and aerobic contribution during maximal exercise in different sports, the longer the duration, the greater percentage of the energy is delivered from the aerobic system (2). Consequently, the energy delivered by the anaerobic system, at the 200m sprint distance, may be greater for the faster athletes. Time of the pre 200m sprint performance varied from 39.2 to 52.2s, which results in contributions from the anaerobic system between 55 and 73% (2). In theory, participants who had a longer sprint time, may be more dependent on maximal aerobic power (VO_2max), which is limited by the cardiorespiratory system. (4) To take this into account, A Mann Whitney U test was used to test for statically significant differences in sprint time between groups, prior to the intervention (table 4). In future studies, sprint test could be executed on a fixed time to ensure as similar aerobic/anaerobic contribution as possible for all athletes. In the Olympic games in Rio in 2016, the winning time in the K1 200m sprint was 35.197s for men and 39.864s for women, and a fixed time could be set at 35s for men and 40s for women, to more accurately imitate the same energy contributions which are required for the best paddlers in the world.

In relation to assessing performance in sports, it is optimal to test in the natural environment and under competing conditions. However, as testing took place in February, it was challenging to make a standardized set-up for evaluating a 200m on-water sprint performance because of factors such as water- and air temperature. In kayaking, ergometry systems have been shown to provide a valid representation of the kinematics and physiological demands of the sports, and therefor gives a reliable alternative for performance testing. (34) Further, in un-published work by the authors, a strong correlation (r = 0.853) was found between a 30s ergometer and on-water sprint performance. Therefore, a kayak ergometer was implemented in the present study design.

In the present study, the participants' strength training was supervised, in a specific timespan, two days a week. However, not all participants executed the strength training in this time period, because of personal matters such as work or school, and instead trained in another time of day or another day. In total, 111 of 341 training sessions were supervised during the intervention. During unsupervised training, it is unclear to the authors, if the program has been followed, though, participants reported that every training has been followed, with the right intensity and volume, with no additional strength training. Further, the participant's normal kayak training was not controlled or supervised, and it is therefore unclear if a part of the improvements in sprint comes from an increase in normal kayak training volume or intensity. However, the participants were divided into two training groups, with the same percentage of participants from each kayak center in each group, to make up for possible differences in normal kayak training regimes between kayak centers.

In conclusion, six weeks of heavy bench press training, improved the 200m kayak ergometer sprint performance, while six weeks of maintaining strength in bench press and -pull resulted in no improvements for the 200m kayak ergometer sprint performance. Results are in agreement with the hypothesis that increased maximal bench press strength will result in improved 200m kayak ergometer sprint performance. From this study it cannot be ruled out, if an enhancement in only 1RM bench press or -pull strength, isolated, will improve a 200m kayak ergometer sprint performance, as significant differences were shown in both exercises.

Practical application

In kayaking, strength training is a common component of training and preparation to competition, and sports scientists and coaches aim to select training with the highest probability of improving an athlete's performance. From the present study it has been highlighted that 200m sprint kayak paddlers should focus on enhancing maximal bench press and -pull to improve 200m kayak performance. Even though, the participants of the present study demonstrated improvements in maximal bench press strength of 7.52% ± 5.9% on average, athletes following the same protocol might not experience the same improvements, due to different physiological factors or training experience, and therefor training protocols should always be adapted to the individual athlete.

In the Olympic Games in Tokyo in 2020, K4 500m will be a competing discipline, and future research would be relevant to investigate the demands of different strength qualities in addition to performance in this distance. Using video of the men's K4 500m finals in the World Cup 2019, the average stroke rate of the participating teams was counted, by the present authors, to approximately 140 strokes per minute. As the stroke rate in K4 500m is very similar to the average stroke rate seen in the present study, it is relevant to consider that maximal bench press and -pull strength might have a high importance in performance, as it has been shown for the 200m kayak ergometer sprint.

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