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Section: Original Investigation

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Authors: Mark R McKean and Brendan J Burkett

Affiliations: School of Health and Sport Science, Faculty of Science, Health and Education, University of Sunshine Coast, Queensland, Australia.

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THE INFLUENCE OF UPPER BODY STRENGTH ON FLAT-WATER SPRINT KAYAK PERFORMANCE IN ELITE ATHLETES

Submission Type: Original Investigation

Authors:

Mark R McKean and Brendan J Burkett

School of Health and Sport Science,

Faculty of Science, Health and Education,

University of Sunshine Coast, Queensland, Australia

Corresponding Author:

M. R. McKean – mmckean@usc.edu.au,

Research Fellow – School of Health and Sport Science, Faculty of Science, Health, Education and Engineering, University of Sunshine Coast

Phone - +61 7 5456 5528, Fax - +61 7 5459 4600

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Abstract

Dry-land strength training is a fundamental component for elite kayak performance. The aims of this research were three-fold; firstly, to determine the relationship between performance time and strength scores for elite kayakers. Secondly, to identify how strength changes (gains or losses) over three training years relate with changes in performance time for elite kayakers. Thirdly, to compare the progression in performance times for elite athletes with the top three performers from the national championships. The performance data for 15 elite male kayakers and 10 elite females was collected over a two year timeframe. This group was reduced to nine males and eight females in the third and final year. There were direct and significant correlations between strength scores and performance times across a three year period. Bench-Press 1RM increased by 34.8% for males and 42.3% for females. Over the three seasons, the mean 1000-m time decreased by approximately 4.8%, 500-m times decreased by 7.3% (females), and 200-m times reduced 9.1%. The women K1 500-m moved from 11.9% difference to medallist to within 1.1%, during the 3 years. During the three years of this study a change in 1RM Bench-Press of 13% for males and 6.5% in females coincided with a change in performance times of 1%. For 1RM Pull-Up a change of 10% in males and 2.3% in females coincided with a change in performance times of 1%.

Key Words: 1RM, Bench-Press, Pull-Up, Strength-Ratio

Introduction

Recent changes to flat-water sprint kayaking for the 2012 London Olympic Games resulted in males and females competing over different distances. Males (K1) compete in the 1000-m and 200-m events, females (WK1) in 500-m and 200-m distances. Whilst the distances are not new to kayaking, the removal of the 500-m for males and 1000-m for females may see a change in the athlete preparation, in particular their associated strength training program. The race times for male events are quite different in terms length ranging from 35 seconds for the 200-m up to 3 minutes 30 seconds 1000-m respectively. For females the times range from 45 seconds and 1 minute 50 seconds for the 200-m and 500-m respectively. These ranges therefore generate different physiological demand [1]. The different power requirements may naturally evolve to more event-specific dry-land training.

Elite flat-water kayakers have a blend of unique physiological traits including specific anthropometrical measures, high aerobic and anaerobic capacities, combined with upper body strength [2-5]. When comparing Olympic level kayakers between the 1976 Montreal and the 2000 Sydney Games there have been some distinct morphological changes in upper body structure, specifically increases in chest and upper arm girths, as well as lean muscle mass [5]. An increase in body weight can be detrimental to performance in body weight related sports, such as flat-water sprint kayak, due to associated changes in drag and possible reductions in power-to-weight ratios. The two new distinct race distances for males (200-m and 1000-m), may now see further change and the evolution of two different strength-to-performance athlete profiles.

Dry-land resistance strength training and the assessment of strength measures is a essential component of elite kayak training [6-8]. Typically elite flat-water sprint kayakers use strength training to further develop their strength and/or stability in specific body regions.

Explosive resistance training has been shown to enhance the rapid development of force and speed maintenance, while slow resistance training was more suitable for the acceleration phase of starting in sprint kayaking [9,10]. With respect to the mechanics of the kayak stroke, strengthening within the 'pull' and 'push' motions have been highlighted as important [7]. Differences between gender for this 1RM pull-to-push strength ratio has been identified as 1.3 for males and 1.5 for female sub-elite kayakers [8]. For elite juniors kayakers the 1RM barbell bench-press and one-arm cable row were good predictors for the start phase in kayaking, an aspect that is certainly more critical in the shorter 200-m event [7]. The authors of this recent research suggest however that whilst these scores may be good predictors for the start phase, the relationship with on-water performance is not known and has not been reported in elite senior athletes.

Due to the nature of elite athletes and sport, longitudinal studies on strength training and subsequent changes to performance are difficult to track. There are limited (if any) published longitudinal studies on sprint kayaking and the role of strength training. To address this issue, the aims of this research were three-fold; firstly, to determine the relationship between performance times and strength scores for elite kayakers. Secondly, to compare strength changes (gains or losses) over three training years with changes in performance times for elite kayakers. Thirdly, to compare changes in performance times of the athletes in the research group with the top three performers from the national championships.

Methods

Subjects- The project commenced with 15 elite male (K1) kayakers (21.8 years ± 5.5) and 10 elite females (WK1) (18.8 years ± 3.6) in the initial two years (years 1 and 2). This group was reduced to nine males (24.8 years ± 5.5) and eight females (21.8 years ± 3.6) in the third and final year of the project. All kayakers were members of the national teams program and had competed internationally. All participants gave informed consent prior to commencement of the institutional ethics committee approved study.

Design- Experimental design involved a longitudinal descriptive study.

Methodology- Participants height (cm), weight (kg), and baseline strength measures were assessed two weeks prior to national titles over the course of three consecutive years, resulting in four data sets; start of year 1 (Baseline), and end of years 1, 2, and 3. Performance times for all participants, to the nearest tenth of a second, were taken over 200-m, 500-m and 1000-m from official race times recorded at Australian National Titles. All athletes had not yet specialised in any specific distance and as such had no preferred race distance. The average race time of the three medallists for each event was used to determine the differences between the athletes in the research group and the top three performers each year. The direct comparison made within the same event enabled the event-specific conditions to be normalised between athlete groups.

Maximal strength (1RM) testing was conducted using standard Olympic bars, plates and collars (Australian Barbell Company Melbourne, Australia). These methods were similar to those previously reported.[7,8,11] Following a graduated warm up, 1RM-Bench-Press and 1RM-Pull-Up were used to test strength and to define the Pull-Push ratio. Width of grip for both exercises was set at bi-acromial width. Following a warm up set, four sets of decreasing reps (4,3,2,1) with increasing load (50%, 70%, 90%, 95%) were performed before 1RM was attempted. Several 1RM attempts were then allowed with four minutes rest between each trial. Tempo was controlled at 2-3 seconds descent, athlete's self-selected tempo for ascent phase. The sum of body weight plus any additional weight lifted was included for the 1RM Pull-Up test. A single rep was counted if the chin was raised above the bar, tempo controlled to the lowered position. A complete repetition for the Bench press was counted if the tempo was controlled correctly during descent and the bar touched the chest before being pressed to full elbow extension. A certified strength coach provided correct protocol and spotting during the tests.

The annual periodised training program was based on a national competitive season from December to March, the international competitive season continued through to August. The training plan followed a general training period (May to September), a specific training period (September to January) and competitive period (January to March). A typical training week during the general training period involved three to four strength sessions, 60-70 minutes each. The sessions consisted of 6-8 repetitions (3-4 second eccentric and 1-2 second concentric tempo), 4-6 sets, 75-85% 1RM with 60-90 second inter-set rests. The specific training period involved three strength sessions lasting 50-60 minutes. These sessions used 3-6 repetitions (2-3 second eccentric and dynamic concentric tempo), 4-6 sets, 85-95% 1RM with 90-120 second inter-set rests. The competitive period involved two strength sessions lasting 50 minutes each, using 4-8 repetitions (1-2 second eccentric and dynamic-explosive concentric tempo using bands), 4-6 sets, 65-80% 1RM with 120 second inter-set rests. Strength programs typically involved six exercises performed as pairs completed in a super-set style. Strength training sessions were preferentially arranged before on-water sessions, or after at least half a day rest. Key movements such as bench pull, pull ups, bench press and a range of rotational core strength exercises were common to all programs.

Statistical Analysis- A multi-factor ANOVA between male and female kayakers was conducted across each of the four data sets (3 year time frame) to determine significant differences across gender. A Pearson's correlation analysis ($p<0.05$) was conducted between all strength measures and performance times for both male and female kayak data, across all four data sets. A moderate correlation was defined as $0.40 > r < 0.69$, strong $0.70 > r < 0.89$ and excellent $r > 0.90$. A Crossover Effect statistical analysis was conducted to determine both raw and percentile change between the following groups; Baseline to Year 1, Year 1 to Year 2, Year 2 to Year 3, and Baseline to Year 3 data sets. . Cohen’s *d* effect sizes were defined as: 0.21>*d*<0.5 small, 0.51>*d*<0.8 medium and *d*>0.8 large.

Results

The results for the strength scores and performance scores are presented in Table 1. There were significant differences across all but one measure, the Pull-Push ratio for year 3 between genders. The mean values for each gender also show the kayakers became, taller, heavier, and stronger across the three seasons. Over this time frame the mean value of Pull-Up 1RM increased by 30.5% for males, and 13.4% for females. Similarly, Bench-Press 1RM increased by 34.8% for males and 42.3% for females.

Kayakers’ performance times across the three seasons are presented in Table 2, along with the comparison of the participant’s performance times with respect to the national championship event medallists from the same event. Over the course of the three seasons, the mean value of 1000-m decreased by 4.7% for males and 4.9% for females. Similarly, 500-m times decreased by 3.7% for males and 7.3% for females, and 200-m times reduced 5.4% and 9.1% respectively. The mean value of the group improved their times with males less than 6% off the average time of the medallists for each event and females less than 4% difference.

Pearson correlations between Kayakers’ performance and strength scores for each year and overall across the three seasons are presented in Table 3. Males achieved equally strong correlations for both Pull-Up 1RM and Bench-Press 1RM to performance times, whilst females achieved strong correlations only for the Bench-Press 1RM to performance times. Changes between each year, in terms of raw data and percent effect statistics, presented for males in Table 4 and females in Table 5.

Discussion

The first aim of this research was to determine the longitudinal (36 month) changes in performance time and strength scores for elite kayakers. The strength improved substantially over the course of the three seasons, with males improving each maximal score by approximately 30%. This was also reflected in the Pull-Push ratio, with a similar average across the three seasons of approximately 1.3. Female kayakers increased Bench-Press 1RM by a massive 42.3% over the three seasons, which was quite different to the changes in Pull Up 1RM of only 13.4%. Pull-Push ratio decreased steadily over the three seasons from 1.7 to a value of 1.3 similar to that of males. Using a slightly different version of 1RM strength testing, the Bench Pull (row) and Bench Press for eleven male Turkish kayakers, Akca and Muniroglu (2008) found a Pull:Push ratio of 1.04. Whilst a ratio of 1.10 was reported for eight high performance young adolescent kayakers [12]. Over the course of this study it appears that male kayakers tended to remain at or around a Pull:Push ratio of 1.30, and females approached this same ratio by the end of the third year. The authors suggest that a common Pull:Push ratio as described in this research of 1.30 may exist and coaches should consider identifying this ratio in sprint kayak paddlers as part of the strength and conditioning program. As these measures were tracked across a three year period, it may also suggest that as paddlers mature this ratio may stabilise, however the exact ratio of the world's best paddlers may differ again due to their longevity in sprint kayaking.

There were large changes in strength for males Pull-up 1RM (d=1.07) and Bench Press 1RM (d=0.87). Similarly large changes for females were also found for Pull-up 1RM (d=0.90) and Bench Press 1RM (d=2.15). The current study reports strength scores at the seasons end rather than after any specific period of training where 1RM was the focus. It would be expected that 1RM strength would be at its highest during the specific training period and reduce due to altered training focus during the competitive period [13]. In a study involving 11 elite male kayakers there were significant change in both 1RM values for Bench Press (4.2%, P<0.05) and Prone Bench Pull (5.3%, P<0.05) after a periodised 12 week training cycle [14]. No previous literature has been found on strength changes in elite female sprint kayak paddlers.

Both strength scores for males achieved moderate to strong significant correlations for both year 1 and year 2, as well as overall across the three seasons for all three distances. Year 3 strength scores for males achieved no significant correlation, this suggested that changes in performance times in third year related to factors other than changes in strength. This may be due to the concept that kayak paddling may require a specific level of strength, and once achieved changes in strength are not related to improvement in performance times. Whilst strength scores changed by a similar amount each year; approximately 10kg; the lack of any significant correlation in year 3 suggests peak strength may have already been achieved. Further this may indicate that in developing sprint kayakers strength changes may coincide with changes in performance but not necessarily be directly responsible for those changes due to the many factors of training that result in increased performance times. Once reached these strength levels may simply underpin overall performance rather than be directly attributable to them.

The second aim of this research was to identify how strength changes (gains or losses) over three training years compared with changes in performance times for elite kayakers. Female kayakers achieved much smaller raw changes in overall strength especially in Pull-Up 1RM. However females achieved strong significant correlations between both strength measures and the 500-m and 200-m distances in years 1 and 2; and strong to excellent significant correlations with all three distances in year 3. Female kayakers also decreased their average performance times by almost double the percentage in the 500-m and 200-m events, when compared with males in years 2 and 3. Bench-Press 1RM for females achieved regular and similar changes in the strength of correlations across the three years with excellent significant correlations for 1000-m and 500-m distances, and a strong significant correlation for the 200-m distance in the final year. The initial Bench-Press scores for females in this study may reflect the lack of strength training typically performed by females through developmental stages of training. As females reach national level it is more common for them to undertake regular strength training and this may explain why this measure improved most over the course of the three year study.

Bench-Press 1RM scores reported for this group in year 3 is similar to previously reported national level female kayakers. [8,9] However, in these studies no correlations between strength scores and performance times were indicated, which is different to the current study where several correlations of strength and performance times were found in both males and females across all distances. These results show that in this group of kayak paddlers there were direct and significant correlations between strength scores and performance times across the three year period. It is not expected that this relationship is open-ended, instead training time may limit continued strength improvement. It may be that an ideal level of strength could be reached and then maintained in the long term kayak athlete. Further, these athletes in this study were of an age where growth was still occurring and changes in body composition expected. Relative changes in times and strength were also expected for athletes during their early career and in more established or successful athletes these growth related changes will not occur[15].

The final aim of this research was to compare changes in performance times of the research group with the top three performers from the national championships. The times of the medallists were used to account for conditions such as variations in water, wind direction, and other environmental factors. The average times for the current research participants approached the average time of the three medallists with regular decrements each year.

During the past four year Olympic cycle the Men's K1 500-m, and Women's K1 1000-m distances were not a focus, as they were not an Olympic event. These events resulted in the smallest amount of change cross the three year period, and the greatest difference between the participant group and medallists in the final year (year 3). Across the three years for males there was an effect statistical increase in the key predictor of Pull Up 1RM of nearly 30% (P=.002) and a large Cohen's effect decrease in performance times (d>.08)

Males reduced K1 1000-m time differences by 5.6% across the 3 years to be within 4.5% of the medallists during the final year (d=-1.88). Similarly males reduced K1 500-m times by 3.3% to draw within 5.4% of the top three during the final year (d=-1.88). Whilst the times of the medallists performances varied by less than 2 seconds across the three years for males, the participant group reduced the time deficit considerably. Across all events for male kayakers there was a large (d>.0.8) decrease in differences between the participant group and medallists for all events. Female kayakers reduced the difference for Women's K1 500-m time by 11.9% across the 3 years to be within 1.1% of the medallists with Cohen's effect changes of -1.49, -0.77, -0.35 respectively over each year. For the Women's K1 200-m times the deficit was reduced by 6.7% to draw within 3.2% of the medallist's average times with equally large changes each year of -1.21, -2.68, and -1.14 respectively. Across the three years for females there was an effect statistical increase in the key predictor of Bench Press 1RM of nearly 47% (P<.001) and effect statistical decrease in performance times.

Bonetti and Hopkins suggest that between seasons and across 'A' finalists there is very little change from race to race and season to season as most athletes try their best at the elite level. In order to move into medal contention a kayaker must improve their time by 0.3%. When enhancing physiology, Bonetti and Hopkins suggest a change in power in the order of 0.9% is required to achieve a time improvement of 0.3%. Pull up 1RM improved by nearly 30% for males and 17% for females and Bench press 1RM improved by 38% and 47%

respectively across the three years of this study. This was matched with changes in performance times of 2.5-3.1% across all distances during the same time for males and 5.0-9.3% for females. Overall performance times as an average for all distances decreased by 2.9% for males and 7.3% for females across the three year period. This is an improvement against the top 3 paddlers in the country and this cohort from 10% in year 1 to just under 5% in year 3 for males and 11.1% to 2.5% for females. During the three years of this study a change in 1RM Bench-Press of 13% for males and 6.5% in females coincided with a change in performance times of 1%. For 1RM Pull-Up a change of 10% in males and 2.3% in females coincided with a change in performance times of 1%. The results of this study suggest strength has an important role to play in developing elite athletes and providing a foundation to long term elite performance times.

Practical applications

The results of this study show several strategies that would benefit coaches. Firstly a Pull:Push ratio of 1.3 was achieved after the three years and suggests that for sprint kayakers this ratio of upper body strength may be important in strength training. There is also good evidence to show that changes in strength are linked to worthwhile changes in performance times in developing elite athletes. During early years of elite kayakers, strength training would play an important role in developing the physique and strength of an elite kayaker. A limitation of this longitudinal athlete study is participant drop out. Our participant numbers changed over the three years and this may influence the results as only the successful kayak paddlers remained in training for the three years. Future research may require a greater cohort of paddlers to allow for drop out and retain higher numbers after the three years.

Conclusion

Strength training has long been associated with sprint kayaking. For the first time significant correlations between strength measures and on-water performance times across a three year period have been identified in developing elite athletes. Changes in strength coincided with improved times and Cohen's effect showed large reductions in time differences between the participants and medallists at national level. Strength training appears to have an important role to play in developing the physical attributes required for elite level performance times in sprint kayaking

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Table 1 - Kayakers' height, weight and strength scores presented as mean (SD).

Males	**Baseline measures N=15**	**Year 1 N=15**	**Year 2 N=15**	**Year 3 N=9**
Height (cm)	181.4 (9.5)	183.4 (8.4)	185.1 (7.4)	187.7 (7.2)
Mass (kg)	78.9 (11.4)	81.6 (10.9)	83.9 (7.2)	87.5 (4.3)
1RM PU (kg)	102.5 (24.0)	112.1 (24.3)	122.8 (17.2)	133.8 (15.8)
1RM BP (kg)	75.9 (25.1)	85.6 (24.4)	96.8 (16.6)	102.3 (13.5)
PU:BP Ratio	1.41 (0.25)	1.34 (0.17)	1.28 (0.11)	1.31 (0.06)#
Females	**Baseline measures N=10**	**Year 1 N=10**	**Year 2 N=10**	**Year 3 N=8**
Height (cm)	169.5 (8.1)	170.8 (8.3)	171.7 (8.2)	172.6 (8.6)
Mass (kg)	64.3 (8.5)	65.2 (8.0)	65.7 (6.5)	68.0 (6.0)
1RM PU (kg)	68.4 (11.4)	74.8 (9.8)	77.3 (10.0)	77.6 (9.7)
1RM BP (kg)	41.6 (7.8)	48.5 (9.0)	54.0 (7.0)	59.2 (5.9)
PU:BP Ratio (%)	1.67 (0.29)	1.57 (0.22)	1.44 (0.16)	1.31 (0.08)#

There was a significant difference between genders ($p<0.01$) for all measures in Table 1 EXCEPT PU:BP Ratio (%) in year 3 shown by #

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Table 2 - Kayakers' performance times (seconds) comparing participants with national championship event medallists from the same event presented as mean (SD), effect change presented in raw data and percent presented as mean (±95%CI), significance (P), and Cohen (d).

Males	Year 1 N=15	Year 1 medallists	Effect change in Raw Data	Effect change as %	Year 2 N=15	Year 2 medallists	Effect change in Raw Data	Effect change as %	Year 3 N=9	Year 3 medallists	Effect change in Raw Data	Effect change as %
K1 1000-m	239.3 (19.5)	218.2 (0.7)	-21.1 (10.8) P=.001 d=-1.45	-8.6 (4.4) P<.001 D=-1.54	234.8 (6.8)	220.2 (2.9)	-14.5 (5.7) P<.001 d=-2.65	-6.2 (2.5) P<.001 D=-2.68	228.6 (5.8)	219.5 (2.7)	-9.1 (5.7) P=.006 d=-1.86	-4.0 (2.6) P=.008 d=-1.88
K1 500-m	113.5 (10.1)	103.2 (0.6)	-10.3 (5.6) P=.002 d=-1.36	-8.7 (5.0) P=.001 d=-1.41	109.1 (3.3)	101.8 (0.6)	-7.2 (2.0) P<.001 d=-2.86	-6.6 (1.9) P<.001 d=-2.94	109.5 (4.0)	103.6 (1.2)	-6.0 (3.4) P=.003 d=-1.86	-5.4 (3.2) P=.003 d=-1.88
K1 200-m	42.6 (3.7)	36.9 (0.3)	-5.8 (2.1) P<.001 d=-2.09	-13.3 (4.9) P<.001 d=-2.26	40.7 (1.7)	37.5 (0.3)	-3.2 (1.0) P<.001 d=-2.60	-7.9 (2.5) P<.001 d=-2.66	40.4 (1.7)	38.3 (.02)	-2.1 (1.3) P=.006 d=-1.61	-5.2 (3.3) P=.006 d=-1.63
Females	**Year 1 N=10**	**Year 1 medallists**	**Effect change in Raw Data**	**Effect change as %**	**Year 2 N=10**	**Year 2 medallists**	**Effect change in Raw Data**	**Effect change as %**	**Year 3 N=8**	**Year 3 medallists**	**Effect change in Raw Data**	**Effect change as %**
WK1 1000-m	276.2 (25.6)	246.5 (5.1)	-29.7 (19.2) P=.006 d=-1.48	-10.5 (7.0) P=.005 d=-1.58	268.6 (11.4)	251.3 (2.9)	-17.3 (8.8) P=.001 d=-1.92	-6.4 (3.4) P=.001 d=-1.95	263.2 (11.9)	254.2 (4.3)	-9.0 (11.3) P=.103 d=-0.91	-3.3 (4.4) P=.105 d=-0.91
WK1 500-m	132.8 (15.6)	114.8 (0.6)	-18.0 (11.2) P=.006 d=-1.49	-13.0 (8.5) P=.004 d=-1.59	123.5 (5.5)	120.1 (1.8)	-3.4 (4.5) P=.013 d=-0.77	-2.6 (3.7) P=.134 d=-0.75	123.8 (5.1)	122.3 (0.9)	-1.5 (4.3) P=.443 d=-0.37	-1.1 (3.6) P=.469 d=-0.35
WK1 200-m	50.3 (5.9)	45.0 (0.5)	-5.3 (4.3) P=.022 d=-1.44	-9.9 (8.5) P=.017 d=-1.21	47.0 (1.9)	42.7 (1.0)	-4.3 (2.1) P=.002 d=-2.64	-9.2 (5.0) P=.004 d=-2.68	46.1 (1.8)	44.6 (0.6)	-1.5 (1.7) P=.071 d=-1.03	-3.2 (3.7) P=.075 d=-1.14

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Table 3 – Pearson correlations between Kayakers' performance and strength scores for each year and overall across the three seasons.

Males	**Year 1**			**Year 2**			**Year 3**			**Overall**		
	K1 1000-m	**K1 500-m**	**K1 200-m**	**K1 1000-m**	**K1 500-m**	**K1 200-m**	**K1 1000-m**	**K1 500-m**	**K1 200-m**	**K1 1000-m**	**K1 500-m**	**K1 200-m**
Pull Up 1RM	**-.71****	**-.82****	**-.87****	**-.69****	**-.60***	**-.69****	-.55	-.55	-.43	**-.70****	**-.73****	**-.79****
Bench Press 1RM	**-.66****	**-.79****	**-.85****	**-.62***	**-.55***	**-.56***	-.54	-.42	-.27	**-.66****	**-.71****	**-.76****
Pull-Push Ratio	.37	.46	**.55***	.10	.13	-.01	.11	-.23	-.35	.32	**.39***	**.41****

Females	**Year 1**			**Year 2**			**Year 3**			**Overall**		
	K1 1000-m	**K1 500-m**	**K1 200-m**	**K1 1000-m**	**K1 500-m**	**K1 200-m**	**K1 1000-m**	**K1 500-m**	**K1 200-m**	**K1 1000-m**	**K1 500-m**	**K1 200-m**
Pull Up 1RM	-.56	**-.78****	**-.75***	-.63	**-.73***	**-.79****	**-.85****	**-.78***	**-.71***	**-.59****	**-.66****	**-.63****
Bench Press 1RM	-.56	**-.75***	**-.71***	-.52	**-.81****	**-.79****	**-.97****	**-.91****	**-.84****	**-.64****	**-.75****	**-.74****
Pull-Push Ratio	.21	.27	.24	-.13	.12	.03	-.16	-.11	-.07	.24	.35	.36

** Correlation is significant at 0.01 level (2-tailed), * Correlation is significant at 0.05 level (2-tailed)

A moderate correlation was defined as 0.40 > r < 0.69, strong 0.70 > r < 0.89 and excellent r > 0.90

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Table 4 - Changes between each year, in terms of raw data and percent effect statistics, presented as mean (±95%CI), significance (P), and Cohen (d), for males.

	Baseline to Year 1		**Year 1 to Year 2**		**Year 2 to Year 3**		**Baseline to Year 3**	
Males	**Effect change in Raw Data**	**Effect % change in Raw Data**	**Effect change in Raw Data**	**Effect % change in Raw Data**	**Effect change in Raw Data**	**Effect % change in Raw Data**	**Effect change in Raw Data**	**Effect % change in Raw Data**
Height (cm)	2.0 (1.4) P=.007 d=.21	1.1 (0.8) P=.007 d=.22	1.8 (1.3) P<.001 d=.19	1.0 (0.7) P=.010 d=.19	0.7 (0.9) P=.086 d=.08	0.4 (0.5) P=.088 d=.08	4.8 (4.6) P=.043 d=.51	2.7 (2.60) P=.043 d=.51
Weight (kg)	2.7 (2.7) P=.051 d=.24	3.6 (3.5) P=.045 d=.24	2.3 (2.7) P=.090 d=.20	3.3 (3.5) P=.058 d=.22	2.0 (3.9) P=.281 d=.17	2.7(5.1) P=.261 d=.18	6.8 (8.2) P=.093 d=.60	9.6 (11.39) P=.084 d=.61
1RM PU (kg)	9.7 (3.6) P<.001 d=.40	9.8 (3.5) P<.001 d=.38	10.7 (6.3) P=.003 d=.44	11.1 (7.1) P=.005 d=343	6.7 (4.7) P=.011 d=.28	5.4 (3.7) P=.010 d=.22	28.4 (11.6) P<.001 d=1.18	29.9 (14.0) P=.002 d=1.07
1RM BP (kg)	9.6 (4.1) P<.001 d=.38	14.6 (5.6) P<.001 d=.37	11.3 (5.6) P<.001 d=.45	16.5 (9.2) P=.002 d=.41	4.0 (4.1) P=.056 d=.16	4.8 (5.0) P=.058 d=.13	24.4 (12.0) P=.002 d=.97	38.1 (13.0) P=.006 d=.87
PU:BP Ratio	-0.07 (0.08) P=.068 d=-.28	-4.2 (5.5) P=.106 d=-.24	-0.07 (0.07) P=.067 d=-.27	-4.6 (5.3) P=.069 d=-.26	0.01 (0.06) P=.837 d=-.02	0.6 (4.9) P=.775 d=-.03	-0.09 (0.16) P=.202 d=-.37	-6.0 (11.5) P=.231 d=-.34
K1 1000-m (sec)			-4.6 (8.3) P=.340 d=-.23	-4.8 (3.3) P=.375 d=-.22	-3.6 (2.6) P=.032 d=-.39	-1.5 (1.1) P=.032 d=-.40	-7.6 (8.1) P=.121 d=-.18	-3.1 (3.5) P=.130 d=-.20
K1 500-m (sec)			-4.5 (4.3) P=.089 d=-.44	-3.6 (3.7) P=.096 d=-.43	2.2 (1.7) P=.039 d=-.30	2.0 (1.6) P=.041 d=-.29	-3.0 (5.0) P=.294 d=.22	-2.5 (4.6) P=.328 d=.23
K1 200-m (sec)			-2.0 (1.2) P=.015 d=-.53	-4.3 (2.7) P=.012 d=-.53	0.4 (0.8) P=.406 d=-.37	0.9 (1.9) P=.403 d=-.37	-1.4 (1.5) P=.134 d=.10	-3.1 (3.7) P=.144 d=.11

Cohen's d effect sizes were defined as: 0.21>d<0.5 small, 0.51>d<0.8 medium and d>0.8 large

Table 5 - Changes between each year, in terms of raw data and percent effect statistics, presented as mean (±95%CI), significance (P), and Cohen (d), for females.

	Baseline to Year 1		**Year 1 to Year 2**		**Year 2 to Year 3**		**Baseline to Year 3**	
Females	**Effect change in Raw Data**	**Effect % change in Raw Data**	**Effect change in Raw Data**	**Effect % change in Raw Data**	**Effect change in Raw Data**	**Effect % change in Raw Data**	**Effect change in Raw Data**	**Effect % change in Raw Data**
Height (cm)	1.3 (0.8) P=.005 d=.16	0.8 (0.5) P=.005 d=.16	0.9 (.07) P=.019 d=.11	0.5 (1.0) P=.020 d=.11	1.4 (2.0) P=.145 d=.17	0.8 (1.2) P=.150 d=.17	4.0 (3.0) P=.017 d=.49	2.4 (4.2) P=.019 d=.49
Weight (kg)	1.0 (3.0) P=.494 d=.11	1.60 (6.8) P=.500 d=.12	0.5 (1.5) P=0.499 d=.06	1.0 (2.4) P=.371 d=.07	2.6 (1.5) P=.005 d=.31	4.2 (2.5) P=.006 d=.31	5.1 (4.6) P=.035 d=.59	8.3 (7.4) P=.033 d=.61
PU (kg)	6.4 (2.8) P<.001 d=.56	9.9 (4.7) P=.001 d=.55	2.4 (3.2) P=.117 d=.21	3.2 (4.0) P=.100 d=.19	1.3 (1.9) P=.144 d=.11	2.0 (2.3) P=.088 d=.11	10.6 (5.0) P=.002 d=.94	16.7 (8.6) P=.003 d=.90
BP(kg)	6.9 (3.6) P=.002 d=.87	16.4 (7.8) P=.001 d=.85	5.6 (3.9) P=.011 d=.71	12.2 (7.8) P=.007 d=.64	6.1 (3.2) P=.003 d=.77	12.0 (6.6) P=.004 d=.63	18.4 (6.2) P<.001 d=2.34	46.9 (14.7) P<.001 d=2.15
PU:BP Ratio	-0.10 (0.12) P=.087 d=-.35	-5.6 (7.2) P=.094 d=-.33	-0.13 (0.10) P=.019 d=-.45	-8.0 (6.9) P=.019 d=-.48	-0.14 (1.10) P=.015 d=-.48	-9.0 (7.1) P=.014 d=-.54	-.36 (0.23) P=.007 d=-1.27	-20.6 (14.3) P=.005 d=-1.31
K1 1000-m (sec)			-7.6 (11.3) P=.245 d=-.30	-2.5 (3.8) P=.251 d=-.28	-5.01 (4.14) P=.056 d=-.58	-1.9 (1.6) P=.054 d=-.58	-14.9 (14.6) P=.095 d=-.20	-5.0 (5.0) P=.085 d=-.21
K1 500-m (sec)			-9.4 (6.8) P=.032 d=-.60	-6.6 (4.8) P=.027 d=-.60	-0.4 (1.1) P=.500 d=-.72	-0.3 (0.9) P=.542 d=-.71	-11.2 (8.7) P=.046 d=-.03	-7.7 (6.4) P=.043 d=-.03
K1 200-m (sec)			-3.2 (2.7) P=.059 d=-.54	-6.0 (5.1) P=.050 d=-.55	-1.3 (0.5) P=.002 d=-.84	-2.7 (1.0) P=.001 d=-.87	-5.0 (3.8) P=.040 d=-.21	-9.3 (7.2) P=.032 d=-.24

Cohen's d effect sizes were defined as: 0.21>d<0.5 small, 0.51>d<0.8 medium and d>0.8 large