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Upper-body strength measures and pop-up performance of stronger and weaker surfers

Joanna Parsonage[1,2], Josh L. Secomb[1,2], Jeremy M. Sheppard[2,3], Brendon K. Ferrier[1,2,4], Rebecca A. Dowse[1,2], and Sophia Nimphius[1,2]

[1]Surfing Australia High Performance Centre, Casuarina Beach, Australia
[2]Centre for Exercise and Sport Science Research, School of Medical and Health Sciences, Edith Cowan University, Joondalup, Australia
[3]Canadian Sports Institute-Pacific, Victoria, Canada
[4] Edinburgh Napier University, Edinburgh, Scotland, United Kingdom

Corresponding author:

Joanna Parsonage, MSc, BSc
1 Grevillia Road, Cabarita Beach, NSW, 2488
+61 478088707
joanna@surfingaustralia.com

Abstract

The primary purpose of this study was to investigate the reliability of the isometric push-up (IPU), dynamic push-up (DPU), and force plate pop-up (FP POP) as measures of upper-body isometric and dynamic strength qualities in surfing athletes. Furthermore, the study aimed to compare pop-up performance between stronger and weaker surfers. Eighteen female (n=9) and male (n=9) surfers (age=28.1±6.4 yrs, mass=69.6±10.4 kg, height=172.5±6.7 cm) completed a battery of upper-body strength assessments, of which exhibited high between-day reliability: (IPU, (CV%=4.7, ICC=0.96), DPU (CV%=5.0, ICC=0.90), FP POP (CV%=4.4, ICC=0.90). Participants were subsequently split into stronger (n=9) and weaker (n=9) surfers based on normalized peak force (PF) attained in the IPU. Pop-up performance was measured both in the water and during the FP POP, and was referred to as time to pop (TTP). Significant between group differences were observed for normalized PF during IPU (d=1.59, $p<0.01$) and DPU (d=0.94 p=0.04). Although not significant, there was a large magnitude difference in FP POP (d=0.80, p=0.08) and FP TTP (d=0.85, p=0.07). Significant correlations were identified between normalized IPU PF and normalized DPU FP (r=0.69, p=0.03) and FP TTP (r=0.73, p=0.02) in the stronger group. The weaker group exhibited a significant inverse correlation between normalized IPU PF and in water TTP (r=-0.77, $p<0.01$). The results suggest improvements in pop-up performance may be elicited by improving dynamic strength for stronger surfers, whereas pop-up performance in weaker surfers may be elicited by improving maximum strength. The upper-body strength assessments provided a novel insight into strength qualities that are associated with in water performance of surfers (TTP).

Key words: Reliability, Isometric, and Dynamic, Novel, Force plate, Push-up, Surfing

INTRODUCTION

Strength assessments have been frequently implemented in sports settings to assess the neuromuscular qualities of athletes, and are representative of sports specific performance (16). McGuigan and colleagues emphasized that the assessment of any physical capacity needs to be specific to the athlete cohort (16), as strength and power characteristics are key determinants of sporting success (3). A variety of tests can be applied to different athletic populations provided they are reliable, valid and sensitive to training-induced changes (30). Strength assessments utilizing a maximal isometric contraction have become more common in strength and conditioning because they are more time efficient, minimize the risk of injury (6), and have been correlated to dynamic performance (29). For example, the isometric mid-thigh pull (IMTP) has been shown to be a reliable tool in the assessment of lower-body isometric strength (8, 13, 22) and highly correlated with dynamic performance in collegiate throwers (25), Olympic weightlifters (4), and rugby league players (29).

Prior research has investigated the reliability of upper-body isometric assessments, largely focusing on the isometric bench press (3, 19). The isometric bench press has been shown to be a reliable assessment of upper-body strength across multiple joint angles (ICC=0.89-0.97, CV%<5) (13, 18, 30). However, isometric measures of force production utilizing the isometric bench press have been identified as poor predictors of dynamic performance, or more specifically seated medicine ball throw (r=0.45-0.47) (18).

To our knowledge, there is limited research on the measurement of upper-body isometric strength qualities utilizing a push-up and its relationship to sports specific dynamic performance (5).

To our knowledge only one study has investigated the reliability of an isometric push-up in assessing upper-body isometric strength (5). This research showed that an isometric assessment in a push-up position had good within-day reliability (ICC=0.98), with a multiple regression model (r^2=0.86, p≤0.01) identifying isometric peak force as a significant predictor of one repetition maximum (1RM) bench press (p≤0.01). In addition to isometric push-up assessments, a dynamic push-up has also shown to be a reliable assessment (ICC=0.85-0.97) of upper-body strength and power, and can be used to predict 1RM bench press (28). Thus, both dynamic and isometric push-up assessments may be a useful method of assessing upper-body strength in other athletic populations such as surfers. Surfing athletes require upper-body strength in order to change from a prone paddling position, to a standing position in one explosive movement (15). This specific movement is termed the pop-up. During the pop-up surfers are required to move ~75% of their body weight in less than a second (29), and therefore high levels of upper-body force production within a time constraint is critical for success (24). However, there are no current investigations that evaluate the relationship between different assessments of strength (e.g. isometric, dynamic or dynamic sport specific) and in water pop-up performance in surfers.

Therefore, the primary purpose of this study was to investigate the reliability of the isometric push-up (IPU), dynamic push-up (DPU), and force plate pop-up (FP POP) as measures of upper-body isometric and dynamic strength qualities in surfing athletes. The secondary purpose of this study was to compare pop-up performance between stronger and weaker surfers and subsequently investigate if any relationships existed between upper-body strength and dynamic performance measures.

METHODS

Experimental approach to the problem

A repeated-measures study design was implemented to assess the between-day reliability of upper-body strength and dynamic performance measures in surfers. Participants were familiarized with all testing procedures prior to completing a full battery of upper-body strength and dynamic performance tests, including the IPU, DPU and FP POP. All tests were conducted at approximately the same time of day on two separate occasions, separated by 48 hours. Within these 48 hours, participants were instructed to refrain from any vigorous physical exercise outside of their normal activity.

Participants

Eighteen female (n=9) and male (n=9) surfers (age=28.1±6.4 yrs, mass=69.6±10.4 kg, height=172.5±6.6 cm) participated in the current study. All participants had surfed for a minimum of 10 years, and on average surfed more than three times a week. Due to large standard deviations in performance measures when analyzed as one group, participants were separated into groups: stronger (n=9) and weaker (n=9) surfers based on normalized IPU performance. Participants with a normalized IPU of >1.8N•BW^{-1} based on a median split were placed in the stronger group, with the remaining athletes placed in the weaker group.

The stronger group consisted of seven males and two females and the weaker group consisted of two males and seven females. All participants were free of any upper-body injuries or medical conditions that were contraindications to participation. The University Human Research Ethics Committee approved the research and all procedures. All participants were given an information letter and were explained the benefits and risks of participation followed by providing their written informed consent prior to participation.

PROCEDURES

Anthropometry

Stature was measured to the nearest 0.01m using a wall-mounted stadiometer. Body mass recorded to the nearest 0.01kg using a calibrated electronic scale.

Upper-body strength assessments

All upper-body strength assessments were performed on a force platform (400 Series Performance Force Plate, Fitness Technology, Adelaide, Australia) sampling at 600 Hz. The force platform was interfaced with computer software (Ballistic Measurement System, Fitness Technology, Adelaide, Australia) that allowed for direct measurement of force-time characteristics. The force plate was calibrated prior to each data collection, using a two-point calibration for a fitted regression as per the manufacturer's instructions.

To normalize for body weight, each participant was instructed to lay prone with his or her chest placed on a yoga block situated in the middle of the force plate. Hands were placed so that the thumbs were aligned with the armpit at approximately 100% of biacromial width, whilst a force-time curve was recorded for a period of five seconds (Figure 1a). The average peak force (PF) over a three second period was used in subsequent analysis to normalize for body weight. All participants underwent the same standardized warm-up, consisting of five inclined push-ups performed at 60cm, 45cm and 30cm in a descending order. A five-minute rest was provided between the IPU, DPU and FP POP assessments

Isometric push-up assessment

Participants were required to lay prone in the same starting position as adopted during the normalization. Whilst maintaining a straight line between the torso and lower-body, a modified pull-up belt fixed to an immovable base plate was placed over the participant's thoracic spine and adjusted to ensure all participants maintained an elbow flexion of 100° (Figure 1b). The elbow flexion angle of 100° was determined using a goniometer (Robinson pocket, JAMAR, North Ryde, Australia) with the lateral epicondyle of the elbow used as a pivot point in relation to the forearm and upper arm. An elbow flexion angle of 100° was specified, as pilot studies found it to elicit greatest PF with minimal discomfort compared to 80° and 120° (21). Prior to the push phase, participants were instructed to take up the slack of the modified pull-up belt to ensure that there was minimal compliance that may have reduced the PF recorded (Figure 1c). During each trial participants were instructed to "push the ground away as hard as possible" for a period of five seconds, ensuring the straight line between the torso and lower-body did not change. Verbal encouragement was provided throughout the trial and if a participant did not maintain the straight line between torso and lower-body; the trial was subsequently discarded and repeated.

Based on force-time data elicited from pilot studies, participants were only required to complete two trials, with two-minutes rest allocated between each trial. The PF recorded from the force-time curve during the IPU was recorded for subsequent analysis.

INSERT FIGURE 1a, 1b, 1c ABOUT HERE

Dynamic push-up assessment

Participants were required to adopt the same starting position as the IPU (Figure 2a). They were then instructed to explosively push-up by extending their elbows from a flexed to fully extended position prior to returning their hands to the force plate (Figure 2b). Participants were encouraged to maintain a straight line between the torso and lower-body, throughout the concentric action. Verbal instructions were provided to the participants to "push away from the force plate as quickly as possible". Separation of hands from plate was encouraged, to ensure that participants performed the DPU as explosively as possible. Participants were required to complete two trials, with two- minutes rest between each trial. The PF elicited during the DPU was recorded as the highest PF occurring between onset of push and take off.

INSERT FIGURE 2a, 2b ABOUT HERE

Force plate pop-up assesment

For the FP POP, participants were required to start in the same position as the IPU and DPU (Figure 3a). They were instructed to pop-up from a prone position, to their surf-specific stance in one explosive movement (Figure 3b).

In addiiton to force plate analysis, the pop-up was video recorded (*HERO3 Silver Edition HD3.02.03.00, California, USA)* sampling at a rate of 100 frames per second. The pop–up phase was analyzed from the time at which the participant's chest left the force plate to the time of front foot contact. This was referred to as time to pop-up (TTP). The PF elicited during the FP POP was recorded as the highest PF occurring between onset of push and take off.

INSERT FIGURE 3a, 3b ABOUT HERE

In water pop-up assessment

Video footage was recorded from an in water vantage point (*HERO3 Silver Edition HD3.02.03.00, California, USA)* sampling at a rate of 100 frames per second. The camera was attached to the nose of the participant's surfboard prior to a one thirty-minute surf. Swell height, wind direction and tidal conditions were noted over this period. Testing was only conducted during similar weather and tide conditions for all participants, and only when swell height fell within 0.66–1.0 m height, to allow for a means of standardization in a non-controlled setting. The pop–up phase was analyzed from the time at which the participant's chest left the surfboard to the time of front foot contact. This was referred to as time to pop-up (TTP), with an average of the two fastest pop-ups being used for further analysis.

Statistical analysis

All data are presented as mean ± standard deviation (SD). Reliability of each test was assessed by calculating the intra-class correlation coefficient (ICC), typical error (TE) and the coefficient of variation (%CV), which were set at a 95% confidence intervals

(11). The %CV was calculated as; 100 x (SD/mean) using log-transformed data (23) and a CV of ≤10% was set as a criterion to declare a variable reliable (9). Between-day reliability was calculated using the average of the two trials from each testing session. Smallest worthwhile change (SWC) was also calculated using the following equation; 0.2 x between-subject SD (12). The SWC represents the smallest change in testing results that are of benefit to performance (12). Between day normalized PF production for the IPU, DPU and FP POP was assessed using a paired sample t-test to determine if significant changes in each variable occurred between testing sessions. All statistical analysis was conducted as one group (n=18), prior to participants being divided into stronger and weaker groups based on normalized IPU scores. An independent sample t-tests was also conducted to determine whether there was a significant difference in strength and dynamic performance measures between stronger and weaker surfers. Effect size was calculated to determine the magnitude of differences between the groups for each measure. Magnitude of effect was classified as follows; < 0.2 (trivial), >0.2 (small), >0.5 (medium) and >0.8 (large) (7). A Pearson product-moment correlation coefficient was utilized to assess the association between upper-body measures (IPU and DPU) and pop-up performance for both stronger and weaker groups. A fisher's *r*–Z transformation was performed to examine if there was a significant difference in correlations between stronger and weaker surfers. All statistical analyses were performed using PRISM (Version 7.0b; GraphPad Software, Inc., La Jolla, CA, USA) and statistical significance was set at $p \leq 0.05$.

RESULTS

Test-retest reliability of the IPU, DPU and FP POP, aswell as FP TTP are presented in Table 1. Descriptive values for all upper-body strength measures, when analyzed as one group are presented in Table 2. Significant correlations were reported between the IPU (r=-0.55, p=0.01, 95%CI=-0.81, -0.11) and DPU (r=-0.52, p=0.02, 95%CI=-0.79, -0.06), and in water TTP (Figure 4a, 4b). Large significant differences were identified between the stronger and weaker groups for the IPU (d=1.59, p<0.01) and DPU (d=0.94, p=0.04) (Table 3). Large correlations were identified between normalized IPU PF scores and both normalized DPU PF scores (r=0.69, p=0.03, 95%CI=0.05, 0.93) and FP TTP (r=-0.73, p=0.02, 95%CI=-0.94, -0.13) in the stronger group (Table 4). The stronger group also demonstrated significant correlations between FP TTP and in water TTP (r=0.68, p=0.04, 95%CI=-0.28, 0.93). Only moderate, non-significant correlations were identified between normalized IPU PF scores and normalized DPU PF scores (r=-0.64, p=0.06, 95%CI=-0.03, 0.92) in the weaker group (Table 5). A significant difference was identified in normalized IPU PF, between testing sessions (p<0.05). All fisher's Z values fell within the bounds of -1.96 and 1.96; therefore correlation coefficients between strong and weak groups were not significantly different.

INSERT TABLES 1, 2, 3, 4 and 5 ABOUT HERE

INSERT FIGURE 4a, 4b, 4c and 5 ABOUT HERE

DISCUSSION

The primary purpose of this study was to investigate the reliability of the isometric push-up (IPU), dynamic push-up (DPU), and force plate pop-up (FP POP) to measure upper-body isometric and dynamic strength qualities in surfing athletes. The results indicate that the IPU, DPU and FP POP are reliable tests in the assessment of upper-body PF production in surfers (Table 1). The secondary purpose of this study was to compare pop-up performance between stronger and weaker surfers, and subsequently investigate if any association existed between upper-body strength, dynamic strength, and the performance measure of the surfing pop-up. This was thought to be worthwhile to elucidate the extent to which strength, and specific strength qualities, may account for performance in the sporting context. The result of the current study indicate that the strength levels exhibited by surfing athletes in a maximal strength assessment is strongly associated with the force applied in a dynamic performance task (DPU and FP POP), and this is also strongly associated with the sport-specific performance task (TTP).

The high degree of reliability identified for the IPU agree with other isometric assessments, such as the lower-body IMTP (17, 26, 29) and upper-body isometric bench press (13, 30). All intraclass correlation coefficients (ICC) ≥0.9, and therefore considered highly reliable (1). The coefficient of variation was also calculated, with a cutoff value of 10% being reported in previous literature (23). Therefore, a CV of ≤10% was set as the criterion in the current study, of which all variables fell within (9). Although all participants underwent a familiarization of the IPU protocol, a significantly greater mean PF was produced during testing session two compared to session one (*d*=0.12, *p*<0.05). Due to the novelty of this isometric testing protocol, it could be suggested that an additional familiarization session would be advantageous in reducing the absolute variability between data sets. The current study also reported TE and SWC. The lack of familiarity with the IPU protocol could explain the larger SWC% identified between testing sessions. However, as Hopkins highlights, performance tests can produce a greater amount of noise (TE) than the smallest meaningful change, especially when a small sample is used (12).

In contrast, dynamic and plyometric push-up variations have been frequently used in the training, testing and injury rehabilitation of athletes (10, 27). The clap push-up has previously demonstrated high reliability when measuring peak ground reaction force (ICC=0.85-0.91) (14). However, the protocol Koch and colleagues implemented allowed for a downward eccentric phase of movement prior to the participants forcefully pushing up (14). The current study investigated the reliability of a DPU initiated by a concentric contraction from a prone lying position (ICC=0.90, CV%=5.0%), and therefore did not allow the muscle to undergo an active stretch prior to its immediate shortening. This is known as the stretch shortening cycle and has been shown to enhance the muscles ability to produce force during dynamic upper-body movements (20).

The secondary purpose of the current study was to identify if there was a significant difference in isometric and dynamic upper-body strength, in relation to pop-up performance in stronger and weaker surfers. When analyzed as one group (n=18), normalized IPU and DPU scores were positively correlated with in water TTP (Figure 4a and 4b).

Due to the large standard deviation in IPU scores, participants were subsequently split into stronger and weaker surfers to allow for a more comprehensive analysis of correlations.

The stronger group exhibited significantly greater PF production for the IPU and DPU, with normalized IPU PF significantly correlated with dynamic upper-body force production (DPU). Furthermore, PF production during the FP POP was significantly correlated to a quicker in water TTP in the stronger group (Table 4). A quicker TTP would enable a surfer to be on the wave face earlier, and therefore prolong the wave-riding time in which critical manoeuvres could be performed. These results differ from those of Murphy and Wilson (18) who reported no significant relationship between upper-body isometric PF production and a dynamic seated medicine ball throw. However, the sport-specific nature of FP TTP allows for a more sensitive measure of dynamic performance compared to a generic medicine ball throw, perhaps allowing for a more sensitive measure within this cohort. To our knowledge only one other study has identified a significant correlation between upper-body isometric strength and sports-specific dynamic performance. Baiget and colleagues, identified a strong positive relationship between maximal isometric shoulder internal rotation strength and serve velocity in competitive professional tennis players (2). The current and aforementioned studies may suggest the importance of using both upper-body isometric tests in concert with measures of dynamic strength that are relevant to the sport-specific population.

A large significant inverse correlation was exhibited between the normalized IPU PF and in water TTP within the weaker group, with lower IPU PF production associated with a slower in water TTP. When interpreting the correlations in upper-body strength between stronger and weaker groups, it could be suggested that the stronger surfers exhibited greater sports-specific strength, which in turn was transferable to sports-specific performance. Based on correlation analysis, it would appear favorable for a surfer to demonstrate a normalized IPU score of 2.0 N•BW^{-1} or above. However, as observed using a scatterplot of the data (Figure 5), it is apparent that two participants from the weaker group recorded the fastest in water TTP, even with an IPU score that fell below 2.0 N•BW^{-1}. Similarly, two participants from the stronger group who fell marginally below the 2.0 N•BW^{-1} threshold, recorded slower in water TTP. It could be speculated that the two participants from the stronger group, possessed the adequate strength, but perhaps lacked the refined level of skill. Conversely, the faster participants from the weaker group may have possessed a highly refined skill level despite lacking a threshold of strength compared to the mean within this cohort. As with any skill-based movement, there are numerous components that could impact the successful execution of the task itself. However, it could still be speculated that through increasing a surfer's normalized IPU score, a significant improvement in dynamic PF production and TTP could occur. Previous research, demonstrated that lower-body isometric PF was strongly associated with dynamic PF production in explosive sports-specific movements, a relationship that strengthened with training time (25). Future research could investigate the effect of a training intervention aimed at increasing IPU scores on sports-specific TTP. The current study also reported TE and SWC.

As can be seen in Table 3 the difference between stronger and weaker surfers in relation to the FP TTP is more than three times the SWC and therefore clearly discriminates between groups.

The current study determined that stronger surfers who produced significantly greater upper-body normalized PF values for dynamic and isometric strength measures, exhibited greater sports-specific strength as evidenced by a quicker TTP. Furthermore, FP TTP was significantly correlated to in water TTP, highlighting land-based testing as a valid measure of in water performance. Due to the novelty of the IPU, an additional familiarization session is necessary to limit variability in data sets.

PRACTICAL APPLICATION

The high reliability of all upper-body strength measures (IPU, DPU and FP POP) in this study and their relevance to an important performance measure (TTP) warrant their use by strength and conditioning coaches as part of a comprehensive physical testing battery for surfing athletes. Based on the whole group data, the IPU and DPU are valid upper-body strength measures, in relation to sports-specific in water TTP. When applying this testing battery, a threshold of 2.0 $N \bullet BW^{-1}$ or above for the IPU, was identified as being beneficial to sports-specific performance (TTP). However, this was the threshold identified for this specific cohort, and therefore strength and conditioning coaches and sports scientist should determine the threshold that may be of benefit to the performance for their specific population of athletes. Stronger surfers may benefit more by focusing on dynamic strength qualities, whereas weaker surfers may find it of benefit to focus primarily on maximum strength to improve TTP.

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Figure Legends

Figure 1. (a) Position adopted to allow for the normalization of body weight; (b) Modified pull-up belt placed other the thoracic spine; (c) The isometric push-up (IPU).

Figure 2. (a) Starting position adopted; (b) The dynamic push-up (DPU)

Figure 3. (a) Starting position adopted; (b) The force plate pop-up (FP POP)

Figure 4a. Linear regression with 95% confidence intervals and explained variance (r^2) between isometric push up (IPU) in water time to pop-up (TTP) for all surfers (n=18)

Figure 4b. Linear regression with 95% confidence intervals and explained variance (r^2) between dynamic push up (IPU) in water time to pop-up (TTP) for all surfers (n=18)

Figure 4c. Linear regression with 95% confidence intervals and explained variance (r^2) between force plate pop-up (FP POP) in water time to pop-up (TTP) for all surfers (n=18)

Figure 5. Linear regression with 95% confidence intervals and explained variance (r^2) between isometric push up (IPU) in water time to pop-up (TTP) in stronger and weaker surfers

Table 1. Test, re-test reliability of the normalized isometric push-up (IPU), dynamic push-up (DPU), force plate pop-up (FP POP) in N•BW^{-1} and force plate time to pop-up (FP TTP) in seconds.

	IPU	**DPU**	**FP POP**	**FP TTP**
Mean	1.80	1.50	1.41	0.63
SD	0.40	0.20	0.18	0.09
ICC	0.96	0.90	0.90	0.87
TE	0.20	0.35	0.34	0.38
CV%	4.7	5.0	4.4	5.6
SWC	0.08	0.04	0.03	0.02
SWC%	4.44	2.66	2.12	3.17

SD = Standard deviation, ICC = Interclass correlation coefficient, TE = typical error, CV% = coefficient of variation, SWC = smallest worthwhile change.

Table 2. Mean ± SD, for all upper-body strength measures

	n=18
Isometric Push-up (IPU)	
Peak Force (N)	981.80±300.44
Relative force (N•BW^{-1})	1.83±0.42
Dynamic Push-up (DPU)	
Peak Force (N)	804.08±202.76
Relative force (N•BW^{-1})	1.50±0.25
Force Plate Pop-Up (FP POP)	
Peak Force (N)	749.03±169.15
Relative force (N•BW^{-1})	1.40±0.19
Time to pop-up (seconds)	0.62±0.09
In water Pop-Up	
Time to pop-up (seconds)	0.64±0.08

Table 3. Mean ± SD, and results of one-way ANOVA for all upper-body strength measures in stronger and weaker surfers

	Stronger Group (n=9)	**Weaker Group (n=9)**	***p***	***d***	**Interpretation of Effect Size**
Isometric Push-Up (IPU)					
Peak force (N)	1211.85 ± 185.06	751.76 ± 196.19	<0.01	1.53	Large
Normalized force ($N \bullet BW^{-1}$)	2.16 ± 0.28	1.49 ± 0.22	<0.01	1.59	Large
Dynamic Push-Up (DPU)					
Peak force (N)	910.30 ± 183.20	697.87 ± 168.56	0.02	1.05	Large
Normalized force ($N \bullet BW^{-1}$)	1.62 ± 0.25	1.39 ± 0.18	0.04	0.94	Large
Force Plate Pop-Up (FP POP)					
Peak force (N)	831.93 ± 164.30	666.13 ± 135.42	0.03	0.98	Large
Normalized force ($N \bullet BW^{-1}$)	1.48 ± 0.22	1.33 ± 0.11	0.08	0.80	Large
Time to pop-up (seconds)	0.59 ± 0.08	0.66 ± 0.08	0.07	0.85	Large
In Water Pop-Up					
Time to pop-up (seconds)	0.62 ± 0.06	0.66 ± 0.09	0.38	0.51	Moderate

Table 4. Pearson correlation coefficients (with 95% confidence intervals) between upper-body strength measures in the stronger group (n=9).

	DPU	**FP POP**	**FP TTP**	**In water TTP**
Isometric Push-Up (IPU)	0.69* (0.05, 0.93)	0.64 (-0.05, 0.91)	- 0.73* (-0.94, -0.13)	- 0.51 (-0.88, 0.23)
Dynamic Push-Up (DPU)		0.79** (0.28, 0.95)	- 0.53 (-0.89, 0.19)	- 0.59 (-0.90, 0.10)
Force Plate Pop-Up (FP POP)			- 0.65 (-0.91, 0.02)	- 0.78** (-0.94, -0.25)
Force Plate Time to Pop-Up (FP TTP)				0.68* (-0.28, 0.93)

Significant at **p*<0.05, ***p*<0.01

Table 5. Pearson correlations coefficients (with 95% confidence intervals) between upper-body strength measures in the weaker group (n=9).

	DPU	**FP POP**	**FP TTP**	**In water TTP**
Isometric Push-Up (IPU)	- 0.64 (-0.03, 0.92)	0.29 (-0.46, 0.79)	- 0.59 (-0.90, 0.12)	- 0.77**(-0.95, -0.22)
Dynamic Push-Up (DPU)		0.66 (-0.02, 0.92)	- 0.28 (-0.79, 0.47)	- 0.41 (-0.84, 0.352)
Force Plate Pop-Up (FP POP)			- 0.11 (-0.67, 0.66)	- 0.13 (-0.72, 0.58)
Force Plate Time to Pop-Up (FP TTP)				0.42 (-0.34, 0.85)

Significant at ***p*<0.01

Figure 1

Figure 2

Figure 3

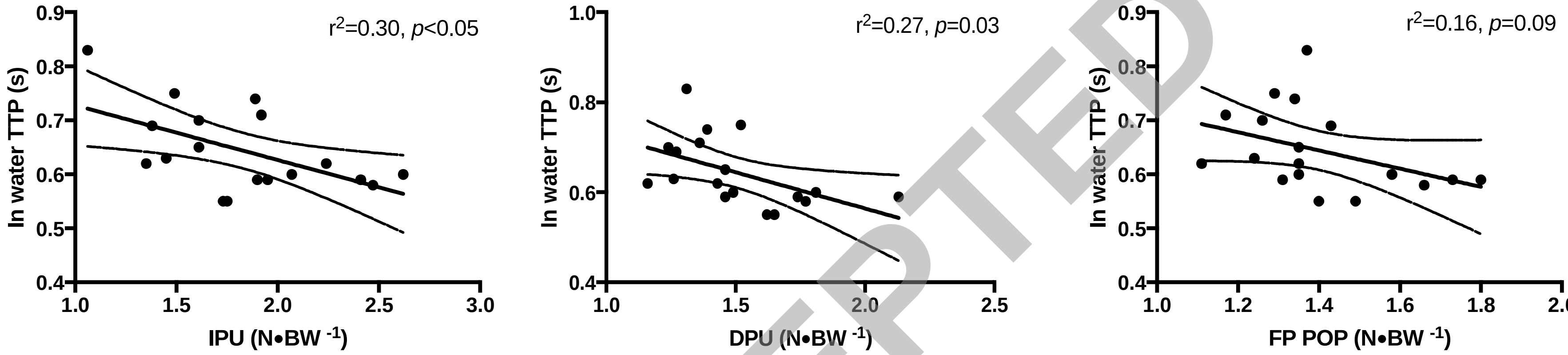

Figure 4a, b, and c

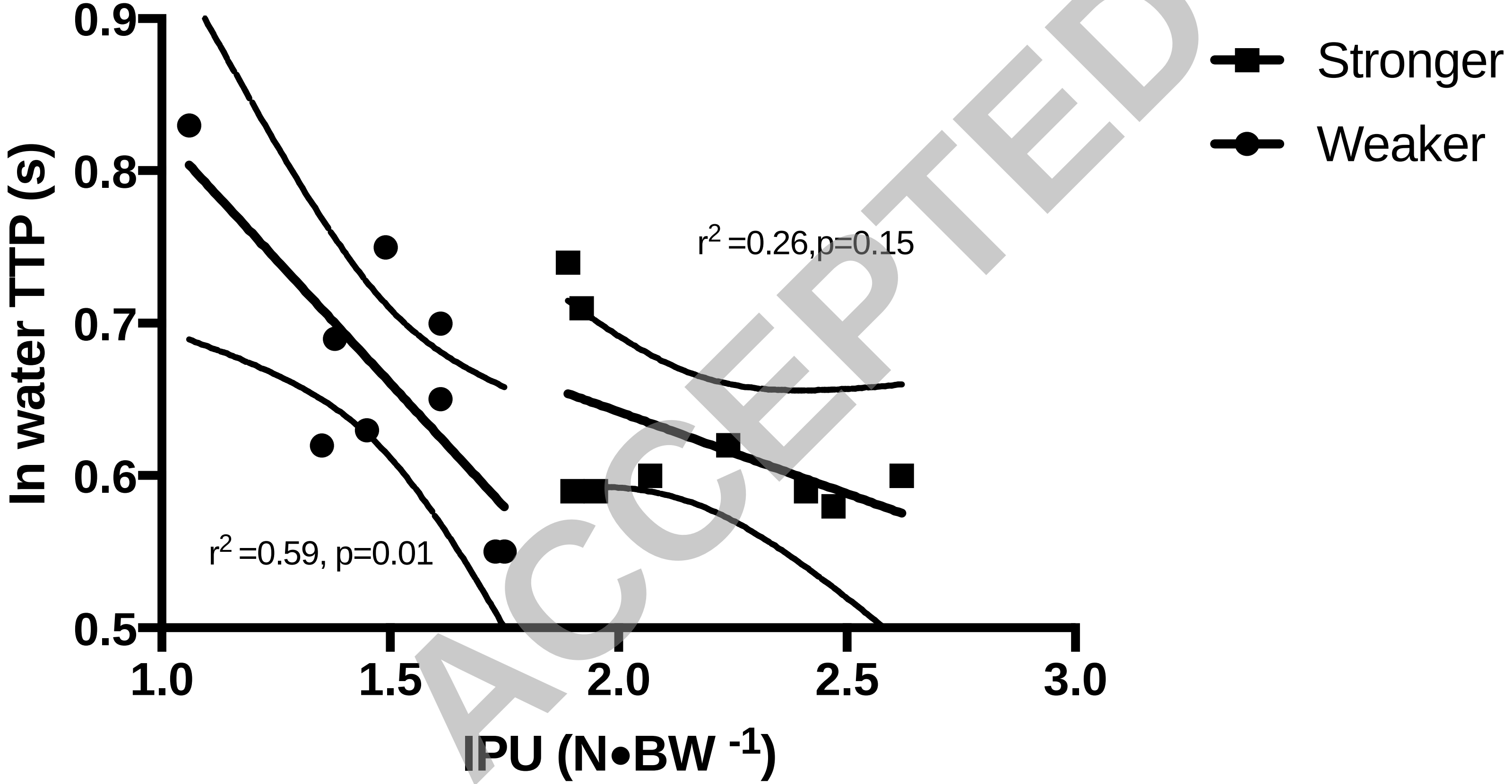
0.9
0.8
0.7
0.6
0.5
In water TTP (s)
1.0
1.5
2.0
2.5
3.0
IPU (N•BW -1)
Stronger
Weaker
r2 =0.26,p=0.15
r2 =0.59, p=0.01

Figure 5