NSCA®
NATIONAL STRENGTH AND CONDITIONING ASSOCIATION

CPSS™

CERTIFIED PERFORMANCE AND SPORT SCIENTIST™

EXAM SUMMARY

CERTIFIED PERFORMANCE & SPORT SCIENTIST™
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THE NATIONAL STRENGTH AND CONDITIONING ASSOCIATION® (NSCA®)

Founded in 1978, The National Strength and Conditioning Association (NSCA) is a nonprofit association dedicated to advancing the strength and conditioning and related sport science professions around the world.

The NSCA exists to empower a community of professionals to maximize their impact through disseminating evidence-based knowledge and its practical application by offering industry-leading certifications, research journals, career development services, networking opportunities, and continuing education. The NSCA community is composed of more than 60,000 members and certified professionals throughout the world who further industry standards as researchers, educators, strength and conditioning coaches, performance and sport scientists, personal trainers, tactical professionals, and other related roles.

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INTRODUCTION

HOW TO USE EXAM SUMMARY

This Exam Summary includes the Detailed Content Outline (DCO) for the Certified Performance and Sport Scientist (CPSS) exam. The purpose of this CPSS Exam Summary is to inform candidates about exam content and format. Areas of emphasis across CPSS exam content are noted within the included DCO.

In addition to the published DCO, two example public case studies are included with sample items for familiarization as to how exam items may be assigned to a specific case.

The Exam Summary and Sample Cases are not meant to be a comprehensive study guide.

CPSS EXAM SUMMARY

ABOUT THE CPSS EXAM

The CPSS exam evaluates competency to practice as a Sport Scientist. An individual's competency is measured by their demonstrated knowledge and application of specific topics. These topics include training theory and process, needs analysis, monitoring, and communication and education relative to the scientific disciplines, knowledge of assessment technology, and in the application of scientific research processes with the primary goal of safely and effectively improving athletic performance. The exam will consist of a combination of multiple-choice case studies and independent items emphasizing research and application. Learn more about the *Scope of Practice* and review the DCO for the Certified Performance and Sport Scientist.

DETAILED CONTENT OUTLINE

CPSS® EXAMINATION **Detailed Content Outline** **Certified Performance and Sport Scientist**	**Crosscutting Concept**			**Total # of Questions**
	Scientific Disciplines	Assessment Technology	Scientific Research Process	
1. TRAINING THEORY AND PROCESS				**23-29**
A. Understand the relevant theory and principles that underpin training.				
B. Design or evaluate a performance program based on sound programming and periodization principles around the constraints of the training environment (e.g., equipment, location, time of year, athlete history, sport).				
C. Understand the multiple dimensions (e.g., psychological, physical, sport development, personal growth, nutrition, recovery, interventions) of athlete preparation in relation to training process.				
2. NEEDS ANALYSIS				**24-30**
A. Research factors related to success in a sport (e.g., organizational, motion, dynamics, biomechanical demands, tactical patterns, technical requirements, injury) through qualitative and quantitative methods.				
B. Establish key performance indicators (KPIs) that relate to performance.				
C. Identify environmental/situational constraints that may impact performance.				

CPSS® EXAMINATION **Detailed Content Outline** **Certified Performance and Sport Scientist**	**Crosscutting Concept**			**Total # of Questions**
	Scientific Disciplines	Assessment Technology	Scientific Research Process	
D. Develop benchmarking (e.g., normative data) around attributes needed for success.				
E. Establish assessment strategies to evaluate performance status.				
F. Establish a resource option to help understand loads as it relates to the sport (e.g., internal loads, external loads).				
G. Identify acquired research and development activities that will facilitate performance planning, ongoing monitoring, and assessment.				
3. ACUTE AND CHRONIC MONITORING				**25-30**
A. Select appropriate and feasible assessment tools to track the key performance indicators (KPIs) identified in the needs analysis.				
B. Design robust data capture protocols that enable appropriate analysis.				
C. Analyze data and apply results to each specific key performance indicator (e.g., training, athlete response).				
D. Use data-driven outcomes to make recommendations, support the decision-making process, and/or directly intervene.				
E. Evaluate the efficacy of existing assessments, protocols, applications, and interventions (e.g., quality assurance process).				
4. COMMUNICATION AND EDUCATION				**19-24**
A. Understand general communication and education strategies for delivering information to athletes, coaches, the high-performance team, management, or sport science community.				
B. Understand current pedagogical techniques (cognitive, learning theories, practical) for designing and delivering education/training opportunities on sport science topics to other members of the high-performance team and administrators.				
C. Understand creative and efficient solutions to disseminate situationally-appropriate and timely information and data to a target audience (e.g., athletes, coaches, performance team).				
D. Translate research and theory to inform best practice within the constraints of the performance program.				
E. Collaborate with other professionals in finding customized performance solutions.				
Total Items	33-38	23-27	35-41	**100**

EXAM ITEM SUMMARY

The CPSS exam consists of a combination of case study-based and independent items (questions). Additional unscored pre-test items are included as part of the exam development and scoring process. See below for a breakdown of exam questions. The included case studies (athlete and research review) will be consolidated at the end of the exam, whereas the independent multiple-choice items will be at the beginning of the exam.

	Athlete Case Studies (5-6 Cases)	Research Review Case Studies (2-3 Cases)	Independent Exam Questions
Scored Questions	45-50 Exam Questions (5-7 Questions Per Case Study)		50-55 Questions
Total Questions	100 Scored Exam Questions, 15 Pre-test (115 Total Items)		
Allowed Time	165 Minutes (2 Hours, 45 Minutes)		

FREQUENTLY ASKED QUESTIONS (FAQ)

For further information and FAQ, refer to NSCA.com/cpss and the NSCA Certification Handbook.

CASE STUDY — PUBLIC EXAMPLES

CASE STUDY INFORMATION

This section includes specific examples of both an athlete case study and a research review case study with associated items. These cases demonstrate the specific layout and template that will be used to convey case study materials, background information, and data within the exam setting.

ATHLETE CASE STUDY

Public Example

Athlete Case Information

1) Sport Information

   Sport: Track: 400m

   Level: Collegiate Division 1, Conference Championship Contributing Level Athlete – Not National/Olympic Level

   Position: *A 100-400m Sprinter who is also used on relays. High volume contributor to the team.*

   Season: Last week of off-season training (August) before pre-season training beings in the Fall Semester (Sept – Dec).

2) Athlete Information

   Age: 22

   Gender: Female

   Other Information: Height = 5’7”, weight = per chart

   Condition: Athlete is cleared to train but has been at home working remotely with athletic trainer or strength and conditioning (S&C) coach.

3) Task Information

   Injury History: The athlete has a history of patellar tendinopathy (jumper’s knee) and shin splints. The athlete previously dealt with these injuries during conference championships last season (May) and after school ended, went home to rest and train on her own during the summer/off-season.

   Current Situation: The athlete states she is feeling “not explosive during lifts” and “has no kick during running workouts” and her “shins have been killing her since the 4th of July”.

Current Reports from other Professionals: The S&C coach notes that they have observed a decrease in the athlete's reported lifting intensity and her written feedback, via the team's online S&C software program, is noticeably shorter and generic. Performance data is presented from the athlete's eight previous workouts, conducted over the last three weeks. All testing was done in the beginning of the day's training session.

Table 1: Performance Data from the last eight workouts, over the past three weeks.

Evaluation	Personal Best	Workout Number 1	2	3	4	5	6	7	8
Bodyweight	**N/A**	144lb (65.3kg)	146 (66.2kg)	145 (65.8kg)	148 (67.1kg)	144 (65.3kg)	151 (68.5kg)	147 (66.7kg)	146 (66.2kg)
Total Training Volume Change Compared to Previous Workout	-	-	+5%	+5%	+5%	-12%	-8%	-5%	-5%
Vertical Jump	19.25 in (48.9 cm)	18.75 in (47.63cm)	-	18.25in (46.36cm)	-	17.5in (44.45cm)	-	17.4in (44.2cm)	-
Squat (3RM)	245lb (111kg)	215lb (97.5kg)	-	210lb (95kg)	-	215lb (97.5kg)	-	210lb (95kg)	-
Clean (1 RM)	185lb (84kg)	-	175lb (79kg)	-	175lb (79kg)	-	180lb (81.6kg)	-	175lb (79kg)
3x200 meter with 3:1 Rest – Goal Time 26.0 Seconds Per Run	25.6s / 25.4s / 25.9s	25.7s / 26.1s / 26.0s	-	-	26.3s / 26.5s / 26.8s	-	-	-	27.9s / 27.8s / 28.1s
Rate of Perceived Exertion (RPE) For the Entire Training Day (1 rest, 10 maximal)	N/A	7	8	9	10	10	10	10	10

** RM = Repetition Max, Blank = Did not complete that session*

Athlete Case - Sample Questions

1) What phase is the most likely contributor to the decrease in vertical jump height over the last eight workouts?

    a. transitioning from initial Alarm Stage to resistance
    b. transitioning from resistance to exhaustion
    c. competitive supercompensation

2) What is the most likely contributor to the decrease in sprint performance over the last eight workouts?

   a. overtraining
   b. undertraining
   c. injury

3) Based on the results from the table, which of the following performance indicators gives the sport scientist the most information to determine how to adjust the training load of the athlete?

   a. squat
   b. clean
   c. sprint time

4) What training focus should the sport scientist recommend on the track to improve sprint performance?

   a. sport psychology sessions and a maximum speed and power development program, for 4-6 weeks
   b. acceleration and hypertrophy development, for 4 weeks followed by max speed and strength development, for 6 weeks
   c. proper rehabilitation from injury coupled with sport psychology sessions and a return to play protocol, for 6 weeks

5) Which of the following is the greatest risk of the shin splints injury recurring?

   a. increase the hamstring to quad ratio strength
   b. increase volume of high-intensity plyometrics
   c. improvement of landing and push-off mechanics in plyometric training

6) Which of the following performance data give the sport scientist the most information to determine how to adjust the training load of the athlete to elicit the best adaptive response to avoid overtraining?

   a. bodyweight, intensity, frequency
   b. frequency, volume, intensity
   c. bodyweight, volume, frequency

ANSWER KEY

1=b, 2=a, 3=c, 4=c, 5=b, 6=b

RESEARCH REVIEW CASE STUDY

Public Example

Research Review Case Information

Citation (Full-Text Included Below): Parsonage, J., Secomb, J., Sheppard, J., Ferrier, B., Dowse, R. and Nimphius, S. *Upper-Body Strength Measures and Pop-Up Performance of Stronger and Weaker Surfers.* Journal of Strength and Conditioning Research, 34(10), 2982-2989.

1) Context

Sport: Surfing

Level: Professional

Position: *N/A*

Season: Pre-Season on the World Championship Tour (highest level international competition)

2) Athlete Information

Age: 22

Gender: Female

Condition: The athlete is competing on the World Championship Tour and is currently free of any injuries.

Performance: The athlete has recently qualified for the World Championship Tour for the upcoming season, which requires the athletes to compete in waves that are larger than those on the World Qualifying Series (second highest tier of competition). With her coach, it has been identified that she must improve her performance in larger waves to increase her opportunity to succeed at this level of competition, as she has previously experienced her worst results in larger waves. Specifically, her coach has noted that although she can paddle fast enough to catch these larger waves, they believe her time to pop-up to a wave riding position, from a prone paddling position is limiting her ability to perform in these larger waves.

3) Task Instructions

The sport scientist working with this surfing athlete wants to use the paper "Upper-Body Strength Measures and Pop-Up Performance of Stronger and Weaker Surfers" to help improve this athlete's physical capacities to enhance her ability to perform a successful and fast pop-up. It is anticipated that if her time to pop-up can be improved, her potential for competitive success on the World Championship Tour will be increased. The athlete performed the testing battery as per the provided paper and her results were *Isometric Push-Up (IPU):* $1.42 N \cdot BW^{-1}$, *Dynamic Push Up (DPU):* $1.27 N \cdot BW^{-1}$ and *In-Water Time To Pop-Up (TTP):* 0.67s. Answer the questions below using the paper and the athlete information provided.

Research Review Case - Sample Questions

1) According to the paper (see page 13), what is the broad physical requirements of an athlete to perform an effective pop-up during surfing?

    a. The ability to integrate lower-body strength and dynamic stabilization to perform.
    b. Utilizing upper-body pulling strength to increase the velocity of the surfboard through the water.
    c. Moving the majority of their bodyweight with upper-body pushing force production within a time constraint.

2) How much variance in all surfers in-water time to pop-up (TTP) was explained by maximal isometric push up (IPU) relative strength?

    a. 0.27
    b. 0.30
    c. 0.51

3) When benchmarking the current athlete against the means presented in this paper and categorizing her performance in each test as worse than or better than average, which would be the most appropriate summary of her performance?

    a. Her performance in the IPU, DPU and In-Water TTP is better than average.
    b. Her performance in the IPU, DPU and In-Water TTP is worse than average.
    c. Her performance in the IPU and DPU is worse than average, but her performance in the In-Water TPP is better than average.

4) Which of the following is a primary consideration when making performance-based decisions for the athlete from this paper?

    a. The results from this study were correlational, which doesn't always translate to causal.
    b. The athlete is at the low-end of the age standard deviation used by this study.
    c. The limited time before the start of the World Championship Tour.

5) What finding do the authors report about the relationship between upper-body physical capacities and performance measures in the weaker group?

    a. There was a significant correlation between the isometric push-up (IPU) and In-Water TTP (r = -0.77), but no significant correlation between the dynamic push-up (DPU) and In-Water TTP.
    b. There was a significant correlation between the isometric push-up (IPU) and In-Water TTP (r = -0.59), but no significant correlation between the dynamic push-up (DPU) and In-Water TTP.
    c. There was no significant correlation between the isometric push-up (IPU) and In-Water TTP or the dynamic push-up (DPU) and In-Water TTP.

6) Considering the provided testing results for the athlete and the findings of the paper, what appears to be the most appropriate initial performance solution for this athlete?

   a. The athlete has the required underpinning physical capacities for the pop-up, so should focus on enhancing the technical components of this skill.
   b. The athlete lacks coordination and reaction time required for the pop-up. She would likely benefit from a mesocycle focused on increasing performance in this capacity.
   c. The athlete lacks the underpinning upper-body physical capacities required for the pop-up. She would likely benefit from increasing her relative maximal upper-body pushing strength.

ANSWER KEY

1=c, 2=b, 3=b, 4=a, 5=a, 6=c

Reference Article (Full-Text)

The specific full-text article associated with each research review case study will be included for reference during the exam. The article for the above public example is included on the following pages.

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]

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Abstract

Parsonage, J, Secomb, JL, Sheppard, JM, Ferrier, BK, Dowse, RA, and Nimphius, S. Upper-body strength measures and pop-up performance of stronger and weaker surfers. *J Strength Cond Res* 34(10): 2982–2989, 2020—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 years, mass = 69.6 ± 10.4 kg, and height = 172.5 ± 6.7 cm) completed a battery of upper-body strength assessments, of which exhibited high between-day reliability: IPU, (coefficient of variation [CV%] = 4.7, intraclass correlation coefficient [ICC] = 0.96), DPU (CV% = 5.0, ICC = 0.90), and 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-up (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 et al. (16) emphasized that the assessment of any physical capacity needs to be specific to the athlete cohort because 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 using 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 with dynamic performance (29). For example, the isometric midthigh 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).

Previous 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 (intraclass correlation coefficient [ICC] = 0.89–0.97, coefficient of variation [CV%] <5) (13,18,30). However, isometric measures of force production using 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

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Figure 1. A) Position adopted to allow for the normalization of body weight; (B) modified pull-up belt placed other the thoracic spine; and (C) the isometric push-up (IPU).

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

To our knowledge, only 1 study has investigated the reliability of an isometric push-up (IPU) 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 ($r^2 = 0.86$, $p \leq 0.01$) identifying isometric peak force (PF) as a significant predictor of 1 repetition maximum (1RM) bench press ($p \leq 0.01$). In addition to IPU assessments, a dynamic push-up (DPU) 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 IPU assessments may be a useful method of assessing upper-body strength in other athletic populations such as surfers. Surfing athletes require upper-body strength to change from a prone paddling position to a standing position in 1 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 IPU, 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 before 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 2 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.

Subjects

Eighteen female ($n = 9$) and male ($n = 9$) surfers (age = 28.1 ± 6.4 years, mass = 69.6 ± 10.4 kg, and 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 3 times a week. Because of large *SD*s in performance measures when analyzed as 1 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 >1.8 $N \cdot BW^{-1}$ based on a median split were placed

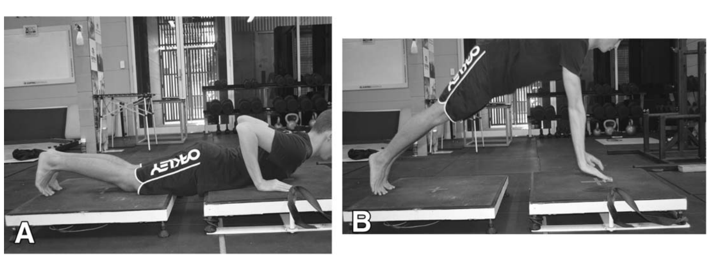

Figure 2. A) Starting position adopted; (B) the dynamic push-up (DPU).

Figure 3. A) Starting position adopted; (B) the force plate pop-up (FP POP).

in the stronger group, with the remaining athletes placed in the weaker group. The stronger group consisted of 7 men and 2 women, and the weaker group consisted of 2 men and 7 women. All participants were free of any upper-body injuries or medical conditions that were contraindications to participation. Edith Cowan 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 before participation.

Procedures

Anthropometry. Stature was measured to the nearest 0.01 m using a wall-mounted stadiometer. Body mass recorded to the nearest 0.01 kg 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) that allowed for direct measurement of force-time characteristics. The force plate was calibrated before each data collection, using a 2-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, while a force-time curve was recorded for a period of 5 seconds (Figure 1A). The average PF over a 3-second period was used in subsequent analysis to normalize for body weight. All participants underwent the same standardized warm-up, consisting of 5 inclined push-ups performed at 60, 45, and 30 cm in a descending order. A 5-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. Although 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.

Table 1. Test, retest reliability of the normalized isometric push-up (IPU), dynamic push-up (DPU), and force plate pop-up (FP POP) in $N \cdot BW^{-1}$ 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

*ICC = intraclass 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 ($N \cdot BW^{-1}$)	1.83 ± 0.42
Dynamic push-up (DPU)	
Peak force (N)	804.08 ± 202.76
Relative force ($N \cdot BW^{-1}$)	1.50 ± 0.25
Force plate pop-up (FP POP)	
Peak force (N)	749.03 ± 169.15
Relative force ($N \cdot BW^{-1}$)	1.40 ± 0.19
Time to pop-up (s)	0.62 ± 0.09
In-water pop-up	
Time to pop-up (s)	0.64 ± 0.08

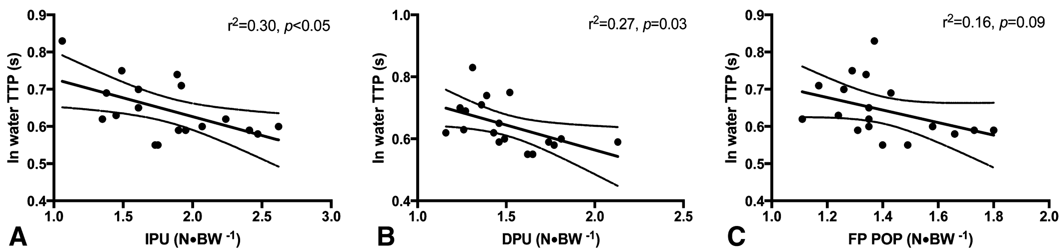

Figure 4. A) Linear regression with 95% confidence intervals and explained variance (r^2) between isometric push-up (IPU) in-water time to pop-up (TTP) for all surfers ($n = 18$). B) Linear regression with 95% confidence intervals and explained variance (r^2) between dynamic push-up (DPU) in-water TTP for all surfers ($n = 18$). C) Linear regression with 95% confidence intervals and explained variance (r^2) between force plate pop-up (FP POP) in-water TTP for all surfers ($n = 18$).

An elbow flexion angle of 100° was specified because pilot studies found it to elicit greatest PF with minimal discomfort compared with 80° and 120° (21). Before 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 5 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 2 trials, with 2-minute rest allocated between each trial. The PF recorded from the force-time curve during the IPU was recorded for subsequent analysis.

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 before 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 2 trials, with 2-minute rest between each trial. The PF elicited during the DPU was recorded as the highest PF occurring between onset of push and take off.

Force Plate Pop-Up Assessment. 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 1 explosive movement (Figure 3B). In addition to force plate analysis, the pop-up was video recorded (GoPro, HERO3 Silver Edition HD3.02.03.00;

Table 3. Mean ± *SD* and results of 1-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)	1,211.85 ± 185.06	751.76 ± 196.19	<0.01	1.53	Large
Normalized force (N·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·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·BW⁻¹)	1.48 ± 0.22	1.33 ± 0.11	0.08	0.80	Large
Time to pop-up (s)	0.59 ± 0.08	0.66 ± 0.08	0.07	0.85	Large
In-water pop-up					
Time to pop-up (s)	0.62 ± 0.06	0.66 ± 0.09	0.38	0.51	Moderate

*ANOVA = analysis of variance.

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 $p \leq 0.05$.
†Significant at $p < 0.01$.

CA, 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.

In-Water Pop-Up Assessment. Video footage was recorded from an in-water vantage point (HERO3 Silver Edition HD3.02.03.00) sampling at a rate of 100 frames per second. The camera was attached to the nose of the participant's surfboard before a 130-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 2 fastest pop-ups being used for further analysis.

Statistical Analyses

All data are presented as mean ± *SD*. Reliability of each test was assessed by calculating the ICC, typical error (TE), and the %CV, which were set at 95% confidence intervals (CIs) (11). The %CV was calculated as follows: 100 × (*SD* per 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 2 trials from each testing session. Smallest worthwhile change (SWC) was also calculated using the following equation: 0.2 × 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 whether significant changes in each variable occurred between testing sessions. All statistical analyses were conducted as 1 group ($n = 18$) before participants being divided into stronger and weaker groups based on normalized IPU scores. An independent sample *t*-test was also conducted to determine whether there was a significant difference in strength and dynamic performance

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 $p < 0.01$.

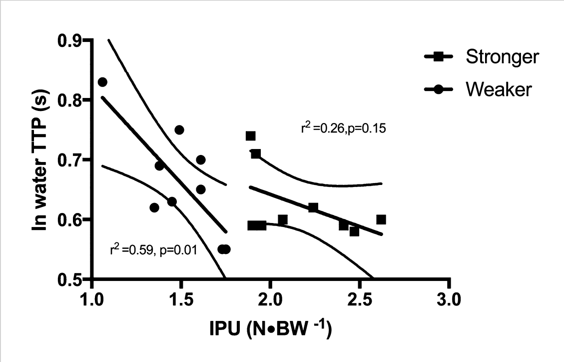

Figure 5. Linear regression with 95% confidence intervals and explained variance (r^2) between isometric push-up (IPU) in-water time to pop-up (TTP) in stronger and weaker surfers.

measures between stronger and weaker surfers. The 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 used 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 whether 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 and FP TTP is presented in Table 1. Descriptive values for all upper-body strength measures when analyzed as 1 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), DPU ($r = -0.52$, $p = 0.02$, 95% CI = −0.79, −0.06), and in-water TTP (Figure 4A, B). 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, nonsignificant 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 ($p \leq 0.05$). 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.

Discussion

The primary purpose of this study was to investigate the reliability of the IPU, DPU, and 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 indicates 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 ICC ≥0.9 and, therefore, considered highly reliable (1). The %CV was also calculated, with a cutoff value of 10% being reported in the 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 2 compared with session 1 ($d = 0.12$, $p \leq 0.05$). Because of 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 (12) highlights, performance tests can produce a greater amount of noise (TE) than the smallest meaningful change, especially when a small sample is used.

By 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 et al. (14) implemented allowed for a downward eccentric phase of movement before the participants forcefully pushing up. 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 before 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 whether 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 1 group ($n = 18$), normalized IPU and DPU scores were positively correlated with in-water TTP (Figure 4A, B). Because of the large *SD* 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 with 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 maneuvers 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 with a generic medicine ball throw, perhaps allowing for a more sensitive measure within this cohort. To our knowledge, only 1 other study has identified a significant correlation between upper-body isometric strength and sports-specific dynamic performance. Baiget et al. (2) identified a strong positive relationship between maximal isometric shoulder internal rotation strength and serve velocity in competitive professional tennis players. 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 $N \cdot BW^{-1}$ or above. However, as observed using a scatterplot of the data (Figure 5), it is apparent that 2 participants from the weaker group recorded the fastest in-water TTP, even with an IPU score that fell below 2.0 $N \cdot BW^{-1}$. Similarly, 2 participants from the stronger group who fell marginally below the 2.0 $N \cdot BW^{-1}$ threshold recorded slower in-water TTP. It could be speculated that the 2 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 with 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 3 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 with in-water TTP, highlighting land-based testing as a valid measure of in-water performance. Because of the novelty of the IPU, an additional familiarization session is necessary to limit variability in data sets.

Practical Applications

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 $N \cdot BW^{-1}$ 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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