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Field Test Performance of Junior Competitive Surf Athletes following a Core Strength Training Program

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ABSTRACT

International Journal of Exercise Science 11(6): 696-707, 2018. Lower body and core muscular strength are essential for optimal performance in many sports and competitive surfers have similar strength demands when maneuvering a surfboard to achieve competition success. Presently, the use of unstable surfaces is excessively utilized by surf coaches and trainers and to date, research does not support this as an effective training method for long-term improvements. Therefore, the purpose of this study was to determine the effectiveness of an 8-week Core Strength Training Program (CSTP) on a battery of field tests specific to assessing core musculature and lower body strength for junior competitive surf athletes. Nineteen American junior competitive surf athletes (age:15.7±1.01yrs, height:1.77±0.007m, mass:64.67±9.08kg) completed pre- and post-tests with a transitional pre-season to in-season 8-week CSTP intervention. The battery of tests included: rotational power (RP), time to peak acceleration (TP), maximal acceleration (Ma), maximal countermovement jump (CMJ), estimated peak power (PP), core strength (CS), core endurance (CE), and rotational flexibility (RF). Means, standard deviations, RMANOVA with a significance level of $p < 0.05$, and effect sizes were computed. Results demonstrated significant improvements in L.RP, TP, CMJ, PP, CS, and RF. Based on the results, the CSTP is an effective training program for surf coaches and strength and conditioning professionals to improve strength in the core musculature and lower body. In addition, we conclude implementation of the CSTP enhances athletic performance measurements which will likely increase competition success.

KEY WORDS: Surfing, conditioning, pre-season, rotational sports, power

INTRODUCTION

Due to the prestige and increased sponsorship of professional surfing, surf athletes are striving to achieve peak surf performance which requires strength, power, and endurance to execute difficult maneuvers on the most challenging waves. As a result, surf-specific training is on the rise; however, many coaches and trainers in North America may not implement evidence-based training principles which may lead to injury and lower competition scores. During competition, an athlete's performance is scored by a panel of judges using a 10.0 rating scale. This scale attempts to reflect the degree of difficulty in a single move or a combination of innovative and progressive maneuvers that have speed, power, and flow (20). Paddling endurance and strategic positioning are essential for successful wave take off. Previous literature states wave riding accounts for approximately 3.8-8% of time during a surf session and surfers travel 1605 ± 313.5 m in 20 minutes, of which 947 ± 185.6 m and 128.4 ± 25 m are spent paddling and wave riding, respectively (2). Recent literature reports significant differences in lower body power based on international surf ranking. Surfers ranked in the top 50 and those in the 51-100 ranking positions performed average counter movement jumps of 38.2 ± 4.2(cm) and 31.4 ± 4.8 (cm), respectively (10). Furthermore, Secomb, Nimphius, Farley, Lundgren, Train, and Sheppard state significant differences in countermovement jump and squat jump outcomes 0.61± 0.06 m and 0.49±0.05 m of strong and weak Australian elite surf athletes respectively (36). The current literature exemplifies the necessity for lower body power in surfing and these findings support a surfer's lower body power is critical for competition success.

For athletic purposes, the core is defined as the area between the sternum and the knees, with a focus on the abdominal region, low back, and hips (5,14,27,38,45). The enhanced muscular stiffness of the torso more effectively transfers force resulting in greater limb speed (15,22,30,43). Surfing includes a variety of technical skills such as barrel riding, a snap, cutback, or aerial maneuvers (9); thus, muscular forces are generated in the core and subsequently transferred to the lower extremities to control the surfboard. To achieve the required angular velocity for movements occurring in the sagittal and/or transverse planes, it is critical the core musculature produces forces synergistically to transfer to the extremities and that the muscular stiffness stabilizes the spine against perturbations caused by external forces, such as movement from the ocean (1,8,11,22,26,40). If muscular forces are generated and not efficiently transferred, then performance will be hindered (38).

This recently acquired Olympic and non-traditional sport has limited evidence-based training principles defining a successful strength and conditioning program to enhance athletic performance. Incorporating sport-specific exercises are essential to mimic the instability of a surfboard, although research suggests unstable surface training should be supplement to the training program. Research does not support significant increases in strength and power measurements from unstable surface training albeit positive outcomes include enhanced proprioception and motor control abilities (11). Negative outcomes such as decreased force output, increased risk of injury, muscle imbalances, overtraining, and boredom are likely to result. Saeterbakken and Fimland compared EMG recordings of rectus femoris, vastus medialis, vastus lateralis, biceps femoris, soleus, rectus abdominis, oblique external, and erector spinae during a squat on stable and unstable surfaces. The EMG activity revealed no significant difference in force output on the different surfaces, except for the rectus femoris which produced greater force output during the stable squat (32). Furthermore, Kohler, Flanagan, and Whiting reported that during a 10 RM seated overhead press, the EMG activity of the core stabilizers decreased when performed on an unstable surface (e.g. Swiss-ball) compared to a stable surface, such as a bench (24). Tse, McManus, and Masters failed to show a positive effect in endurance plank positions, vertical jump, broad jump, 10-m shuttle run, 40-m sprint, and medicine ball throws of collegiate rowers utilizing a Swiss-ball core training protocol (42). In addition, Cressey, West, Tiberio, Kraemer, and Maresh reported no significant improvements in performance tests of elite soccer players following a 10-week unstable surface training protocol (4). It is suggested to utilize unstable surfaces for sport-specific movements only and refrain from heavy loading during a complex, multi-jointed exercise on an unstable surface.

Previous literature has described the benefits of a strong core for improved performance, injury prevention, and rehabilitation (22,25,28,33,38). A strong relationship between increased core strength and improved performance in baseball, golf, soccer, running, and swimming has been reported in previous studies. Adherence to a core training program resulted in improved performance on tests such as increased 3RM rotary torso strength, increased club-head swing and ball carry distance, vertical jump, and decreased 5K running times (19,23,31,34,40). Junior male soccer players completing 12 weeks of core stabilization exercises versus conventional exercises demonstrated significant improvements in Cooper's test, rebound jump, vertical jump, and 30m sprint (19). High school baseball athletes significantly improved torso rotational strength and sequential hip-torso-arm rotational strength compared to a control group upon completing a 12-week medicine ball core training program (40). These studies concluded those athletes engaging in core resistance training a minimum of 2x per week will increase overall core strength and improve transfer of muscular forces. The evidence-based training approach is critical for junior surf athletes and implementation of periodized macro-micro cycles utilizing complex, multi-joint, and rotational resistance training exercises may enhance competition success and decrease the chance of injury.

Therefore, based upon the previous literature, a strength training protocol for the core and lower body may be essential to improve performance in competitive surfing. The purpose of this study was to determine the effectiveness of an 8-week core strength training program (CSTP) on field test performance variables in American junior competitive surf athletes.

METHODS

Participants

This study implemented a quasi-experimental design since it compared pretest and posttest data for one group of participants. Twenty-six nationally ranked junior male surf athletes with a minimum of two years of competitive experience volunteered to participate in this study. Participants were younger than 20 years old and free of any muscular-skeletal injuries. Participant dropout due to age limit, injury not resulting from this study, illness, and/or relocation, resulted in a total of 19 participants completing this study (age: 15.9 ± 1.0 years, height: 1.8 ± 0.01 m, mass: 64.0 ± 9.0 kg. All participants completed an approved Institutional Review Board (IRB) parent/legal guardian informed consent and child assent form prior to participation in the study.

Protocol

This study examined the effect of a transitional pre-season to in-season 8-week CSTP in American junior competitive surf athletes using a pre-post measures research design. Changes in rotational power (RP), maximal acceleration (Ma), time to peak acceleration (TP), maximum countermovement jump (CMJ), estimated peak power (PP), core strength (CS), core endurance (CE), and rotational flexibility (RF) were measured using performance-based field tests. Due to the limited number of American junior competitive surf athletes, having adequate sample size for both an experimental and control group would have been difficult; therefore, no control group was chosen for this study. The 8-week CSTP included 2x per week supervised training sessions led by a certified strength and conditioning specialist.

All participants completed 3 days of testing. Day 1 was a “practice day” and participants were familiarized with the battery of performance tests. Day 2 and 3 were the “pre-test” and “post-test” respectively. The first session was included to reduce a possible practice effect and improve reliability. Each participant’s height and mass were recorded at the start of testing, and then each participant completed a defined dynamic warm-up. Following the warm-up, the field tests were performed in this order for both the pre- and post-testing sessions: RP-TP-Ma, CMJ, CS, CE, RF in order to minimize random effects due to testing order. Upon pretest completion, the participants began the 8-week CSTP. All participants were instructed to maintain a normal diet, sleeping patterns, surfing regimen, and refrain from any additional resistance training.

Rotational power (RP) was measured using a 3-kg dumbbell equipped with a TENDO Fitrodyne Sports Powerlyzer (V-204, TENDO Sports Machines, Slovak Republic). Previous research has shown reliable measurement of muscle power using the Fitrodyne with intraclass correlation coefficients of 0.97 (1, 21). For this study, participants sat at a height of 0.457m and grasped the dumbbell with both hands and positioned the dumbbell at chest level. On a verbal cue, the participant was instructed to rotate 180 degrees forcefully and then slowly return to the starting position. A total of 6 trials, 3 rotating right and 3 rotating left, with 2 minutes of rest between each were obtained.

Acceleration (TP & Ma) utilized a dumbbell equipped with a 3-D accelerometer (3D-BTA, Vernier Software & Technology, Beaverton, OR) and time to peak maximal acceleration (TP) and maximal acceleration (Ma) were collected via Logger Pro 3.8.6 (Vernier Software & Technology, Beaverton, OR). The use of an accelerometer in providing reliable measures has been established by Sato with an intraclass correlation coefficient of 0.94 (35). The accelerometer trials were measured simultaneously with the RP trials.

Maximum Countermovement Jump (CMJ) was measured using a Vertec (Vertec, Sports Imports, Hilliard, OH). Vertical jump has been determined as a valid and reliable field testing procedure to estimate lower body power with an intraclass correlation coefficient 0.89, a standard error of measurement 2.1, and coefficient of variation 6.9% (12,13,29,37). Each participant performed 3 trials of a maximal countermovement jump, and 2 minutes of rest was allotted between each trial.

Estimated Peak Power (PP) was determined by the CMJ and the following formula given by Duncan, Hankey, Lyons, James, and Nevill: $PP = 1.27 \times (mass^{1.149}) \times (CMJ^{0.854})$ (7).

Core strength (CS) was measured using a dynamic medicine ball toss using a protocol established by Cowley and Swenson with an intraclass correlation coefficient of 0.93 (6,18). Participants were instructed to perform this on one knee and rotate forcefully in the transverse plane while holding a 2kg-medicine ball with their arms extended in line with their chest, and then toss the medicine ball with maximal effort. The distance of the medicine ball throw was measured at its initial contact with the ground. A total of 6 trials, 3 rotating right and 3 rotating left, with 2 minutes of rest between each were obtained.

Core Endurance (CE) was measured using a timed prone plank test established by Strand, Hjelm, Shoepe, and Fajardo (39). On verbal cue and the start of timing, participants supported their weight on their toes and forearms in a static position as long as possible. The participant lowered to the ground when he reached failure or could no longer maintain spine stabilization. Time was measured using a hand-held stop watch (2832 Sportsline Inc, 2006, China). Three trials were performed with 2 minutes of rest allotted in-between each trial.

Rotational Flexibility (RF) was measured using a dynamic trunk rotation flexibility protocol established by Bobo and Yarbrough (3). An 8.5 X 11 inch placard with a large "X" was placed on a wall, and participants were an arm's length distance from the wall and another X placard was placed between the participant's feet. The participant stood with his back to the wall with arms at chest level and their hands together. The participant flexed at the hips to touch the X between their feet and then rose and twisted to right to touch the X on the wall behind them. The participant then touched the X between their feet again and twisted to the left and touched the X on the wall. This was repeated as fast as possible for 20 seconds and number of "X" touches were recorded. Three trials were completed with 2 minutes of rest in between.

The CSTP was designed as a periodized 8-week/2x per week intervention training program. All athletes in the cohort completed the same program. The program was created with micro and meso-cycles of endurance, strength, power, peaking and maintenance phases of training based upon exercise selection, sets, repetitions, rest time, and over-all intensity. Exercise selection integrated multi-joint, dynamic exercises that research supports enhanced muscular strength and power, such as squats, lunges, barbell landmines, planks, and medicine ball training (see Table 1 for sample program). As previously stated, rotational medicine ball exercises engage the core musculature to enhance a transfer of force output to the limbs (40). Each training session began with dynamic warm-up for 8-10 minutes and finished with a static cool-down stretch for 5-10 minutes. Participants were expected to maintain a 90% adherence rate for all training sessions or were removed from the study.

Table 1. Sample 8-Week Core Strength Training Program (CSTP).

Phase of Program	Day 1	Sets x Reps	Day 2	Sets X Reps
Week 1: Endurance				
	Depth jump	3x10	Squat w/ MB Rotation	4x12
	Split squat BL weight	3x12	Squat Jump	4x12
	MB standing Russian twist	3x12	Reverse Lunge w/ ROT	4x12
	Static Paloff press	4x30 sec	Plank	4x1min
	SL deadlift	3x12	BB Floor wipers	3x12

Week 4: Strength-Power				
	Suitcase squat	4x5	Depth jump + squat jump	5x5
	Standing long jump	4x8	Tuck jump	4x8
	Reverse lunge with MB ROT	4x12	Forward lunge BL weight	3x12
	Plank reach	4x1min	MB toss seated	4x12
	Paloff press	4x12	BB roll out	3x12
Week 6: Power-Peaking				
	Squat jumps resist	4x5	Depth jump + squat jump	5x6
	Resistance band power ROT	4x8	Squat jump 180+Bosu	4x6
	Forward lunge MB ROT	4x12	Split squat ROT MB toss	4x8
	Seated MB ROT toss	5x8	Plank dynamic ROT	5x20
	MB sit-up throws	4x10	SL MB toss/catch	4x8
Week 8: Maintenance				
	Depth jump + 2 LJ	5x5	Progressive box jumps	5x4
	BB chops	3x10	Squat jumps resist	5x6
	MB slams	3x12	BB landmines	2x10
	Plank US	3x45sec	US split squat MB ROT	3x12
	Paloff Press	3x12	Floor wipers	3x12
			MB sit-up throws	3x12

*BL- bilateral, MB- Medicine ball, SL-single leg, BB- Barbell, ROT- rotation US-unstable

Statistical Analysis

All statistical analyses were performed with SPSS version 22.0 (SPSS Inc., Chicago, IL). Descriptive statistics were computed, and normality was assessed using a Shapiro-Wilk test. The following variables were found to have a non-normal distribution: Pre-RTP, Pre-RRP, Pre-CMJ, Pre-CE and Post-CE. Therefore, a log_{10} transformation was performed on the non-normally distributed variables as well as the corresponding posttest variables to maintain similar scales. After transformation, all variables were normally distributed except for Pre-CMJ. The two confirmed outliers were removed for CMJ only. One-way, repeated measures ANOVA was computed for each pre-post pair of dependent variables. Effect size was computed using partial eta² squared (η^2) for repeated measures.

RESULTS

Means, standard deviations, and percentages of performance improvements are presented in Table 2. At the conclusion of the CSTP, the 19 participants demonstrated improvements in all the field testing variables except for R.RP. Moderate effect sizes (0.40 – 0.70) were observed for left core strength and rotational flexibility. The remaining significant variables had effect sizes ranging from 0.24 to 0.39. Improvements from pre- to post-test were observed in all variables except R.RP. In addition, the large standard deviation for CE in the post-test may have limited a significant finding for this variable.

Table 2. Pretest vs. Posttest for Performance Tests (N=19).

Variable	Pretest (M±SD)	Posttest (M±SD)	% Change (M±SD)	*p*-value	η²
R.TP (sec)	0.13±0.01	0.10±0.01*	22.0±42.0	0.030	0.24
L.TP (sec)	0.10±0.01	0.07±0.01*	33.0±12.0	0.005	0.36
R.Accel (m/s²)	41.25±2.03	43.12±2.52	5.0±24.0	ns	
L.Accel (m/s²)	33.00±3.45	33.28±3.03	1.0±12.0	ns	
R.RP (Watts)	186.05±13.95	178.00±8.76	-4.0±-37.0	ns	
L. RP (Watts)	173.74±7.87	198.42±8.43*	14.0±7.0	0.012	0.300
CMJ (m)±	0.51±0.04	0.55±0.02*	7.0±58.0	0.006	0.386
PP (Watts)	4511.92±887.22	4821.57±971.07*	7.0±9.0	0.006	0.383
R.CS (m)	7.19±0.31	7.91±0.26*	10.0±16.0	0.013	0.295
L.CS (m)	7.45±0.26	8.26±0.28*	11.0±7.0	0.001	0.465
CE (sec)	225.05±28.88	374.00±90.85	66.0±215.0	ns	
RF (# repetitions)	37.37±1.15	42.79±1.14*	15.0±-1.0	0.000	0.643

* $p < 0.05$, ns=non-significant; ± N =17 for CMJ with outliers removed

DISCUSSION

Competitive surf athletes rarely engage in evidence-based training protocols and the junior surf athletes completing the transitional pre-season to in-season 8-week CSTP improved their rotational power, time to peak acceleration, maximal countermovement jump, estimated peak power, core strength, and rotational flexibility. A novel aspect of this study demonstrates the effectiveness of a short-term core and lower body training intervention for surf athletes to peak for competition success. Furthermore, the 19 participants adhering to the CSTP demonstrated comparable improvements as those reported in other core training studies (16, 19, 31, 40). In general, the sport of surfing is year-round, and execution of a well-designed program to peak for performance is paramount for an athlete's success.

The increase in L.RP, R.TP, and L.TP during the seated rotation may indicate a faster and or more efficient Type IIa and Type IIb muscle fiber recruitment. These results suggest a surf athlete will be able to produce and transfer greater amounts of angular velocity and force to the extremities for a competitive advantage. As previously stated, high school baseball players significantly increased torso rotational strength by completing 12-weeks of a medicine ball core training program with an increase in 3RM torso rotational strength in their dominant and non-dominant (17.1 and 18.3%) sides respectively (40). Although baseball differs from surfing, mechanically these sports are similar regarding explosive movements and require core strength training regimens. In contrast, maximal acceleration in the right and left sides did not significantly increase nor R.RP, although individual participant's testing values improved. Existing research states contrary reports of the external dynamometer and further validation is necessary for a gold standard of testing rotational power (44).

The lower kinetic chain has been overlooked in previous competitive surfing research until recently and the results of the present study significantly increased in CMJ and PP for junior surf athletes. The outcomes of this study demonstrate greater athleticism in these junior surfers compared to internationally ranked surfers. As previously stated, internationally ranked surfers CMJ range from 31.4 ± 4.8 cm to 38.2 ± 4.2 cm compared to current pre/post values 0.51±0.04 m and 0.55±0.02 m, respectively (10). In addition, Australian junior surfers have reported CMJ of 0.49± 0.05 m for their national team selected athletes (41). Based upon these findings, the internationally ranked surfers may not have engaged in a training regimen during their competition season which may define their lower CMJ results. In addition, the participants in this study may have successful professional surfing careers based upon the greater values in CMJ. It is advised surfing organizations include CMJ as a field test for talent identification. Although tactics and experience influence competition outcomes, it is strongly advised to incorporate core and lower body strength training to enhance competition outcomes. A fundamental aspect of this study demonstrates values are comparable to other junior elite athletes. The participants had greater vertical jump than athletes in swimming (32.45± 4.2 cm) and soccer (40.96± 2.62 cm), but similar results to basketball athletes (51.6± 6.9 cm) (16,19,31,). The estimated PP is a reliable and efficient parameter to utilize throughout the season to monitor an athlete's training program (7).

Implementation of the CSTP resulted in increased medicine ball throw distances which is indicative of an increase in force production of the external obliques (18). Shinkle, Nesser, Demchak, and McMannus stated Divison-I football players demonstrated significant correlations in medicine ball throws and various athletic tests that supports the core musculature is an important component to sport and athleticism (38). This finding lead to the development of a field test utilizing the medicine ball throw. As previously mentioned, Szymanski, Szymanski, Brandford, Schade, and Pascoe demonstrated significant increases in medicine ball throw distances upon completing a 12-week medicine ball intervention (40). These results are comparative to the current study for an increase in medicine ball throw distances. Although the participants had marginal differences in throw distances compared to baseball players, albeit the 10% improvement in the current study states the CSTP enhanced core strength. The distance thrown demonstrates the explosiveness and sequential torso strength necessary to the maneuvers in surfing. The data support the CSTP increased overall CS for these participants and medicine ball training should be incorporated in surf-specific training protocols because it allows the athlete to move at high velocities in patterns similar to the skills employed by the sport (8,40). This test allows surf coaches and trainers an easy and reliable field testing protocol for future surf specific training.

Core endurance did not significantly improve due to minimal isometric exercises throughout the CSTP however, normative data by Strand et al states the 90^{th} percentile of collegiate varsity male athletes have similar CE outcomes compared the current studies pre-testing values (39). Surf competitions may last 1-7 days with 20-35 minute heats, and endurance of the core is necessary to maintain stabilization and coordination during wave-riding skills. A surf athlete with greater muscular endurance is less likely to fatigue and may result in the likelihood of heat wins and overall competition success. Lastly, RF significantly improved and suggests the CSTP increases range of motion and movement time in the lower kinetic chain. Although the most common flexibility test is the static "Sit and Reach" (12) the RF test engages the core musculature in a dynamic function. Flexibility is essential to a surf athlete's overall physical fitness, injury prevention, and efficient performance and implementing the CSTP will enhance junior athlete's flexibility and movement time to adapt to the wave's interchanging environment.

This study has provided a framework for future surfing research and training protocols for enhancing athletic performance variables related to surf performance. Program development for junior athletes is fairly recent and further research is necessary for determining whether asymmetries in rotational skills are detrimental to performance. Asymmetrical strength may occur due to the athlete's surf stance and overall preference of riding wave's front side or back side. Data in this study demonstrated the CSTP did not improve symmetry of the core; however, performance based field tests values did improve. A limitation of this study is that no evaluation of surfing performance was done during a competition. This was due to inconsistent swell patterns and competition locations during the study and future research may be necessary in utilizing wave pool technology for a standardized competition arena.

In summary, significant improvements in a battery of field tests were achieved in American junior competitive surf athletes who completed the 8-week CSTP. These achievements may be attributed to the periodization and greater training intensities incorporated into the CSTP. The results demonstrated those surf athletes engaging in periodized land-based training 2x a week enhanced their core musculature strength, power, countermovement jump, peak power, and rotational flexibility. Future studies should include a control group and/or a comparative intervention group and attempt to control for time spent surfing. In addition, studies determining reliability and validity of CE and RF tests should be completed. These inclusions would address the major limitations of the current study.

This study was designed to afford surf coaches, trainers, and sports-scientists validation for incorporating a battery of field tests applicable to the core musculature and lower body for surfing maneuvers. The CSTP is an effective protocol during a surf athlete's pre-season and in-season training to improve strength in the core musculature and lower body to enhance athletic performance and minimize the risk of injury. In addition, the CSTP may also be used in the rehabilitation field in recovering from previous musculo-skeletal injuries to regain core strength. In general, evidenced-based surf-specific training protocols will increase strength in the core and lower body which is likely to increase competition success and decrease the chance of injury for surf athletes.

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