Profiling elite stand up paddle boarders

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Published in:
Journal of Fitness Research

ORIGINAL RESEARCH

PROFILING ELITE STAND UP PADDLE BOARDERS

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ABSTRACT

Introduction: Stand up paddle boarding (SUP) is a rapidly growing sport and recreational activity where anecdotal evidence exists for its proposed fitness, injury rehabilitation & core strength benefits. A review of the literature failed to identify a single article which examined the potential physiological adaptations associated with SUP.

Aims: The purpose of this study was to profile elite stand up paddle boarders in relation to balance, muscular strength and muscular endurance.

Methods: Eight elite SUP's were recruited from the Stand Up Paddle Surfing Association of Australia. Anatomical measures of multifidus cross-sectional area (via ultrasound), postural control under static and dynamic conditions and an isometric test of lumbar extension were performed.

Results: Results found no significant differences in height, significantly less mass ($p = 0.001$) and significantly lower BMI ($p < 0.05$) than published Australian Bureau of Statistics data. Significantly lower static postural control indicated by increased velocity of sway (($p < 0.01$), Eyes Open (EO) = +72.02% Eyes Closed (EC) = +76.34%) and significantly higher levels of dynamic postural control indicated by decreased velocity of sway ($p < 0.01$, Eyes-Open-Anterior-Posterior instability condition (EOAP) -34.54%, Eyes –Closed-Anterior-Posterior instability condition (ECAP) -35.83%, Eyes Open Medial Lateral instability condition (EOML) -16.91%, Eyes Closed Medial Lateral instability condition (ECML) -10.42%) were recorded in all but one condition when compared to national level surfers, which we attributed to time spent in the standing position on an unstable surface.

Conclusion: These results indicate that stand up paddle boarding may indeed be beneficial for strength and endurance training of the trunk musculature, for balance training for other sports and useful as a rehabilitation tool for musculoskeletal dysfunction.

Key Words: water sports, stand up paddle, paddle boarding, SUP

There were no conflicts of interest of from any authors involved with this original research article.

ISSN 2201-5655

INTRODUCTION:

Stand up paddle boarding (SUP) is a relatively new sport and recreational activity, which is increasing in popularity around the world due to its proposed fitness, core strength benefits and enjoyment. SUP is a hybrid of surfing and paddling in which participants can either distance paddle and/or surf waves [1]. Many websites anecdotally advocate the use of SUP to increase strength, fitness, core stability, balance and decrease back pain. However our recent review of the literature found no scientific evidence to substantiate the proposed benefits.

SUP is an activity in which the participant maintains a standing position on a board similar to a surfboard however stand up paddle boards are longer in length (~8-15'), thicker (4-8") and wider (26-31") than traditional surfboards. The participant propels the board across the surface of the water by the use of a long single-bladed paddle[1].

While the standing position is unstable initially, it is continuously disturbed by the motion of the board and paddle in the water and the movement of the arms in the air, providing a constant postural challenge. The sport is low impact, therefore no repetitive impact on the joints, making it suitable for all ages.

SUP requires the participants core musculature to be activated at all times to stabilise while muscles of the legs, arms, back, even feet and toes are used to maintain balance on the varying stability aquatic environment. This stance is also known as the neutral power stance in yoga, which requires individuals to utilise postural muscles. It has been previously reported that relaxed postures rely on passive lumbopelvic support structures for the maintenance of upright position against gravity, as slumped postures have been associated with motor dysfunction of the spine stabilising muscles, including the lumbar multifidus and the deep abdominal musculature [2].

It has been reported that improved core stability occurs when training on unstable surfaces [3] and core stability training is commonly integrated in later stages of rehabilitation programs due to higher demands on the motor control system and increased electromyographic (EMG) recordings from the abdominal musculature [4]. Due to the fact that unstable surface training normally dictates using lighter weights and movement velocities, such training is more suited for developing muscular endurance rather than muscle strength and power [5].

The measurement of postural sway is well documented, and has several potential applications in sports including selection of skilled athletes, study of techniques of sports which require high levels of postural control and prevention and treatment monitoring of sports injuries [6]. Measurements utilizing force platforms have been shown to be reliable and data such as length of sway, area of sway, velocity and frequency of sway can be obtained [7].

Surfing is a similar water based sport to SUP in that it requires a high level of balance from its athletes. A small number of articles have investigates the balance ability of elite level surfers to which comparisons to a SUP population can be drawn [8, 9].

In the context of a global obesity epidemic, it is of interest to investigate the BMI of these SUP competitors. On a population level, BMI is a valuable tool for assessing body mass. There is an enhanced risk of morbidity and mortality due to elevated BMI [10]. Due to high muscle mass, there are some limitations of BMI as an index for athletic populations [11].

The purpose of this study therefore was to investigate valid and reliable outcome measures for assessing static and dynamic balance in SUP, and assess the trunk musculature strength of elite stand up paddle boarders. We hypothesise that the dynamic balance control of these athletes would be similar to previously published data for elite surfers and that these athletes would have high levels of trunk muscle endurance.

METHODS:

Participants

A total of eight elite ranked SUP individuals (avg. experience 4.5yrs) recruited from the Stand Up Paddle Surfers Association volunteered to participate in this study. SUP athletes were without a history of back pain, current lower limb injury, not currently pregnant, and had no documented history of any mental health disorders, balance disorders or neurological impairment. The study was approved by the University Ethics Committee and each participant signed an informed consent form prior to taking part in the study.

Data for comparative purposes from the Australian National Health Survey 2007-2008 was obtained via the Australia Bureau of Statistics (ABS). The data contained unit record files for the Australian population with identifiers removed and some ratio data (such as age) collapsed into categorical format.

Protocol:

Anatomical Measures: The participants height, weight and percentage body fat were measured with bio-impedance electronic scales (Tanita, BF-679W) prior to any test being conducted. Measures of multifidus cross-sectional area, postural control and back extensor endurance were then recorded.

Postural Control was assessed via a portable force platform (Kistler 2812D with Bioware 4.0, 100 Hz sampling rate) with three piezoelectric force sensors used to calculate the centre of pressure (COP) foot positions. Eight postural conditions were tested: Standing feet together on the platform, on foam (F), on a See Saw (Stabilometre, Techno Concept, France) facing anteriorly (AP) and finally the See Saw facing medial to lateral (ML) [9]. The see saw was a segment of cylinder, radius 55cm, height 6cm (figure 3) which was placed on the force platform under the dynamic conditions. These conditions were tested with eyes open (EO) and then repeated with eyes closed (EC). The tests were conducted in order from most stable to least stable.

For determination of postural control, participants stood barefoot with their medial malleoli together with their feet forming an angle of 30^{o}, hands by their side and legs straight. The postural tests ran for 50 seconds under the stable tests and 25 seconds under the dynamic conditions. The participants were instructed to stand as still as possible for the duration of the test, with eyes open and their head and eyes looking straight forward. Each test was conducted only once to negate the phenomenon of learning.

COP signals were smoothed using a Butterworth filter with a 10Hz low pass cut off frequency. A 100% square (a square in which all the samples lie equal to a COP area) was calculated post collection via the range of both the x and y deviations. The COP sway path length (the total distance travelled by the COP over the course of the trial duration) was calculated via the distance between each sampling point. From the COP excursion, the COP velocity was calculated (Velocity=Distance/Time).

Ultrasound imaging of multifidus back muscle cross sectional area: was carried out with the participant in a prone position on a plinth with a pillow placed under the hips to eliminate lumbar lordosis, following which the researcher palpated the iliac crest to determine the L4 spinous process. From this reference the L4/L5 multifidus muscle was identified.

A diagnostic ultrasound scanner, (General Electric, model Vivid i) was used to image the left and right multifidus muscle according to the methods previously described by Stokes [12]. Images captured were subsequently saved to USB and analysed using specialised image processing and analysing software (Image J 1.45S, National Institute of Health). Cross sectional area was determined by manually tracing a line around the circumference of the multifidus muscle by the same investigator.

Lumbar Extensor Endurance: The participants were asked to lie prone on a plinth with their iliac crests in line with the edge of the plinth and their upper body resting on a chair. Participants were asked to keep the body (head, arms and trunk) unsupported in the horizontal position as long as possible. The test was terminated when the participant could no longer hold the horizontal position as determined by the tester and the time was recorded.

STATISTICAL ANALYSES:

Exact p values were calculated in order to conservatively produce a more accurate p value than via conventional asymptotic approximation due to the small sample size. This provided both appropriately accurate data comparisons and reliable inferences for the sample sizes presented in this data set. Non-parametric linear correlations were analysed using Spearman's Correlation. One sample t-tests were used to compare with control data obtained from the ABS. Posture test results were compared across the various surfaces via Friedman tests. Post-hoc testing was conducted using the Wilcoxon Signed Ranks test. This was used together with the Mann-Whitney U test to compare independent groups in the data. A sequential Bonferroni rejective multiple test procedure was used to adjust for multiple comparisons.

A reliability assessment of the ultrasound measurement of the multifidus muscle was also performed. An analysis of statistical comparisons of within-session reliability was produced, as only one investigator was involved. Statistical analysis was conducted using SPSS (version 19). The alpha level was set at $P \leq 0.05$.

RESULTS:

Demographics: The average age of the SUP athletes in this study was 35.7yrs, as seen in Table 1. Heights and weights were compared, to published data from the ABS (data was age restricted to 25-49 years). There was no significant difference in height between SUP males and ABS males (n=5261) or between SUP as a whole compared with the database combined and controlled for gender (n=5361). Males were of comparable mean height to their ABS counterparts (1.76m vs. 1.77m) and females slightly taller (1.68m vs. 1.64m) Over-all, compared to a gender matched ratio of ABS data, SUP heights were not significantly different to the ABS data.

The SUP participants had significantly less mass (72.25kg vs 80.20kg, p=0.001) than the comparative age and gender matched ABS data. As expected for an athletic population, body mass index (BMI) 30kg/m^2 compared favourably with the ABS data. None of the SUP athletes were classified as obese (BMI > 30kg/m^2) which compared favourably with the age-matched range and gender matched ratio of ABS data (n = 5181) for which 24% were classified as overweight. BMI was significantly lower in SUP athletes ($p < 0.05$).

As would be expected, there were significant differences between genders, in terms of body fat and multifidus size. Males demonstrated significantly lower absolute percent body fat (-10.18%) as compared to females (Z = 2.24, p = 0.04) while the males multifidus size measured on the right (+21.91%) and on the left (+21.59%) were both significantly larger (z = 2.24, p = 0.04).

Table 1. Baseline measures of the athletes. (Mean +S.D.)

	Group (n=8)	Males (n=5)	Females (n=3)
Age (years)	36.8 ± 6.3	38.4 ± 7.3	34.0 ± 3.6
Experience (years)	4.1 ± 2.2	5.0 ± 2.3	2.7 ± 0.6
Height (cm)	173.2 ± 5.5	176.2 ± 3.1	168.0 ± 4.7
Weight (kg)	72.3 ± 6.9	75.8 ± 3.3	66.4 ± 8.0
BMI	24.1 ± 2.3	24.4 ± 1.6	23.6 ± 3.7
% body fat	17.5 ± 6.4	13.4 ± 2.3	24.4 ± 4.6

Postural Control: As seen in table 2, postural control was the highest in the EO and EOML positions. The highest 100% squares were found in the ECf condition. The lowest velocity was in the EO condition, with the highest velocity seen in the ECML condition.

Spearman's rho revealed many correlations ($p < 0.05$) between 100% square, way path length (SPL) and velocity for the eight postural control conditions. This was expected given the logical association between different postural balance tasks. This finding and the high ϱ values (highest nonadjusted $\varrho = 0.86$) would indicate that the postural conditions were closely inter-related and that with more extensive testing, on a larger subject group, a suitable inferential model could be developed to identify the most representative variables, streamlining testing procedures.

Comparison of paired conditions EO-EC, EOf-ECf, EOAP-ECAP and EOML-ECML all showed statistically significantly ($Z > 2.5$, $p < 0.01$ for all, via Wilcoxon Signed Ranks exact test) increased 100% square, SPL and velocity when eyes were closed compared to the eyes open condition.

Examining data for the EO condition across the various surfaces via Friedman exact tests indicated significant differences in 100% square ($X^2 = 10.1$, $p < 0.05$), SPL ($X^2 = 21.8$, $p < 0.001$) and velocity ($X^2 = 18.2$, $p < 0.001$). Statistically significant differences existed across the various surfaces with Friedman exact tests performed in the EC case indicating further significant differences in 100%

Table 2: Centre of Pressure (COP) results for the postural tasks (Mean 95%CI).
COP surface: a square drawn around all the points in which the entire sample is contained.
(X*Y) Vel: Velocity of the COP deviation over the entire sample. (V=D/t)

	SUP			Local Surfers (Palliard, 2011)				National Surfers (Palliard, 2011)			
Condition	COP surface (mm^2)	Sway Velocity ($mm \cdot s^{-1}$)	Sway Path Length (mm)	COP surface (mm^2)	*p* value	Sway Velocity ($mm \cdot s^{-1}$)	*p* value	COP surface (mm^2)	*p* value	Sway Velocity ($mm \cdot s^{-1}$)	*p* value
Eyes Open	277.5 ±110.8	13.4 ±2.0	670.6 ±100.5	126.3 ±55.1	0.007*	8.2 ±2.5	<0.001†	112.5 ±26.5	0.004*	7.8 ±1.8	<0.001†
Eyes Closed	467.7 ±184.4	17.8 ±4.3	890.1 ±213.2	112.8 ±84.7	0.048*	10.4 ±2.8	0.002†	137.1 ±61.7	0.043*	10.1 ±2.8	0.001†
Eyes Open foam	502.6 ±115.1	17.2 ±1.4	858 ±71.3	-	-	-	-	-	-	-	-
Eyes Closed foam	1499.0 ±456.6	29.8 ±2.8	1490.3 ±138.3	-	-	-	-	-	-	-	-
Eyes Open Anterior Posterior	364.0 ±104.7	19.3 ±2.1	486.1 ±51.4	268.1 ±142.0	0.032*	39.5 ±15.7	<0.001†	195.7 ±87.0	0.003*	29.5 ±6.8	<0.001†
Eyes Closed Anterior Posterior	1162.4 ±490.4	30.5 ±5.3	762.1 ±131.9	829.8 ±200.0	0.003*	65.5 ±19.6	<0.001†	612.8 ±263.7	0.017*	47.5 ±9.6	<0.001†
Eyes Open Medial Lateral	270.5 ±116.5	18.3 ±3.7	457.1 ±91.7	237.5 ±83.9	0.26	25.2 ±6.0	0.001†	231.1 ±116.7	0.185	22.2 ±4.9	0.024†
Eyes Closed Medial Lateral	1146.2 ±441.8	36.3 ±13.0	907.1 ±324.0	1311.9 ±479.2	0.358	52.1 ±16.5	0.011*	762.1 ±245.9	0.043*	41.1 ±13.0	0.388

* - significant at < 0.05 level after multiple comparison adjustment
†- significant at < 0.01 level after adjustment

($X^2 = 11.6$, $p < 0.01$), SPL ($X^2 = 18.2$, $p < 0.001$) and velocity ($X^2 = 17.3$, $p < 0.001$). Post-hoc Wilcoxon Signed Ranks exact tests, adjusted for multiple comparisons indicated standing on foam in both EO and EC conditions resulted in significantly higher 100% square, SPL and velocity (all $p < 0.01$) than the respective conditions without foam (even despite standing for a shorter time).

In the EO condition, testing on foam produced significantly more 100% square and SPL than the AP and ML results (all $p < 0.05$ after adjustment). The velocity was higher for both ML and AP than foam and for AP this was significantly so ($p < 0.05$). A similar pattern was also confirmed in the EC condition, with testing on foam producing higher 100% square and SPL, together with lower velocity. In this situation however, only SPL was statistically significant ($p < 0.05$, for both foam vs. ML and foam vs. AP) after adjustment for multiple comparisons. Velocity was statistically significantly lower ($p < 0.05$) in each of the EO and EC conditions standing directly on the force plate (FTEO and FTEC) than for each of the AP and ML situations.

When comparing this data to extrapolated from Palliard's study on Surfers [9], (1-sample t-test adjusted for multiple comparisons), surface area was greater than local and national surfers under all eight measured conditions. The difference was significant ($p < 0.05$) in EO, EC, EOAP, ECAP conditions for the local surfers and all conditions except EOML in national surfers.

Multifidus Cross-Sectional Area: With regard to the reliability of measuring multifidus cross-sectional area the very high Cronbach's Alpha of 0.922 and an ICC of 0.922; (95% CI 0.71-0.99) average measures indicated excellent reliability of measurement. The average cross-sectional area measurements for both right and left multifudus muscles for all participants (both female and male) are presented in Table 3. Males demonstrated greater cross-sectional areas than females (multifidus R ($z = 2.24$, $p = 0.04$) and multifidus L ($z = 2.24$, $p = 0.04$)).

Biering Sorensen: With respect to the Biering Sorensen test of isometric endurance, the average endurance time was 129.12±28.94 seconds for the entire group, 125.13±10.78 seconds for males and 137.10±32.93 seconds for females (Table 3). BMI had a strong negative correlation ($\varrho = -0.86$, $p = 0.007$ unadjusted) with the Biering Sorensen test.

Table 3: Multifidus sizes and Biering Sorensen hold times. (Mean±SD)

	Multifidus (R- cm²)	Multifidus (L- cm²)	Biering Sorensen (secs)
Group	6.12 ± 0.79	6.19 ± 0.80	129.12 ± 28.94
Males	6.51 ± 0.51	6.59 ± 0.55	125.13 ± 10.78
Females	5.34 ± 0.41	5.42 ± 0.34	137.1 ± 32.93

DISCUSSION:

Anatomical Measures:

This population of SUP athletes demonstrated lower than average body fat percentages when compared to the average age matched Australian individual. There were no significant differences in the male SUP heights to the average height of age and gender appropriate comparison from the Australian national population [13]. Mendez-Villaneuva found that a shorter stature was more advantageous to surfing performance specifically dynamic balance [14]. The same benefit in a shorter stature could be advantageous on a SUP if surfing was the predominate activity being performed, or alternatively, a taller stature with a greater reach could allow a greater distance per stroke when speed across the water is the primary aim.

The large number of SUP participants being classified as overweight may raise concern about the health and wellbeing of this cohort. It should be noted however that although a high percentage of these athletes were determined to be overweight, BMI does not take in to account lean muscle mass. The athletes amongst this cohort demonstrated body fat percentages which were not significantly different to a team of national water sport professionals [15]($p = 0.338$), therefore BMI should only be considered a general indice of health and estimation of per cent body fat should be considered a better measure [15]. It has previously been reported that BMI only moderately correlates with percentage body fat (r = 0.60 – 0.82) and may erroneously categorise athletes with high muscle mass into being overweight or obese [11].

Multifidus: The results from this study demonstrated an average multifidus cross sectional area (CSA) larger than the more recent work of Hides, but slightly less than Stokes and Lees work in 2005 and 2006 respectively [12, 16, 17]. The average size for male athletes was 6.51 (± 0.51cm^2) on the right and 6.59 (± 0.55cm^2) on the left, less than Stokes and Lee's more recent work [12, 17]. The average CSA of female athletes are similar to the sizes obtained by Hides in 1992 [18], Stokes in 2005 [12] and slightly larger than Hides work in 1995 and 2008 [19, 20].

There have been a wide variation of results published throughout the literature regarding the size of the multifidus CSA measured by ultrasound. There are different interpretations of where the muscle belly finishes laterally due to its proximity to longissimus [12].

Table 4: Previously published results of CSA of multifidus, all taken at L4/5 (mean ± SD)

Author	Male (cm^2)	Female (cm^2)
Hides, 1992	6.15 ± 0.93	5.6 ± 0.8
Hides, 1995	-	4.13
Stokes, 2005	7.87 ± 1.85	5.55 ± 1.28
Lee, 2006 (L;R)	7.62 ± 1.38 7.68 ± 1.29	-
Hides, 2008	4.79 ± 1.70	3.80 ± 1.74

As per the table 4, Hides found L4 CSA's to be 5.42cm^2 amongst a population of asymptomatic athletes and 6.15 (± 0.93) and 5.6 (± 0.8) in her earlier research in 1992 [18]. Stokes found males to have an average of 7.87cm^2, females 5.55cm^2 in 2005. The measured values in this study are well above Hides most recent work, which arguably could be the most valid with more modern ultrasound machines and higher resolution.

Perhaps the lumbar multifidus role as a stabiliser does not require an increased size. Parkkola found type I muscle fibres predominating in this muscle and Mannion showed an increase number of type IIb fibres amongst spinal surgery patient [21, 22]. During stabilisation exercises, multifidus has been found to be contracting only between 27.5 and 28.7% of its maximal voluntary contraction and 74.2% during strength exercises[23]. Perhaps the multifidus is of ample size to fulfil its role as a stabiliser and therefore does not need to be hypertrophied, as demands do not exceed its current capability (specific adaptation to imposed demand principle). Although Danneels reported hypertrophy of the lumbar multifidus muscle following 10 weeks of stabilisation training, this was with a population which had muscle atrophy due to low back pain [24].

The probe used can also have an effect on the cross sectional area measured by ultrasound. During this study a linear probe was used. Convex probes result in a diverging ultrasound image, this has a propensity to exaggerate the size of the area under investigation. This possibly warrants the study of EMG activity of this population while performing the paddling stroke. Providing that the electrical activity of this muscle is sufficient and there is no atrophy or fatty infiltrate within the muscle, it is able to perform its role as a stability muscle.

Postural Sway: The SUP population demonstrated that balance was decreased under conditions when vision and proprioception was deprived. As per our expectations, the smallest COP excursions (sway path length) were found in the EO and EOML conditions. The greatest were in the ECf conditions. This demonstrates a reliance on proprioception amongst this population.

An increased centre of pressure measurement is usually indicative of decreased postural stability and has been shown to be a good predictor of falls in the elderly [25] and associated with low back pain [26]. Deficits of motor skill and co-ordination have also been associated with musculoskeletal disorders. The question has also been raised if these deficits could be a predisposing factor or simply associated with such disorders [7]. Low back pain patients have been found to have a greater degree of sway, increased reliance on a hip strategy for postural control and a posterior centre of pressure when compared to healthy individuals [26].

Studies have shown that the CNS will use a hip or ankle strategy depending on the degree of perturbation to the body. Fine adjustments are made to keep the body's centre of gravity in position by altering the centre of pressure [27]. This can be achieved with either an ankle strategy, hip strategy or a combination of both. During quiet stance medial lateral control is achieved with a hip load, unload strategy with the use of the adductors and abductors, while anterior posterior control was predominant at the ankle via the use of the ankle plantarflexors and dorsiflexors [27].

Palmeri's paper claims that decreased sway velocity represents an increased ability to maintain upright stance whereas an increased velocity represents a decreased ability to control posture [28]. In comparison to Palliards investigation of surfers in 2011 [9], this population of SUP athletes shows a significantly lower velocity in both the AP and ML in both the EC and EO conditions as seen in Figure 1. This could demonstrate a more efficient postural control system under dynamic conditions in this group of paddle boarders over the professional surfers tested by Palliard.

This difference from the surfing population as described may be attributed to the time spent in the standing position as opposed to the prone position in which a surfer paddles. Studies have shown that the time spent in the standing position during surfing was as low as 8% [29]. As the paddling motion is performed in the standing position in SUP, the duration in which balance is challenged is much greater.

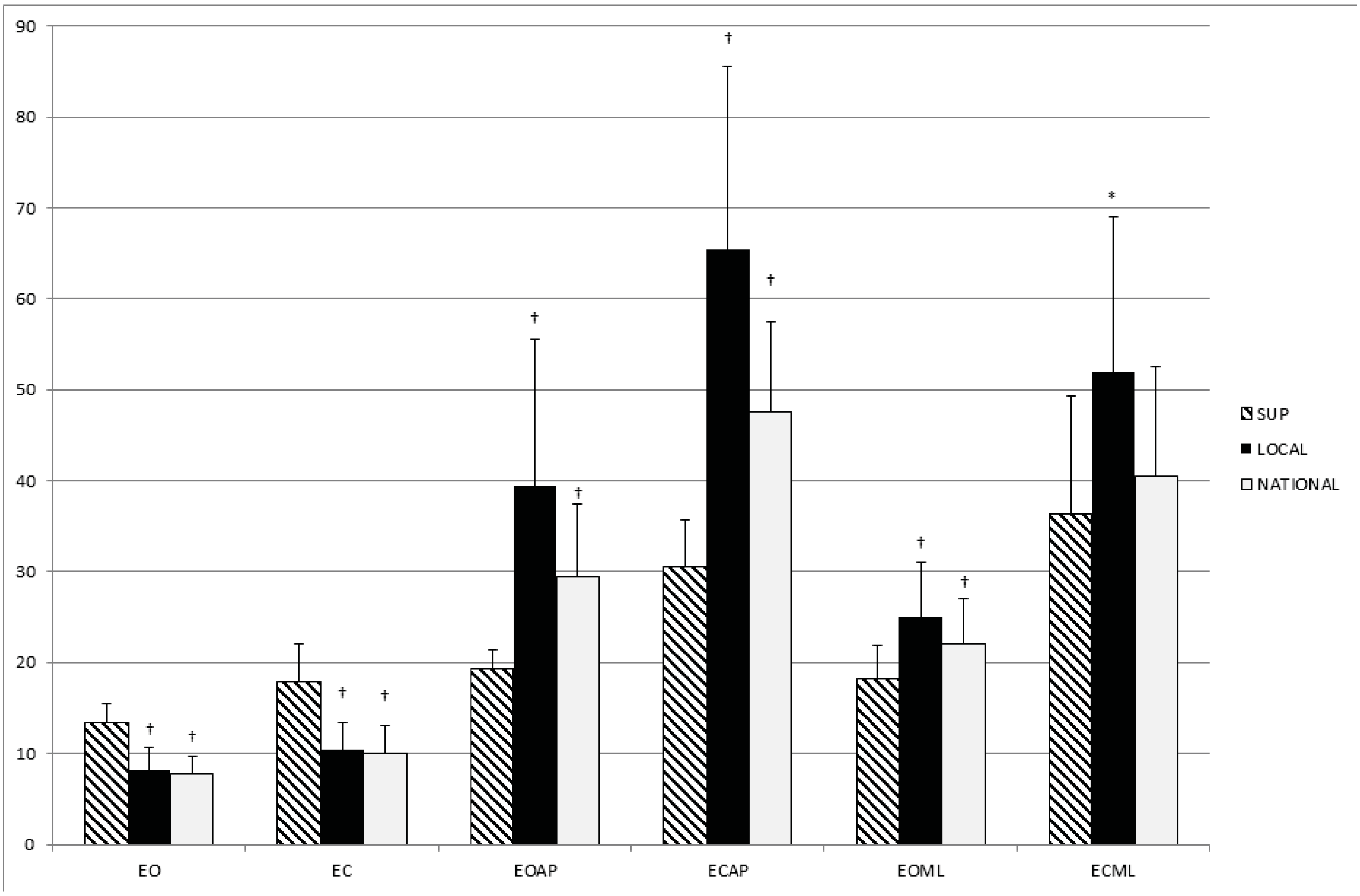

Figure 1: Velocity of static and dynamic sway between SUP and local and national surfers. Mean with SD bars.
* = significant at < 0.05 level after multiple comparison adjustments
† = significant at < 0.01 level after adjustment

It appears as though, as Chapman discussed in his paper, the balance training from this sport allows a flexible strategy of balance control. Although under non-challenging conditions, the SPL or velocity of sway can be quite large, the athlete's COP is still well within the base of support. This SUP population actually shows an increased velocity in the static conditions when compared to their surfing counterparts (Figure 1). It has been suggested that this postural control is due to increased joint stiffness. Lloyd proposed the explanation that specific neural adaptations occur with balance training which possibly suppresses the muscle stretch reflex during postural tasks [30]. He suggested that this limits the amount of destabilising movements and allow the agonist/ antagonist co-contractions to increase joint stiffness, therefore leading to increased balance. It is proposed that improvements in balance in any sport could decrease the reliance on muscles to provide stability, therefore enabling them to contribute to motive force [31].

This increased dynamic postural control could be due to specific adaptation due to the sport or alternatively, as Chapman discussed, possible due to a gravitation toward, and subsequent success in balance related activities from those who have a genetic predisposition toward superior postural control [8].

Kidgell demonstrated that six weeks of training on a mini-tramp was as effective as a dura disc for people who have sustained lateral ankle sprains [32]. It is our hypothesis, that a six week training program on a stand up paddle board could be just as effective, due to the similar unstable surface.

Biering Sorensen: The average endurance time for the Biering Sorensen test of isometric endurance was 129.12s for the entire group, 125.13s for males and 137.1s for females. This increased endurance time for females is in agreement with many of the previous studies[33-35].

Variations in results can be attributed to a difference in termination criteria amongst other studies, 10 degrees versus 6 degrees versus tester determined[35-37]. Other variations of the position include a 45 degree roman chair based test of isometric endurance[35].

McGill's study on young, healthy individuals showed an average men's endurance time of 146s and women's 189s [38]. Adedoyin found 119 (± 47)s for men and 106 (± 44)s for women [33], whereas Alaranta demonstrated 97s men and 87s women [7]. Regardless of the averages for the general population, the results obtained in this study are greater than another study of Australians performed by Stewart in 2003 [39]. In his study, athletes with back pain had average hold times of 107.5s.

Champagne stated that chronic low back pain has been associated with increased fatigability of the lumbopelvic extensor muscles as demonstrated by shorter back endurance test duration [35]. While Aggarwal demonstrated that this extensor endurance can be improved with core training[34]. By way of these two studies, it can be assumed that training using a SUP could hypothetically be used to increase extensor endurance.

Another benefit of SUP is that the paddling motion is performed bilaterally, typically alternating on a regular 10-14 stroke basis. Muscle imbalances are rife amongst competitive canoeists and outriggers who perform the paddling motion on the one side[40]. Unfortunately this was not a pure stand up paddle boarding sample. Many of the athletes tested also surfed, participated in surf lifesaving and kayaked. Kayakers, rowers & surfers are all prone to back pain due to being in either flexed or hyperextended positions for long periods of time [14, 41]. It is unclear how this may have affected the results.

This study had a small sample size due to the desire to profile the elite of this new sport. Further studies could utilise a greater sample size with a variety of skill level, or a longitudinal study to show adaptation over time with participation in this sport.

As core muscle activation has been shown to increase when training on unstable surfaces, EMG analysis of the core musculature is warranted in this population. Further studies could be aimed at determining the maximal aerobic power (VO_{2max}) of these athletes, along with power output in the SUP position to provide some evidence for the claims of fitness benefits. A biomechanical study which identifies the muscles used in the propulsive phase could be performed for coaches and trainers to identify which muscles are most important in this population. Interventional studies showing the change over time in both the amateur SUP participant undergoing a training regime and the rehabilitation of the musculoskeletal dysfunction patient would be logical progressions from this initial study.

CONCLUSION:

The results found in this research have illustrated that the elite stand up paddle boarders assessed show comparable multifidus measures to previously published literature. Biering Sorensen times were of greater duration than those reported in populations exhibiting symptomatic back pain and comparable to the times previously published. Postural sway, particularly dynamic postural sway was superior in this population compared to other aquatic athlethes published previously.

This research has lead us to conclude that SUP shows promising value as a means of balance training for other sports and a tool for strength and endurance training of the trunk musculature.

PRACTICAL APPLICATIONS:

Paddle could be used to increase lumbar erector endurance.

Paddle boarding seems to be an excellent means of dynamic balance training.

Dynamic balance is superior in this population compared to samples of other athletes.

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