ASMFA ADVANCES IN SKELETAL MUSCLE FUNCTION ASSESSMENT

THE USE OF TENSIOMYOGRAPHY TO EVALUATE NEUROMUSCULAR PROFILE AND LATERAL SYMMETRY IN COMPETITIVE FEMALE SURFERS

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ABSTRACT

The aim of this study was to determine the contractile properties and muscle stiffness to assess lateral symmetry in competitive female surfers. Fifteen competitive female surfers volunteered to participate in the study. Tensiomyography was used to derive maximum muscle belly displacement, and time delay duration of the Biceps Brachiis, Biceps Femoris, Deltoid, Gastrocnemius lateral head, Rectus Femoris, Tibialis Anterior, Triceps Brachii and Vastus Medialis. No significant differences between right and left limbs at in any of the tested muscles were observed ($p > 0.05$). Competitive female surfers showed that upper body muscles had the ability to generate force rapidly during contractions, while the lower body muscles generated force at a slower rate. Surf specific training seems to have had an influence on the contractile properties, and stiffness of these muscles. The neuromuscular profile provided here provides further normative data to this unique population.

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INTRODUCTION

Surfing is a physically demanding sport that is intermittent in nature and its growing popularity has led to increased scientific interest in the sport. Surfing was recently recommended for inclusion in the Tokyo 2020 Olympics and as such, developing a corpus of knowledge relating to performance of the sport is important to assist athletes, coaches and sports scientists in preparation for this event. Previous studies have investigated the physiological demands of surfing [1,2,3,4] reporting that surfers spend 3.8 - 8.1 % of the total time surfing with paddling contributing 35 – 54 %, waiting 28 – 42 % and miscellaneous activities such as "duck diving", wading, and "wipe-outs" contributing 2.5 – 5 %. Of these activities, only the surfing element is judged in order to generate scores, but paddling can represent the most demanding element, and is critical to ensure the surfer is in the correct position to capitalise on high scoring wave opportunities when they arise. Typically during these activities, average heart rate has been shown to be between 64-80 % of laboratory tested maximum heart rate [1,5]. Furthermore, in response to the demands of the sport, surfers have been identified as having good aerobic fitness with an average $\dot{V}O_{2peak}$ of ~46.83 ml•kg^{-1}•min^{-1} with power at $\dot{V}O_{2peak}$, anaerobic power and the power at lactate threshold being related to ranking in surfing [1,6]. Anthropometrically surfers are shorter than other age-matched athletes [7] and it is suggested that muscularity is positively associated with ability and competitive ranking in both male and female surfers [2,8].

Despite the popularity of the sport, apparently there is very little data about the neuromuscular profile in female surfers. While some data does exist regarding joint stiffness, leg power and proprioception [9], the neuromuscular profiles of individual muscles have yet to be quantified, especially to assess lateral symmetry. Tensiomyography is a non-invasive [10] evaluative method for ascertaining the neuromuscular profile of a muscle, through detecting the muscular reaction to electrical stimulation [11]. As such, TMG is an ideal method for competition-day assessment as no physical effort is required of the individual being evaluated [10]. TMG measures the radial displacement, and time response of the stimulated muscle during the evoked isometric contraction to evaluate stiffness, contractile properties of the muscle [10]. Previous research has indicated suitable validity and reliability of the manufacturer-informed protocol for using TMG [12-14].
The aim of this descriptive study was to investigate the applicability of Tensiomyography assessment in elite female surfers to derive normative neuromuscular data for this athletic population, specifically to investigate measures of muscle stiffness and contractile properties between right and left limbs to assess lateral symmetry.

METHODS

Participants

Fifteen competitive female surfers (age, 23.8 ± 4.4 years; height, 165.5 ± 5.5 cm; mass, 63.4 ± 5.6 kg) volunteered to participate in the present study. The surfers were recruited at the English National Surfing Championship held at Watergate Bay, Cornwall, England in May 2015. These surfers were likely to train rigorously and also compete regularly in high level surfing competitions. This study was approved by the Local Research Ethics Committee within the school of Sport, Carnegie Faculty, Leeds Beckett University and was consistent with the requirements for human experimentation in accordance with the Declaration of Helsinki. Informed written consent was obtained when participants were fully informed of the associated risks and benefits of the study prior to participation.

Procedures

All measures were performed at the contest venue and included stature measured to the nearest 0.5 cm (Seca 225, Birmingham UK), and body mass which was measured to the nearest 0.01 kg using a digital scale (SECA 770, Birmingham UK). A Tensiomyography device (TMG measurement system, TMG-BMC Ltd., Ljubljana, Slovenia) was used to evaluate neuromuscular profiles. All TMG assessments were made by the same scientist researcher who was experienced in taking these measurements. Each muscle was tested once on both the right, and left limbs at the following sites; Biceps Brachii (BB), Biceps Femoris (BF), Deltoid (DT), Gastrocnemius lateral head (GL), Rectus Femoris (RF), Tibialis Anterior (TA), Triceps Brachii (TB) and Vastus Medialis (VM). Quadriceps muscle sites were assessed with the participant positioned supine, and the knee flexed at 120°, and hamstring sites were assessed lying in prone position with the knee in full extension. Upper body sites were taken with the participant in an upright seated position.

A displacement transducer sensor (TMG, Panoptik, Ljubljana, Slovenia) was positioned perpendicular to the muscle axis [15], at the maximal bulge of the muscle belly for each participant individually to account for anatomical differences [16]. In line with previous research [16], self-adhesive electrodes (Med Fit, SA 10, Taiwan) were placed approximately 5 cm away from the sensor with the positive electrode positioned superior to the negative electrode. To initiate the isometric contraction, a single twitch electrical stimulus with 30 mA starting amplitude lasting 1 ms was delivered to the muscle site using an electrostimulator (TMG-BMC, Ljubljana, Slovenia). Pulses increased by 10 mA until the maximal displacement of the muscle belly was obtained [15]. A 10 second rest period was ensured between stimulations to avoid fatigue [12] or post activation potentiation effects [17]. The stimulation resulting in the greatest radial displacement of the muscle was considered for analysis.

The muscle contraction parameters obtained included maximum radial muscle belly displacement (Dm; measured in mm), and time delay (Td; measured in ms), for the tested muscle to reach 10 % of the maximum Dm. The Dm represents the stiffness of the muscle [18], where high values represent low muscle tone, tendon stiffness or fatigue, and low Dm values represent high muscle tone and increased stiffness of the tendon [16]. Td represents muscle fibre type that is dominant in the assessed muscle [18]. Here, high values are indicative of type I muscle fibres and a low value represents a majority type II fibres [16].

Statistical analysis

Data are presented as mean and standard deviation. Normality was tested through Kolmogorov-Smirnov test. To compare lateral symmetry (right vs left limb) a dependent sample t-test was computed, unless data were non-parametric (Td VM, Td TA, and Td TB), a Wilcoxon signed-rank test was used. Significance level was set at $p < 0.05$. All data were analysed using the Statistical Package for the Social Sciences for windows (version 22.0, SPSS, Chicargo, USA).

RESULTS

Descriptive statistics for maximum radial displacement (Dm) and time delay duration (Td) from TMG assessments are shown in Table 1. No statistically significant differences ($p < 0.05$) were found between right and left limbs for either Dm or Td in each of the muscle assessed.

Table 1: TMG parameters for the Biceps Brachii (BB), Biceps Femoris (BF), Deltoid (DT), Gastrocnemius lateral head (GL), Rectus Femoris (RF), Tibialis Anterior (TA), Triceps Brachii (TB) and Vastus Medialis (VM) of both the right and left limbs.

Muscle	TMG Parameter	Right Limb	Left Limb	Right limb vs. left limb (*p*-value)
BB	Dm (mm)	13.86 ± 3.68	13.00 ± 4.29	0.35
	Tc (ms)	28.12 ± 4.22	28.57 ± 5.00	0.14
BF	Dm (mm)	4.79 ± 2.35	4.80 ± 2.24	0.12
	Tc (ms)	29.46 ± 4.93	27.74 ± 5.01	0.11
DT	Dm (mm)	3.18 ± 1.67	3.70 ± 2.85	0.09
	Tc (ms)	18.23 ± 1.54	18.78 ± 2.31	0.43
GL	Dm (mm)	5.63 ± 2.46	7.79 ± 11.64	0.68
	Tc (ms)	25.67 ± 2.92	29.71 ± 13.22	0.32
RF	Dm (mm)	5.66 ± 2.55	9.92 ± 12.25	0.29
	Tc (ms)	25.58 ±1.98	24.67 ± 2.02	0.83
TA	Dm (mm)	1.62 ± 0.65	4.09 ± 9.03	0.88
	Tc (ms)	25.87 ± 8.88	30.61 ± 29.41	0.69
TB	Dm (mm)	7.57 ± 4.27	10.33 ± 11.94	0.94
	Tc (ms)	22.62 ± 4.16	22.57 ± 3.25	0.82
VM	Dm (mm)	6.20 ± 2.26	5.15 ± 1.87	0.17
	Tc (ms)	23.94 ± 2.23	24.93 ± 3.26	0.51

DISCUSSION

Measured responses of electrically stimulated muscles were collated from competitive female surfers. The results showed no significant ($p < 0.05$) difference in neuromuscular profile at any tested muscle site between right and left limbs of competitive female surfers for either Dm or Td variables measured using tensiomyography. This suggested that the surfers were well-trained and that both the right and left limb musculature respond similarly to training [15].

The Dm parameter is associated with muscle stiffness, in addition to the adaptations of cross sectional area of the muscle [16] and can also be influenced by tendon stiffness [19], where amplitude of Dm response is inversely related to muscle belly stiffness. Despite the limited research on TMG in females, two studies have analysed the neuromuscular profile of the major muscles used in other sport modalities. Similar to our results, a study on female kayakers also did not find any significant differences between the left and right side in Dm for deltoid, trapezius or latissimus dorsi [16]. Likewise, from the data presented by Rodriguez Ruiz et al. [18], no substantial differences were found in Dm between left and right sides for vastus medialis, rectus femoris, vastus lateralis and bicep femoris in beach volleyball players. By comparison, the Dm results of the present study show that rectus femoris was lower compared to beach volleyball players. Thus competitive female surfers have stiffer rectus femoris muscles compared to female beach volley ball players (all other muscle sites were within 1.5 mm difference). This could be due to the different physiological profiles of these sports that produce changes in the muscle which affect the neuromuscular profile [20]. In surfing, control and dynamic balance during wave riding is paramount, as such lower body strength and power exercises have been recommended for female surfers [21]. It could be that during a surf the rectus femoris contributes to such balance, and is therefore more toned than beach volleyball athletes that typically perform greater explosive movements, such as vertical jumps [18]. Indeed, in windsailing, the rectus femoris has been shown to be active to stabilise the leg during standing [22]. However, as surf judging criteria favours performances of radical, yet controlled manoeuvres with the greatest speed, explosive leg power would appear to be pivotal for success in the sport [7]. In previous surfing literature, vertical leg muscle stiffness has been assessed during hopping in a range of surfing abilities [9]. Here, higher levels of surfing experience was associated with lower leg stiffness in female surfers. Although these results differed compared to the present study, it is difficult to directly compare the stiffness of a specific muscle, measured here, to the stiffness of the leg as a whole.

The Td variable indicates the fibre type distribution within the assessed muscle [23]. Again similar to the Dm variables, no significant differences between right and left limbs were identified. In comparison to the female kayakers, Td of the deltoid was very similar [16]. This may indicate similar fibre type composition at the deltoid between the two sports. When surfing, a deficit in shoulder joint strength may impair sprint paddling and ability to catch waves [21]. Likewise, the role of shoulder joint musculature is important in kayaking, particularly during the recovery phase of a stroke [24]. Where muscle samples have been taken previously, the deltoid was reported to have a higher percentage of type I fibres than type II fibres [25]. Based on the 30 ms threshold implied by Rey et al. [20], the female surfers in the present study, and female kayakers from previous research would be interpreted as having majority type II fibres at the deltoid (18.23 and 17 ms respectively). This is notable considering females typically demonstrate slower firing rates compared to males [26]. However, it could be the case that adaptation has occurred in the muscle fibre profile of the deltoid due to specific training, competition loads [27] and that a high proportion of this time is spent paddling [3]. In contrast to the deltoid, displaying the shortest Td duration, the biceps femoris displayed the longest. Explosive bursts in upper body activity are prevalent in surfing when paddling out to catch a wave. This sport specific demand may produce faster muscles in the upper extremities, in comparison to the more fatigue resistant muscles of the lower body.

In the present study, contralateral limb was selected as the independent variable in assessing lateral symmetry, based on its use elsewhere in the literature [16,18]. It could be that a comparison between dominant and non-dominant limbs may be more appropriate due to reported increases in muscle strength on the dominant side [28]. However, where this approach was taken elsewhere, no statistically significant differences were reported, and so it could be that such a comparison is not justified [29]. Future work may consider averaging both right and left sides together as no significant differences were found here or in previous similar research [16,18], or between dominant and non-dominant limbs elsewhere [15]. This study supports the method pooling bilateral TMG data, a technique that has been used previously [30]. Lateral symmetry may therefore be more valuable for assessing lateral differences due to injury on an individual basis, opposed to analysing group mean differences.

CONCLUSION

In conclusion, tensiomyography is a useful and non-invasive method for assessment of the neuromuscular characteristics in elite female surfers. Our results provide normative neuromuscular values for this unique population. This study has established lateral neuromuscular symmetry for a range of muscle sites, and contributes to the literature on the neuromuscular profile of competitive surfers. Surf coaches and female athletes should consider neuromuscular responses to electrical stimulation to monitor adaptations to training and recovery in preparation for competition.

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CONFLICT OF INTEREST

All authors have declared there is not any potential conflict of interests concerning this article.

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