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Activity of trunk and leg muscles during Stand Up Paddle Surfing

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Abstract

Originating from an ancient Hawaiian tradition Stand Up Paddle Surfing (SUP) is a growing pastime and sports activity in which a person stands upright on a surfboard and propels it using a single paddle. It is expected that SUP is an ideal full-body workout for amateurs as several muscle groups are required for the paddling motion. Therefore measurements of muscular activity of eight subjects were executed during on-water and treadmill-trials using wireless surface electromyography (sEMG). sEMG of 16 muscles of the trunk plus video data were acquired at three different paddling speeds. The results showed that all measured muscles of the trunk were activated and that their activity can be allocated to the different paddle-stroke phases. The study proved that although the paddle stroke is mostly performed through upper extremity activation, also the trunk as well as the hip and knee stabilizer generate power and show high muscular activation.

Keywords: SUP ; EMG ; sEMG ; muscular activity ; full-body workout

1. Introduction

The Hawaiian paddle sport Stand Up Paddle Surfing (SUP) differs significantly from simply kayaking or simply surfing. It is an unique combination of these sports which makes it interesting and successful. During SUP the rider stands on an oversized surfboard which is between 3m and 5m long and up to 1m wide. To propel the board the rider uses a single paddle which is about 2m long. With this paddle, the rider is able to control the board in the current or reach fast breaking waves. There is no need of wind or waves like in wind or wave-surfing [1]. With a SUP a new dimension of surfing has been established which makes it interesting for coasts, rivers or lakes as an alternative on low wind days as it is possible to paddle under all conditions [2]. Paddlers of all ages can try SUP and quickly improve because also wide and stable boards are available.

A few years ago SUP was discovered as an effective full-body workout and has grown in popularity ever since being advertised throughout different social media and internet magazines. During SUP the whole body is supposed to get exercised. Paddling strengthens the arm and trunk muscles and constant equilibrating movements strengthen the legs and improve the balance.

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Fig. 1. SUP ergometer during laboratory tests, subject is equipped with 16 bipolar sEMG electrodes and currently in the power phase

Choosing the right board is important in SUP. Depending on the board size, speed, stroke rate, effort and stroke range are changing. Furthermore the choice of the paddling stroke has a big influence on the rider who chooses the stroke in dependency of skill level and circumstances of riding.

There are no studies which examine the appropriateness of SUP as an effective full-body workout, but there is literature about muscular activity and intramuscular coordination, injury of the lower spine, electromyography (EMG) variations in dependency of power output and differences in muscular activity on different ergometers in rowing [3–5]. However no study has been conducted so far concerning muscular activity and recruitment patterns during SUP.

According to [6] the movement pattern of SUP consists of four clearly distinguishable phases: (A) catch: In this phase the paddle dives in the water. The aim is to achieve a big reach by dunking the paddle into the water perpendicularly to the surface of the water close beside the nose of the board. (B) power phase, in which the paddle moves from the nose to the tail. The aim is to use all muscle groups to generate high paddling speeds. The characteristics of this phase are that the blade is completely under water, the paddle moves straight along the side of the board, from the nose to the tail. (C) exit phase: The paddle is taken out of the water in a fluent motion. The aim is a dynamic and nonresistant rotation of the blade to get it out of the water with no reduction of the speed. (D) recovery phase: In this last phase in which the paddle is swung to the nose to start a new paddle stroke. While back swinging the rider tries to relax his muscles.

In this study we are investigating the muscular activity and muscle activation patterns during different stroke phases, as well as the duration of the stroke phases in ergometer and on-water trials during SUP.

2. Materials and Methods

For the evaluation of the muscular activity two test-series were conducted: (1) Laboratory trials on a SUP ergometer (KayakPro USA LLC, USA)(Fig. 1) and (2) on-water trials on a lake using different SUP boards. During both conditions bilateral surface electromyography (sEMG) measurements with a wireless EMG system (Myomonitor IV, Delsys Inc., USA) of the following muscles m. rectus abdominis (RA), m. obliquus externus (OE), m. pectoralis major (PM), m. rectus femoris(RF), m. gluteus maximus (GM), m. multifidus (MF), m. erector spinae (ES) and m. latissimus dorsi (LD) were conducted with a recording frequency of 1000Hz. The electrodes were placed according to SENIAM guidelines [7]. For an ensured hold each electrode was additionally fixed with self-adhesive leukotape. A reference electrode was placed at at the spinal process of the seventh cervical vertebra. During the laboratory trials the EMG measurement was synchronized with a digital video camera to clearly distinguish the four phases of the paddle

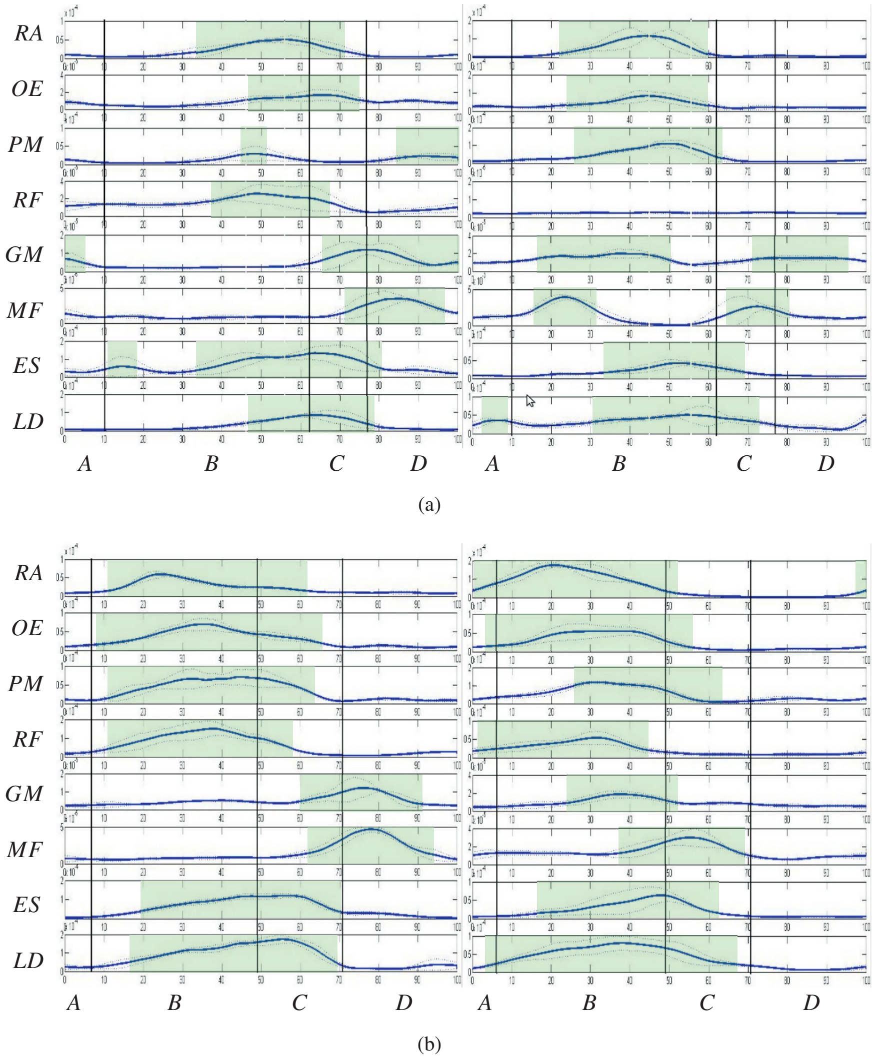

Fig. 2. Example ((a) expert (30W), ergometer trial, left side paddle stroke; (b) expert, on-water trial) of rectified, filtered and time-normalized mean EMG-amplitude ± standard deviation data of all muscles, opaque colored areas mark increased muscle activity (left: left side, right: right side, m. rectus abdominis (RA), m. obliquus externus (OE), m. pectoralis major (PM), m. rectus femoris(RF), m. gluteus maximus (GM), m. multifidus (MF), m. erector spinae (ES) and m. latissimus dorsi (LD)), beginning and end of the stroke phases are marked with vertical lines (*A*: catch, *B*: power, *C*: exit, *D*: recovery)

stroke and thus being able to divide the EMG signals in those phases. The camera was placed perpendicular to the longitudinal axes of the SUP ergometer.

For the laboratory-test five subjects, from novice (3 subjects) to expert (2 subjects) were tested. For most of the novices it was the first time ever performing SUP. Whereas novices only performed the lab test, two experienced subjects were also tested in the field.

The subjects had to paddle at three different power outputs which were defined as: Beginner (3 Watt, straight position, little paddling effort), intermediate (10 Watt, basic stroke) and expert (30 Watt, competition stroke, nearly maximum effort).

The synchronisation of EMG measurement and video camera was done by a LED, which was automatically switched on simultaneously to the EMG system. The Delsys EMG system was used as in wireless transmission mode. Subjects paddled until they reached the required watts, and then gave a signal to start the measurement. They

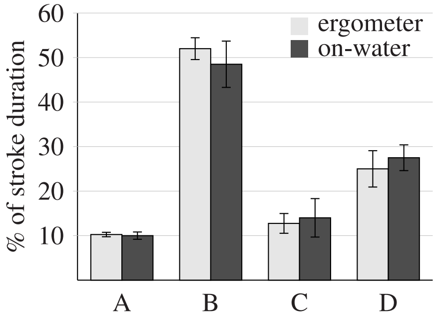

Fig. 3. Duration of the stroke phases (*A*: catch, *B*: power, *C*: exit, *D*: recovery) ± standard deviations in percent of time-normalized stroke duration, dark gray: on-water, light gray: ergometer.

Table 1. Mean duration of the stroke phases (*A*: catch, *B*: power, *C*: exit, *D*: recovery) ± standard deviations (SD) in percent of time-normalized stroke duration.

	ergometer		on-water	
phase	mean	±SD	mean	±SD
A	10.25	0.5	10	0.8
B	52	2.4	48.5	5.2
C	12.75	2.2	14	4.3
D	25	4.1	27.5	2.9

performed 20 paddle strokes on the left side, and 20 paddle strokes on the right side during which they tried to keep the required power-output as constant as possible.

In the field test only the two experienced subjects took part. They wore a dry suit to primarily ensure dry equipment and because of the outside air and water temperature. Again the subjects were asked to perform at three different power output levels which they had to judge by themselves based on the ergometer paddling experience and speed. The first two paddling speeds were performed on a beginner's SUP board of Naish (Naish Hawaii, USA). The third technique was performed on a Naish Race SUP board.

Data were analyzed with MatLab R2009b (The Mathworks, Natick, MA, USA). EMG data were full wave rectified and filtered with moving average filter (windowsize 50ms). The data was divided in single strokes (from beginning of the catch to the beginning of the following catch) and time normalized, resulting in 100% of one paddling motion for each stroke. Of the 20 strokes performed on each side of the board the middle 10 were chosen for analyzing. Mean values and standard deviations were calculated for all muscles.

Furthermore the mean duration of each of the four phases was calculated and compared between on-water and ergometer trials.

3. Results

Fig. 2 shows an example of the muscular activity of all measured muscles during ergometer trials at 30W (Fig. 2(a)) and on-water trials (Fig. 2(b)) for a left side paddle stroke (i.e. right had on top of the paddle, left hand low (cf. Fig. 1)) which is similar for all tested subjects.

For the ergometer trial (Fig. 2(a)) it can be observed that during the catch (A) only low muscular activity is recorded. Only the muscles of the legs (RF, GM) show a certain amount of activity on both sides of the body. The abdominal (RA, OE) as well as pectoral muscles (PM) are active in the late power phase (B). Back muscles (MF, ES, LD) show activity mostly in the exit (C) and recovery (D) phases. The only muscle showing two maxima is MF on the right hand side. During on-water trials (Fig. 2(b)) slight differences can be observed to the ergometer trial. Nearly all muscles show an earlier onset and longer activity than for the ergometer trials. Nonetheless it is noteworthy that most muscles do act rather synchronously for both sides of the body under both tested conditions.

Concerning the duration of the individual stroke phases it was observed that it differs slightly for ergometer and on-water trials (Fig. 3, Table 1) but none of the differences proved to be statistically significant. Thus the single phases can be considered to have a duration of approximately 10% for catch, 50% for the power phase, 13% for the exit phase and around 26% for the recovery phase.

4. Discussion and Conclusion

Until now no studies dealt with muscular activity during SUP. During our investigations we evaluated the muscular activity of 16 bilateral muscles during different conditions as well as the duration of the single stroke-phases.

It could be shown that the phase duration between ergometer and on-water trials did not show any significant difference although the ergometer provides an active pull-back of the paddle during the recovery phase.

However muscular activity differed between ergometer and on-water trials. During ergometer trials muscles of frontal leg, shoulder and pectoral muscles (RF, PM, LD)) were mostly active during the late power phase, muscles for the stabilisation of the trunk (i.e. abdominal and back muscles (RA, OE, MF, ES) showed different patterns. Whereas ES, OE and RA are mostly active in the power phase and in the early exit-phase, MF starts activity in the late exit phase and reaches its maximum in during recovery phase.

Although there are differences to the on-water trial where all tested muscles show an earlier and longer onset time, the patterns (i.e. during which phases and which the muscles are active) are similar for both conditions.

Considering different power outputs it could be shown that lower power outputs show the same muscular activity patterns on a lower activation level therefore it can be assumed that regardless of power output all tested muscles are trained during SUP.

Abdominal and back muscles (RA, OE, MF, ES) which are usually hard to train show clear activation especially during the on-water trials. Obviously there is - due to the high instability of a SUP board and thus a certain amount of wobbling - need for additional stabilisation of the body. Furthermore these muscles are - for both conditions - crucial to transfer the power between paddle and board thus forming a kinetic chain.

Summing up it can be stated that SUP according to our findings is an appropriate training for muscles throughout the body and especially for abdominal and back muscles. On-water training is to be preferred to ergometer training as it leads to extended duration of muscular activity for all tested muscles.

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