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LOWER TRUNK MUSCLE ACTIVITY DURING FRONT CRAWL SWIMMING IN A SINGLE LEG AMPUTEE

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This study examined lower trunk muscle activity during front crawl swimming in a single leg amputee and in a triathlete of equivalent swimming performance level. EMG of four lower trunk muscles was recorded and underwater video was made during a 50m all out front crawl swim. Compared to the triathlete, the amputee demonstrated relatively long periods of activity in the four muscles examined, less relaxation and less symmetry in muscle activity between right and left body side. In both athletes their individual lower trunk muscle activity patterns coincided with specific arm and leg kick movement phases. The individual patterns were consistent for all arm stroke cycles over the entire 50m swimming trial.

KEY WORDS: EMG, Paralympics, Core stability.

INTRODUCTION: Training of core stability has become a growing topic of interest for researchers and coaches over the past decade (Hibbs et al., 2008). Kibbler et al. (2006) defined core stability in sport as the potential to control the position and movement of the pelvis, allowing the integration of production, transfer and control of forces. In general, sufficient core stability is needed to balance out the forces generated by the upper and lower extremities separately. A lack of core stability could lead to injury in athletes. (Pollard & Fernandez, 2004; Hibbs et al., 2008).
With the need for body balance in mind, high level Paralympic swimmers are in many perspectives an interesting group to investigate. Despite their body imbalances due to limb loss, some forms of cerebral palsy or e.g. hemiplegia, they find a way to swim effectively and balance out the dissimilarity in force (or total lack of force in case of amputation) generated by the extremities. These sometimes very small movement adaptations are not only found in their swimming stroke, but in everyday life as well (walking pattern, posture, sitting pattern) (Prins & Murata, 2008).
Training videos present specific exercises and swim suit manufacturers claim that their suit provides extra stability to the lower trunk region (Speedo, 2010). Nevertheless according to Fig (2005) it is not common practice for swimmers to train these muscles. Another problem is the training of core stabilizers in persons with body structure imbalances and limited mobility in general. It has actually never been determined if the exercises commonly suggested might be of any use in this population. In fact, little or no research has been done on this subject in swimming (Hibbs at al., 2008), Therefore the purpose of this study was to examine how typical core stabilizing muscles are active during front crawl in a single leg amputee swimmer as compared to an elite triathlete of comparable swimming performance level.

METHODS: Two highly trained male athletes took part in this study: one 2 time Paralympic class S9 above knee amputee (right leg) swimmer and one Olympic triathlete. These participants had a similar 50m crawl swimming speed. The participants were first asked to swim 50m front crawl at slow pace and after a short rest an all out 50m front crawl stroke swim was performed. During the all out swim, muscle activity (1600 Hz) was registered using, four small independent surface EMG units (EMU: 50mm x 40mm x 15mm, 28g; KINE© EMG 5 51013) including muscle electrode, ground, seven minute memory and a sender. Electrodes were placed on the right and left Erector Spinae (ES) and on the right and left Rectus Abdominus (RA) following the recommendations of the SENIAM (Surface

ElectroMyoGraphy for the Non-Invasive Assessment of Muscles: (www.seniam.org)). Water proofing was obtained by fixing the electrodes with double-sided adhesive tape and by covering them with elastic plastic film (second skin) and sport tape.

Video cameras (Sony Handycam DCR-HC96: 50Hz) were also positioned one behind an underwater window directly in front view at the 25m turning wall and one perpendicular to the movement at 5m from the turn (7.85m from the swimmer). A third camera, software synchronised with the EMG signals, recorded from side view above water. The under and above water video and the EMG signals were then synchronized with flashing LEDs.

Dartfish software (5.5) was used to analyse the video for two stroke cycles in view between the 18m and 23m mark during the 50m swim. Six points on hands, shoulder, hip and feet were digitized. The following variables were then determined: stroke length and rate, relative duration of arm phases: entry-support (hand entry to shoulder-hand angle of 45°), pull (arm angle of 45° to 90°), push (arm angle of 90° to 135°), exit (arm angle of 135° to hand exit from water), and recovery (hand exit from the water to hand entry in the water). Swimming speed was determined from the displacement of a fixed point on the hip during combinations of right and left hand stroke cycles. An arm coordination index was calculated as the relationship in percent stroke cycle time of beginning pull of one arm to end exit of the second arm. This is similar but not identical to that of Chollett et al., (2003). These authors defined the arm propulsion as start of hand backward movement to hand exit of water.

RESULTS: During the 50m all out swim, speed measured from the hip displacement was similar in the two athletes for the arm strokes analysed (1.58m/s amputee vs. 1.59m/s triathlete). Stroke length was 2.10m/cycle vs. 2.37m/cycle and stroke rate was 58spm vs. 52spm. The amputee used a two beat leg kick with his single (left) leg, kicking downward (LLDown) immediately following right hand entry and downward-inward (LLDown-In) following left hand entry (See Figure 1.). The triathlete used a continuous 6-beat kick. In our study there was a 6% lag time between exit of one hand and the opposite arm reaching a 45° degree angle in the single leg amputee and a 17% lag time in the triathlete.

Figure 1 shows muscle activity in two arm cycles of a 50m front crawl sprint in a single right leg amputee. In addition, the defining moments of arm stroke and leg kick phases are indicated on the same time line as muscle activity. RA on the amputated right side showed constant activity. There was greater variability in the left (non-amputated side) RA. A clear reduction in left RA activity coincided with left arm angle 90°. At the same time the left leg kick started and moved straight downward. The drop in left RA activity also occurred during the pull phase of the right arm but continued through the beginning of the push. This might be required to initiate the second left leg kick which was now directed inward compensating for a downward kick by the missing limb needed to keep the trunk role in balance. In the triathlete on the other hand both left and right RA activity were comparable to left RA in the amputee when his kick was directed downward. There was also a much clearer pattern of right-left symmetry in activity. In general in the triathlete when right side muscle activity occurred there was little or no left side activity and likewise for left side activity.

The muscle activity picture of right side active and left side inactive, followed by left on - right off was also the case for ES activity in the amputee (see figure 1). Left ES activity started at left arm water entry in and continued to left arm angle of 135°. This also coincided with right arm water exit and above water recovery. In the triathlete ES activity was only seen during the arm exit phase with no ES activity on either side during arm recovery. Relative ES activity time in the amputee was about 60%-40% activity-inactivity while this was only 20% on - 80% off in the triathlete even while using a continuous leg kick. The individual muscle activity patterns found were consistent for all arm stroke cycles over the entire 50m swimming trial.

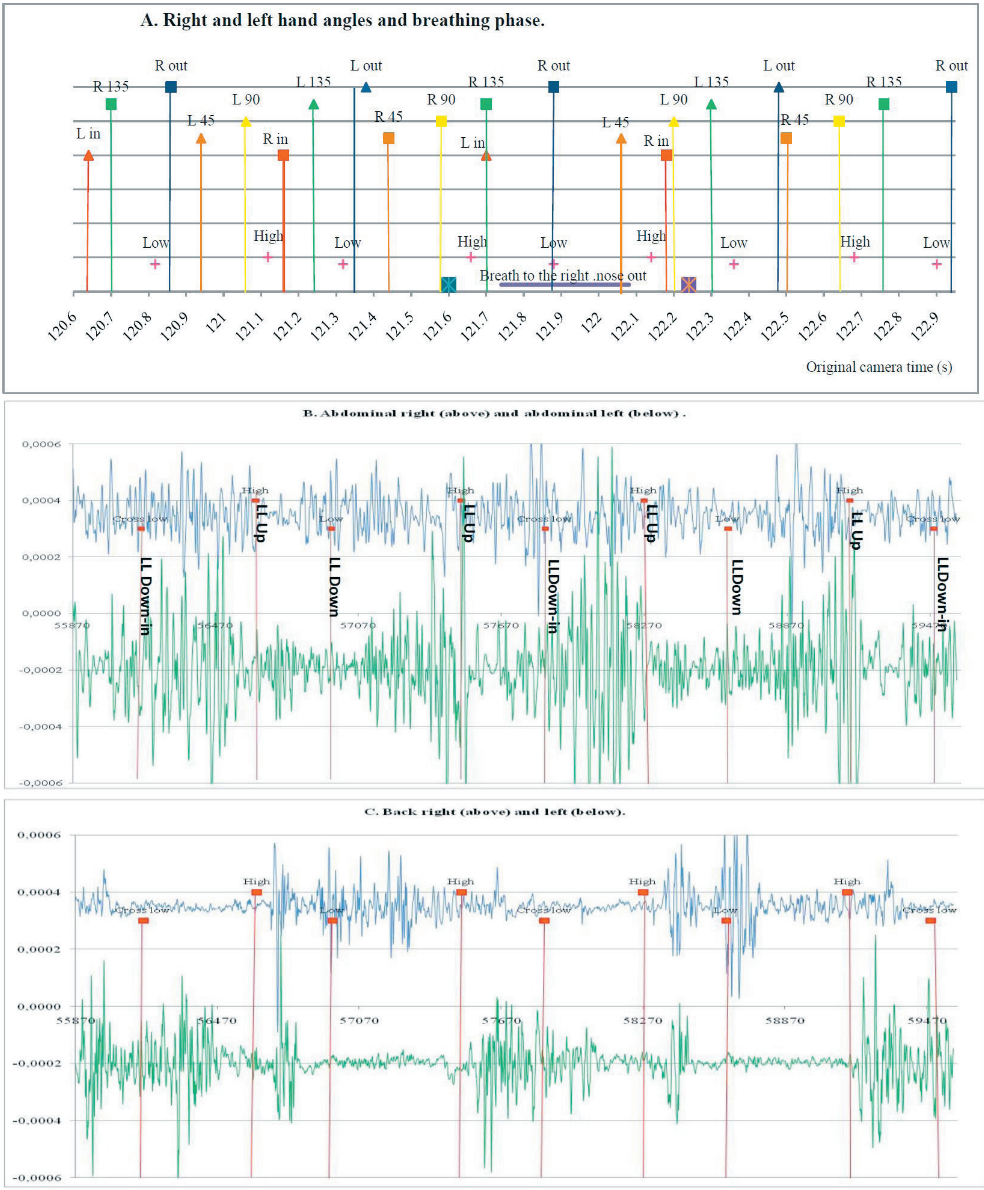

Figure 1: Muscle activity and defining moments of arm and leg movement phases in two arm cycles of a 50m front crawl sprint in a single right leg amputee. Breathing side and duration is indicated. The zero on the Y axis of the EMG diagrams has been shifted but the scale is correct. <u>Top:</u> Moment of right or left arm angle (phases), Breathing: nose in or out, High and low points in leg kick. <u>Middle:</u> Activity of Right (above) and Left (below) rectus abdominus. Time scale coincides with that of phase definition at top. High and Low points in Leg kicks are indicated. <u>Bottom:</u> Activity of Right (above) and Left (below) erector spinae. Time scale coincides with that of phase definition at top.

DISCUSSION: The two swimmers studied were of equivalent performance level. Consistent with function the amputee used a two beat kick with the single leg and a higher stroke rate and short 6% lag time between propulsive arm phases to compensate for lack of continuous

kick. The triathlete had a lower stroke rate and a longer lag time perhaps offset by the continuous kick. As triathlete this participant trained only for long distance.
Especially apparent was the right-left asymmetry of RA muscle activity in the amputee with continuous activity on the effected side. Furthermore in this swimmer systematic ES activity was seen with either right or left ES active at any one time. In the triathlete long periods could be observed during a single stroke cycle in which both right and left ES were inactive.
In most cases lower trunk muscles are examined in relation to activity of daily living and/or as a result of persistent low back pain. In these high level athletes, however, the goal might be to maintain core strength to achieve better body alignment while swimming. On the other hand both these athletes had secondary concerns: the triathlete not only has to swim but to cycle and run. The Paralympic swimmer has to deal with the asymmetric body during gait. In both of these cases dry land low back pain was in fact seen. These athletes did not, however, experience low back pain while swimming and a comparison of muscle activity during swimming with that during a standing balance test on dry land will be carried out elsewhere. It is also not clear from the present results if the trunk activity observed during swimming was primarily related to arm movement or leg action. New tests are being carried out with breathing controlled, leg kick eliminated and at varying swimming speeds and distances. The wireless EMG equipment can and has in fact also been used during actual swimming competitions and training.
A final yet unresolved question is could the amputee adjust his swimming style to be more like the triathlete and if this is necessary. Additional high level single leg amputee swimmers are also available to investigate this.

CONCLUSION: This study examined lower trunk muscle activity during front crawl swimming in a single leg amputee and a triathlete of equivalent swimming performance level. Some clear differences were seen. To confirm these findings more swimmers need to be examined and in a variety of race like situations. These results might then also be helpful in validating traditional testing of core stability in swimmers on dry land.

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