ELECTROMYOGRAPHIC ANALYSIS OF TWO DIFFERENT FEET POSITIONS IN BACKSTROKE START

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The aim of this study was to assess the electromyographic (EMG) activity of *Bíceps Brachii*, *Tríceps Brachii, Deltoideus Anterior*, *Erector Spinae Longissimus, Rectus Femoris, Gluteus Maximus Gastrocnemius Medialis,* muscles at two variants of the backstroke start, one performed with the feet parallel and entirely immerged (BSFI) and the other with the feet parallel and entirely emerged (BSFE). Four high level swimmers performed a 4x15 m maximal protocol of BSFI and BSFE. In both start variants the upper limbs muscles are mainly required during the initial start phases: (i) for BSFI, the *Gastrocnemius Medialis* showed greater electrical activity at take-off phase than hands-off and flight phases, and (ii) for BSFE, *Erector Spinae Longissimus*, *Gluteus Maximus* and *Rectus Femoris* registered similar electrical activity at hands-off and take-off phases.

KEYWORDS: biomechanics, iEMG, swimming, performance.

INTRODUCTION: Swimming races are composed of start, turn and free swimming sections, having the start part a greater contribution to success in the sprint events (compared with longer distances ones). Technical modifications to the swim start have been found to reduce the swimming race time by 0.10 s (Blanksby et al., 2002) and races have been won and lost by a tenth of this margin, emphasising the significance of these improvements (Burkett et al., 2010). Most biomechanical studies related with start performance employed kinetic and kinematical analyses to compare the principal start techniques used in individual ventral events (e.g. Vantorre et al., 2010). However, concerning the backstroke swimming start, the number of studies is rather outdated and scarce (cf. Hohmann et al., 2008).
The use of surface electromyography (EMG) provides valuable information to better understand the swimming technical actions. Despite the importance of the start actions to the final outcome, the EMG studies applied to swimming have been conducted mainly aiming to analyse stroking techniques, not starts. Accepting that the knowledge of the specialized muscular activity contributes to the optimization of sport technique and training possibilities (Clarys, & Cabri, 1993), it was aimed to characterize and compare the EMG activity in selected trunk, upper and lower limbs muscles among three backstroke start phases at two actually used start variants for backstroke events: one with the feet parallel and entirely immerged (BSFI), and one with the feet parallel and entirely above water surface (BSFE).

METHODS: Four male high-level swimmers (mean ± SD: 22.8 ± 1.7 years old, 75.9 ± 8.9 kg, 1.78 ± 0.06 m; 15.5 ± 5.0 years of training background and 89.13 ± 2.97% from the 100 m backstroke) performed an experimental protocol of two sets of four maximal repetitions using BSFI and BSFE over a distance of 15 m, in an indoor 25 m swimming pool. Rest periods of 2 min were provided between each repetition and 1 h interval was respected between sets. A qualitative video analysis was used to breakdown the backstroke start into three phases (adapted from Hohmann et al., 2008): (i) hands-off, comprised between the starting signal and the instant the swimmer's hands left the handgrip; (ii) take-off, from the hands-off until the instant the feet left the wall and (iii) flight, between the take-off until the first hands water contact. Active differential surface EMG recording was conducted to assess the electrical activity of the *Bíceps Brachii*, *Tríceps Brachii, Deltoideus Anterior, Erector Spinae Longissimus, Rectus Femoris, Gluteus Maximus,* and *Gastrocnemius Medialis* muscles.

These muscles were selected according to their propulsive or stabilizing function during swimming starts (Hohmann et al., 2008) and anatomic location. The swimmers' skin was prepared and the active bipolar electrodes were placed accordingly with the European Recommendations for Surface Electromyography (Hermes et al., 1999). Electrodes were water-protected using proper adhesives (Tegaderm3M®) and silver tape. The swimmer used a complete Fast Skin® swimsuit (Speedo®), with a cable entrance opened in the medium-ventral position. Over the water, at a 2 m of height, a steel cable was extended with a pulley solution to fix the seven EMG cables. All these procedures were used to minimize the mobility of the electrodes, allowing regular movements during the test session. A ground electrode was positioned over the patella. The total gain of the amplifier was set at 1100, with a common mode rejection ratio of 110dB. The signals were acquired by an A/D converter (BIOPAC Systems, Inc.) with a sampling frequency of 1000Hz. The EMG data analysis was performed using the MATLAB 2007a software. The steps for the treatment of the EMG signal were: (i) digital filtering, pass-band of 35-500Hz; (ii) removal of the common component (DC offset); (iii) full-wave rectification; (iv) linear envelope; (v) normalization of the signal for the maximum value of maximal isometric voluntary contraction and time (vi) integral of treated signal (IEMG). To synchronise EMG and video, an electronic flashlight signal/electronic trigger was marked simultaneously on the video and EMG recordings. Differences among the backstroke start phases for each variant were performed using the Friedman repeated measure test. Data was analyzed using SYSTAT 13. An intraclass correlation coefficient was used to determine trial-to-trial EMG reliability for each muscle at each backstroke start variant. The ICC scores ranged from 0.63 to 0.97 and 0.67 to 0.95 for BSFI and BSFE, respectively. Level of confidence was set at 95%.

RESULTS: Table 1 presents the iEMG values of *Bíceps Brachii, Tríceps Brachii, Deltoideus Anterior, Erector Spinae Longissimus, Rectus Femoris, Gluteus Maximus,* and *Gastrocnemius Medialis* muscles for the three studied phases at BSFI. It can be noticed that the *Bíceps Brachii* and the *Tríceps Brachii* registered a greater iEMG during the hands-off than the take-off and flight phases. Conversely the *Deltoideus Anterior* presented a shorter activation during hands-off than take-off and flight phases. Differences were not observed between the take-off and flight phases for *Bíceps Brachii* and *Deltoideus Anterior*. The *Erector Spinae Longissimus* and the *Gastrocnemius Medialis* showed greater iEMG values during take-off than hands-off and flight phases. When analyzing the *Gluteus Maximus*, greater iEMG was noted during take-off compared to hands-off and flight phases. In addition, the *Rectus Femoris* registered a greater activation during hands-off and take-off compared to flight phase.

Table 1
Mean ± SD values of the normalized iEMG of the *Bíceps Brachii*, *Tríceps Brachii, Deltoideus Anterior, Erector Spinae Longissimus, Rectus Femoris, Gluteus Maximus and Gastrocnemius Medialis* muscles for the backstroke start with feet immerged (BSFI) at hands-off, take-off and flight phases.

Muscles BSFI	iEMG Hands-off phase	iEMG Take-off phase	iEMG Flight phase
Bíceps Brachii	0.133 ± 0.011 *†	0.080 ± 0.013	0.037 ± 0.009
Tríceps Brachii	0.075 ± 0.006 *†	0.027 ± 0.006†	0.021 ± 0.003
Deltoideus Anterior	0.024 ± 0.003 *†	0.089 ± 0.022	0.048 ± 0.005
Erector Spinae Longissimus	0.076 ± 0.015 *	0.114 ± 0.020 †	0.039 ± 0.005
Rectus Femoris	0.127 ± 0.018 †	0.125 ± 0.014 †	0.010 ± 0.001
Gluteus Maximus	0.091 ± 0.008 *†	0.142 ± 0.014†	0.077 ± 0.006
Gastrocnemius Medialis	0.064 ± 0.002 *†	0.187 ± 0.003 †	0.038 ± 0.004

Note. *, † Significant differences in comparison with take-off phase and flight phases ($p < .05$).

Complementary, Table 2 presents the iEMG values of *Bíceps Brachii, Tríceps Brachii, Deltoideus Anterior, Erector Spinae Longissimus, Rectus Femoris, Gluteus Maximus,* and *Gastrocnemius Medialis* muscles for the hands-off, take-off and flight phases at BSFE. It can also be verified that the *Bíceps Brachii* and the *Tríceps Brachii* registered a greater iEMG during hands-off than take-off and flight phases. Additionally, the *Tríceps Brachii* showed a greater IEMG for take-off when compared to flight phase. Regarding the *Deltoideus Anterior.* and the *Gastrocnemius Medialis* a similar iEMG pattern was observed among the three phases. When analyzing the *Erector Spinae Longissimus*, the *Gluteus Maximus* and the *Rectus Femoris* it was observed shorter iEMG values during flight compared to hands-off and take-off phases, but no differences were noted between hands-off and take-off phases, except for the *Rectus Femoris* muscle.

Table 2
Mean ± SD values of the normalized iEMG of the *Bíceps Brachii*, *Tríceps Brachii, Deltoideus Anterior, Erector Spinae Longissimus, Rectus Femoris, Gluteus Maximus and Gastrocnemius Medialis* muscles for the backstroke start with feet immerged (BSFE) at hands-off, take-off and flight phases.

Muscles BSFE	iEMG Hands-off phase	iEMG Take-off phase	iEMG Flight phase
Bíceps Brachii	0.242 ± 0.025 *†	0.067 ± 0.008	0.038 ± 0.005
Tríceps Brachii	0.119 ± 0.013 *†	0.033 ± 0.006†	0.019 ± 0.002
Deltoideus Anterior	0.037 ± 0.005	0.109 ± 0.024	0.049 ± 0.006
Erector Spinae Longissimus	0.101 ± 0.011 †	0.094 ± 0.013 †	0.048 ± 0.005
Rectus Femoris	0.115 ± 0.015 * †	0.150 ± 0.009 †	0.012 ± 0.002
Gluteus Maximus	0.225 ± 0.012 †	0.209 ± 0.015 †	0.083 ± 0.012
Gastrocnemius Medialis	0.053 ± 0.003	0.114 ± 0.016	0.106 ± 0.023

Note. *,† Significant differences in comparison with take-off phase and flight phases ($p < .05$).

DISCUSSION: Looking at hands-off phase, both *Bíceps Brachii* and *Tríceps Brachii* registered a greater iEMG than take-off and flight phases in both start variants, which is in discordance with Hohmann et al. (2008), whom analyzed the backstroke start without taking into account the different feet position, reporting a greater activation of the *Bíceps Brachii* and the *Tríceps Brachii* during the flight phase. The *Bíceps Brachii* seems to initiate the shoulder flexion, and the *Tríceps Brachii* is the primary elbow extensor (McLeod, 2010). For BSFI, the *Gluteus Maximus* showed shorter muscle activation during hands-off in comparison to take-off phase, which confirms the role played by the referred muscle to extend the swimmer into a streamline position off the wall (Hohmann et al., 2008; McLeod, 2010). The *Deltoideus Anterior* registered similar EMG pattern during the hands-off, take-off and flight phases for BSFE. Particularly at BSFE, this muscle also seems to play an important role to fix the body in a high start position close to the wall.
Regarding take-off phase, *Deltoideus Anterior* showed greater activation during this phase compared to hands-off phase for BSFI. After pushing the hands-off the handgrip, the *Deltoideus Anterior* muscle plays an important role to conduct the shoulder backward during backstroke start (Hohmann et al., 2008). In this above-referred phase, both start variants registered greater iEMG for the *Gluteus Maximus* and *Rectus Femoris* in comparison to flight phase. These findings are in line to the backstroke (Hohmann et al., 2008) and front crawl start previously published EMG studies (Krueger et al., 2003), confirming the essential function of the lower limbs to produce the main portion of the impulse during take-off phase. In fact, to reinforce this idea, Vantorre et al. (2010) pointed out that elite swimmers generated greater values of resultant impulse during take-off than trained swimmers. The *Gastrocnemius Medialis* presented greater iEMG during take-off in comparison to hands-off and flight phases at BSFI. Inter-segmental coordinative analysis of lower extremity joints showed that the relative time to register the peak of ankle angular velocity might be an important variable to explain a greater capacity to obtain maximum horizontal centre of mass displacement during flight for BSFI (de Jesus et al., 2010). It is also interesting to note that

Erector Spinae Longissimus and *Gluteus Maximus* registered similar activation between hands-off and take-off phases for BSFE. In accordance to de Jesus et al. (2010), feet positioned entirely above water level seems to imply a more complex movement sequence during hands-off and take-off phases, that indicates a large demand on the muscles that generate trunk and lower limbs extension.
When observing flight phase, the *Erector Spinae Longissimus* registered a shorter iEMG in comparison to the take-off phase at BSFI and BSFE. Indeed, the *Erector Spinae Longissimus* is mainly activated to move the upper body backward towards the jump off position (McLeod, 2010). Concerning the *Bíceps Brachii* similar iEMG values were observed between flight and take-off phase for BSFI and BSFE. According to Hohmann et al. (2008) the *Bíceps Brachii* contributes a lot to stabilize the body shortly before and during water immersion. Conversely to the BSFI, findings obtained at BSFE for the *Gastrocnemius Medialis* showed a similar activation during the three starting phases. This result might be explained by a higher amplitude of plantar flexion required when feet are positioned above water level. Furthermore, knowing that the flight phase is naturally dependent on what the swimmer does in the start wall (Burkett et al., 2010), this finding can be explained by the greater time to swimmers achieve peak of angular velocity of ankle extension for BSFE (de Jesus et al., 2010), suggesting a complete ankle extension after the feet releases the wall.

CONCLUSION: In both backstroke start variants studied, it can be concluded that *Bíceps Brachii* and *Tríceps Brachii* showed greater muscular activation during hands-off phase, *Gluteus Maximus* and *Rectus Femoris* reduced the workload during flight phase. In addition, for the BSFI, the *Gastrocnemius Medialis* presented a greater activation during take-off compared to hands-off and flight phases and, for BSFE, *Erector Spinae Longissimus* and *Gluteus Maximus* muscles are required similarly during hands-off and take-off phases, and *Gastrocnemius Medialis* is similarly required during the three starting phases.

REFERENCES:

Blanksby, B., Nicholson, L., & Elliot, B. (2002). Biomechanical analysis of the grab, track and handle swimming starts: an intervention study. *Sports Biomechanics, 1*, 11-24

Burkett, B., Mellinfont, R., & Mason, B. (2010). The influence of swimming start components for selected Olympic and paralympic swimmers. *Journal of Applied Biomechanics, 2,* 134-141.

Clarys, J., & Cabri, J. (1993). Electromyography and the study of sports movements: a review. *Journal of Sports Sciences, 11,* 379-448.

de Jesus, K., de Jesus, K., Figueiredo, P., Gonçalves, P., Pereira, P., & Vilas-Boas, J. P. et al. (2010). Biomechanical characterization of the backstroke start in immerged and emerged feet conditions. In: P-L. Kjendlie, R. K. Stallman, & J. Cabri (Eds). *Xth Biomechanics and Medicine in Swimming* (pp. 64-66). Olso: Norwegian School of Sport Science.

Hermes, H. J., Freriks, B., Merletti, Hägg, G. G, Stegeman, D., Blok, J., Rau, C. et al. (1999). European recommendations for surface electromyography. Netherlands, Roessing Research and Development.

Hohmann, A., Fehr, U., Kirsten, R., & Krüger, T. (2008). Biomechanical analysis of the backstroke start technique in swimming. *E-Journal Bewegung und Training, 2*, 28-22.

Kruger, T., Wick, D., Hohmann, A., El-Bahrawi, M., & Koth, A. (2003). Biomechanics of the grab and track start technique. In: J-C Chatard (Ed.), IXth *Biomechanics and Medicine in Swimming* (pp.219-223). Saint-Etienne: University of Saint-Etienne.

McLeod, I. (2010). *Swimming anatomy*. Champaign, Illinois: Human Kinetics.

Vantorre, J., Seifert, L., Fernandes, R. J., Vilas-Boas, J. P., & Chollet, D. (2010) Comparison of grab start between elite and trained swimmers. *International Journal of Sports Medicine*. doi: 10.1055/s-0030-1265150.