A COMBINED BIOMECHANICAL ANALYSIS OF THE FLIP TURN TECHNIQUE

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The purpose of this study was to biomechanically describe the front crawl flip turn technique of an elite male swimmer using and integrating dynamometric, kinematical and electromyographic (EMG) data. Surface active bipolar electrodes, two underwater and four surface fixed cameras, and an underwater force plate were used to evaluate the several phases of this turn. It was observed that the turn rotation phase was performed very close to the wall, imposing excessive lower limb joint flexions, and determining a too long contact phase. Those findings presented probable consequences upon the force curve, the pattern of muscular recruitment, and the velocity of the take-off the wall. However the trunk angle at the take-off the wall allowed a good position during the impulse phase. Therefore, this high level swimmer should improve these aspects in order to improve his performance.

KEY WORDS: swimming, EMG, dynamometry, kinematics, flip turn.

INTRODUCTION:

It is commonly accepted that the turn time represent a significant part of the total time of a swimming event. Lyttle (2006) highlighted that little changes on the turning action performance can imply substantial improvements of the final event time. Swimming turns are complex movements, being difficult to analyse without proper technology. This fact is due to the aquatic environment, namely the resistance, refraction and pressure of the water, but also to the actions of the several body segments, which are moving in different movement plans and axis (Pereira et al., 2007). However, the analysis of this important phase of a swimming event is scarce, which is justified, as stated before, by difficulties of analysis and lack of technology.
During the front crawl events, the flip turn is the technique used by all high level swimmers. This turning technique is the final product of a long evolution process, probably starting with the open turn technique, which is presently still in use but adapted for breaststroke and butterfly events. Following Haljand (1998), and Lyttle and Benjanuvatra (2006), the flip turn can be divided into five phases: (i) approach to the wall; (ii) rotation; (iii) wall contact; (iv) glide and (v) stroke preparation. The purpose of this study was to deeply characterize the flip turn technique of an elite swimmer, combining different biomechanical systems of analysis: dynamometry, kinematics and electromyography.

METHODS:

It was conducted a case study with a male front crawl / backstroke swimmer from the Portuguese national swimming team (2008 World Championship participant, 20 years old, 180 cm of height and 77.3 kg of body mass). The evaluation session took place in a 25x12.5x2m indoor swimming pool, with 27.5ºC of water temperature. The subject performed three flip turn repetitions performed at maximal velocity. The selected variant of the flip turn technique was the one that the swimmer usually applies in training and competition conditions. Performance was videotaped (50Hz) using two underwater and four surface fixed cameras *(Sony® DCR-HC42E)* (Figure 1, left panel). The trials started and finished from a specific and marked spot (at 12.5 m from the turning wall) and were monitored while swimming through a specific calibrated space (using a floating under and over the water structure with 10 reference points, as showed in Figure 1, right panel). The analyses comprised the three intermediate phases of a flip turn: “rotation”, “wall contact” and “glide”. The “glide” phase was considered to be ended at the first leg kick out of the wall.

The video images were digitized using the APASystem *(Ariel Dynamics, USA)* at a frequency of 50 Hz, manually and frame by frame in order to analyse the following variables: maximum knee flexion during the contact phase, the velocity-in (obtained during the approach of the wall and before the rotation), the velocity-out (obtained after the push-off of the wall), and the trunk angle out of the wall (angle defined between the segment fingers-hip and the surface of the water). Zatsiorsky's anthropometric biomechanical model, adapted by de Leva (1996), was used, employing 21 anatomical reference points. Synchronisation of the images, EMG, and dynamometric data were obtained using a light-trigger connected to the acquisition system. The 3D reconstruction of the digitised images was performed using the Direct Linear Transformation procedure (Abel-Aziz and Karara, 1971).

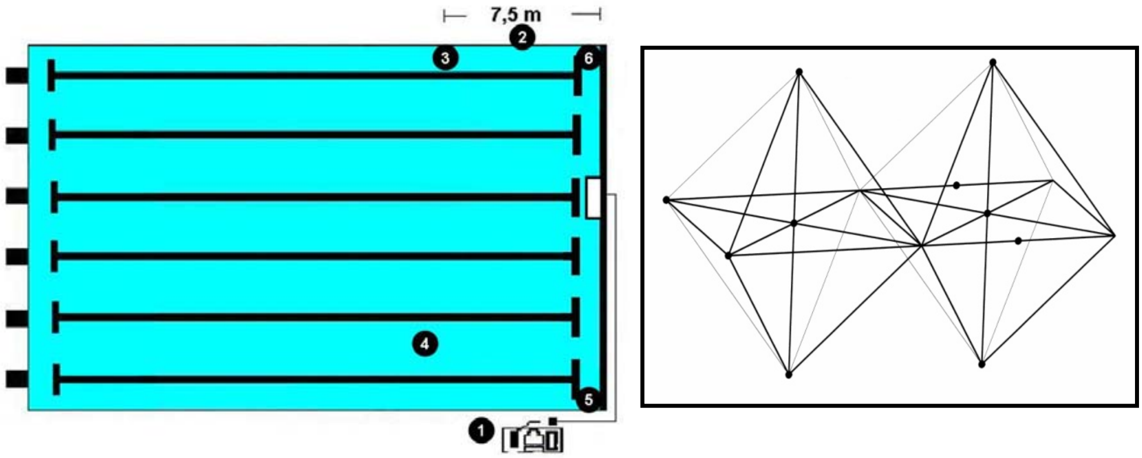

Figure 1. Scheme of the disposition of the cameras and force plate (left panel), and calibration volume (right panel) during the flip turn technique data acquisition. 1 and 2 are surface cameras, and 3 to 6 are underwater cameras.

EMG analysis was conducted with surface active electrodes, which were placed at 20 mm apart and parallel to the muscle fibbers. The muscles analysed were *vastus lateralis* (VA), *gastrocnemius* (GM), *tibialis anterior* (TA) and *biceps femoris* (BF). The swimmer's skin was prepared, shaved and cleaned. Electrodes were water-proofed using proper adhesives (Tegaderm3M®) and silver tape. The swimmer used a Fast Skin ® swimsuit (Speedo®), with a cable entrance and the cables were linked to a sheave over the water (cf. Pereira et al., 2007). All these procedures were used in order to reduce the mobility of the electrodes and to increase the comfort of the swimmer, allowing all "natural" turning movements during the test.

The active electrodes used a pre-amplifier with a 100 gain. The registered and pre-amplified signals were transmitted by 25m cables to the main amplifier in a total amplification of 1100 (Gonçalves, 2006). The signals were acquired by an A/D converter (BIOPAC Systems, Inc.) with a sampling frequency of 1000Hz, supplied by a 15 volts energy source. The converter allowed the ulterior acquisition of the signal by a PC, and its numerical treatment through Acqknowledge® 3.2.5 software (BIOPAC System, Inc.). The routines for the treatment of the EMG signal were: (i) digital filtering, pass-band of 35-500 Hz; (ii) removal of the common component (DC offset); (iii) full-wave rectification; (iv) linear envelope; (v) normalization of the signal to the dynamic peak and (vi) integral of the treated signal (iEMG).

For the acquisition of the dynamic data, an underwater strain gauge platform (similar to Roesler, 1997) with sensitivity of 2N, an error of less than 1% and natural frequency of 60Hz was used. The data was sampled 1000Hz. The force plate was associated to a special support to be fixed to the inside of the turning wall of the swimming pool, in the vertical plan, and on the opposite side to the departure blocks, in lane 4. Data was filter and normalized to the weight of the swimmer's body.

RESULTS AND DISCUSSION:

In Table 1 it is possible to observe the mean ± SD values of the force, time and kinematic parameters studied. The dynamometric and kinematical results were in accordance with the specialized literature (eg. Araújo, 2005; Lyttle, 2006). The horizontal force to time curve dynamics (Figure 2) shows a typical settling on the wall curve, due to high impact forces. According to Lyttle (2006) this fact occur due to an inefficient coordination, using a higher force at the first peak (when contacting the wall), and a lower force during the push-off of the wall, this one greatly important to the final velocity-out. In what concerns the EMG activity, it was also possible to observe these two specific turning moments in a prior study of our group (cf. Pereira et al., 2007).

Table 1. Values of mean ± SD of the horizontal force, time durations and kinematical parameters obtained during a flip turn in an elite swimmer.

Force (N/N)	Mean ± SD	Time (s)	Mean ± SD	Kinematics	Mean ± SD
Mean	1.17 ± 0.16	Rotation	0.96 ± 0.07	Max. Knee Flexion (º)	62.75 ± 1.68
Impulse	0.47 ± 0.09	Contact	0.40 ± 0.04	Velocity-in (m/s)	1.77 ± 0.08
Max. Force	2.05 ± 0.14	Glide	0.93 ± 0.21	Velocity-out (m/s)	3.00 ± 0.09
				Trunk angle-out (º)	13.20 ± 5.38

Additionally, it was observed that the swimmer started the rotation phase very close of the wall (cf. Blanksby et al., 1996), not in accordance with the high level of proficiency of the swimmer. Other aspects that seem to be influenced by the rotation distance from the wall are the contact time and the maximal knee flexion. The contact time assessed was similar to the previously presented by Araújo et al. (2005), but seems too high for an elite swimmer. Similarly, the maximal knee flexion was also too high when compared to the maximal torque value around 110 to 120º of flexion of the knees during the leg extension actions (Wiktorin e Nordin, 1986).

However, the swimmer adopted a very good position when leaving the wall, resulting in a trunk angle out of 13º (an angle of 0º is accepted as criteria). This fact can be, according to Lyttle (2006), of extreme importance, because the body cross sectional area stays small, allowing a more efficient impulse (shown by the 3m/s velocity out).

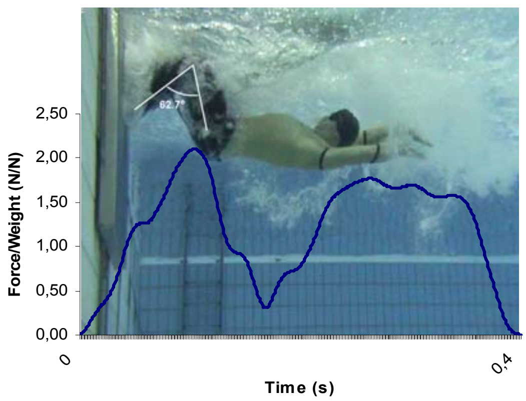

Figure 2. Dynamic of the force to time curve in the phase of wall contact, and angle of maximal knee flexion during a flip turn in an elite swimmer.

The electromyography results showed that the velocity of the rotation phase depends upon the action of the BF and TA muscles in the legs flexion action, which seems to be fundamental to obtain a higher rotation velocity. In order to decrease the contact time, but to maintain its intensity, TA and GM are in co-activation, but is the VL that seems to be the most active muscle (Figure 3). In the beginning of the gliding phase, all the studied muscles presented low intensity EMG signals, which are hard to compare due to the lack of similar literature.

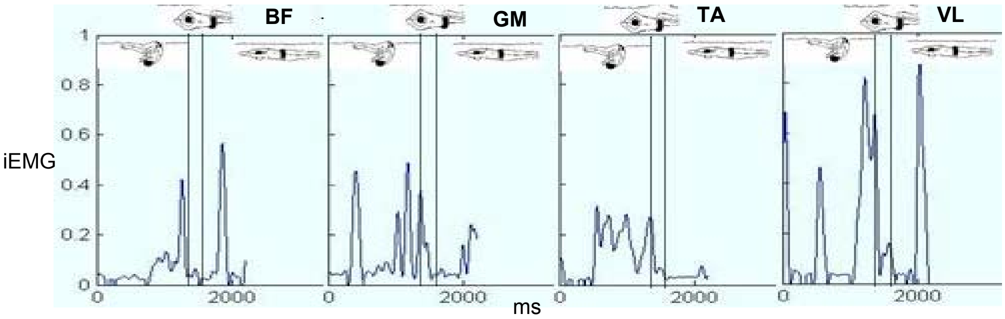

Figure 3. iEMG signals of biceps femoris (BF), gastrocnemius (GM), tibialis anterior (TA) and *vastus lateralis* (VL), and muscles during a flip turn in an elite swimmer.

CONCLUSION:

The results showed that the flip turn of this particular elite swimmer has some technical inaccuracies, related specifically to the fact that the rotation phase was performed very close to the wall, which implied an anticipation of the maximal peak force and a higher contact wall time. Nonetheless, the swimmer's position during the impulse off the wall was very good. The high performance results achieved by this swimmer in real competition situation can be due to other technical qualities, such as the underwater gliding phase after the push-off of the wall, as well as the transition to front crawl swimming. The technology used in this study showed to be proper and efficient for the purpose of studying the swimming turn technique, although it is needed a higher number of subjects in future studies, as well as a more profoundly analysis of the data acquired by the different biomechanical systems used.

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