NEUROMUSCULAR ACTIVATION DURING ROTATION AND PUSH-OFF PHASES OF BACKSTROKE TO BREASTSTROKE TURNING TECHNIQUES IN AGE-GROUP SWIMMERS

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The aim of this study was to assess and compare, through electromyography, the neuromuscular activation during the rotation and push-off phases of four backstroke to breaststroke swimming turns. Eight male swimmers volunteered in this study, comparing the open turn, the back flip turn and the crossover turn. The crossover turn was the one that most activated the studied muscle. Erector spinae (ES) and rectus abdominis (RA), as well as latissimus dorsi (LD) were the main activated muscles during rotation phase. Gastrocnemius medialis (GM) and Tibialis anterior (TA) were mainly activated muscles during the explosive action of the push-off phase. These results provided better understanding about neuromuscular contributions during rotation and push-off of turning performance.

KEY WORDS: swimming, electromyography, core muscles, age-group

INTRODUCTION: The turning techniques used in swimming competition play a critical role in the final outcome of the race (Vilas-Boas et al.,2003; Prins & Patz, 2006) and should be a key concern of the training process (Blanksby et al.,1998). Thus, coaches should design training programs focusing on specific turning technique development to enhance turning efficiency. In fact, late technical changes should be avoided since they may adversely affect performance during the most important competitive phases of swimmers careers. The backstroke to breaststroke changeover (using open, somersault, bucket or crossover techniques) is, perhaps, the most complex of the individual medley turns due to the integrated form of movement, occurring in different planes and axis and being difficult to measure and analyse without proper technology (Vilas-Boas et al., 2003).

Literature regarding biomechanical and electromyography analysis of different backstroke to breaststroke turning techniques is scarce. Thus, current knowledge remains incomplete in what concerns neuromuscular contributions during rotation and push-off phases in determining turning performance. The aim of this study was to assess and compare the electromyographic activity (EMG) of relevant muscles during the rotation and push-off phases in four backstroke to breaststroke turning techniques: open, somersault, bucket and crossover.

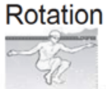
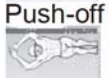
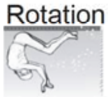
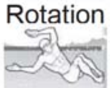
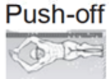
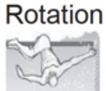
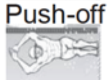
METHODS: Eight age-group male swimmers engaged on a regular basis in regional- and national-level competitions volunteered to participate in this study (mean ± SD: 12.4± 0.6 years old, 155.1 ±13.6 cm of height, 44.6 ± 10.9 kg of body mass, 14.1 ± 5.3 % of body fat and 18.8 ± 2.3 kg/m^2 of body mass index, with 3.5 ± 1.4 years of experience in competitive swimming

and 178.3 ± 10.1 s as best performance over the 200 m individual medley short course – 88.1 ± 4.7% of world junior record and 3.3 ± 0.7 (2-4) of Tanner maturation scale by self-evaluation). Swimmers were specifically trained on the ability to perform all the four turning techniques. The systematically increasing contextual interference intervention program took place during the 4 weeks after a theoretical and practical session, with a frequency of 4 weekly sessions (16 sessions overall), 40 min in each session, to provided progressively increase in the difficulty of the practice with appropriately challenge beyond their skill levels (Jefferys, 2006) and facilitates learning and improving performance (Guadagnoli and Lee, 2004). Following the intervention period, all swimmers were tested in a randomized set of 3 trials for each of the four backstroke to breaststroke turning techniques. The trials started and finished from a mid-pool (at 12.5 m from the turning wall) and swimmers were instructed to swim in and out at maximum speed until the 12.5 m reference. Rest periods of 2 min were observed between each repetition.
EMG activity was recorded using a cable system as described in Pereira et al. (2015), from the vastus lateralis (VL), biceps femoris (BF), tibialis anterior (TA), gastrocnemius medialis (GM), rectus abdominis (RA), external oblique (EO), erector spinae (ES) and lattisimus dorsi (LD), which were selected according to their major biarticular lower limbs muscular contribution and stabilizing function of the core body muscles in rotation–flexion during backstroke to breaststroke turns (Pereira et., 2015; Marras et al., 1998; Kumar, 2010). MATLAB 2008a software (Math Works Inc., Natick, MA, USA) was used for signal EMG processing. Raw EMG signals were filtered using a fourth-order butterworth band-pass filter (bandwidth 20–450 Hz), rectified and averaged to obtain the full wave signals. The integration of the rectified EMG was calculated per unit of time for each phase to eliminate the effect of phase duration (iEMG/T). Signals were partitioned in 40 ms windows to find the maximal iEMG (iEMG max) for all the muscles and iEMG/T was expressed as a percentage of iEMG max to normalize the results. Normalized iEMG/T(%) were then calculated per phase for all muscles. SPSS version 21.0 software (SPSS Inc., Chicago, IL, USA) was used to analyse the data, being checked data normality through the Shapiro–Wilk's W normality test. As normal distribution of EMG data for all muscles in each turn phase could not be assumed due to the small sample size, a non-parametric Kruskal-Wallis test was used to compare EMG variables according to the turn phase.

RESULTS: Table1 presents medians (IQR) of iEMG for each muscle on the four backstroke to breaststroke turn techniques during rotation and push-off phases. ES and RA were mainly activated during rotation phase in bucket turn, open turn and somersault turn and ES and LD were mainly activated during crossover turn. The GM and TA were mainly activated during push-off phase in all the studied backstroke to breaststroke turning techniques.

DISCUSSION: ICC correlation coefficients calculated among trials for iEMG and relative activation time in each turn phase presented moderate to good reproducibility for all turns (0.42 – 0.97). As the swimmers initiated the rotation phase of the turn, they bring the legs up in a tight tuck to the chest by using core body muscles, including the co-activation of hips and abdominal muscles. Antagonist ES and agonist RA were mainly activated during rotation phase in bucket turn (77.0 and 50.3%), open turn (52.5 and 49.6%) and somersault turn (42.8 and 25.2%), respectively. In crossover turn, antagonist ES and agonist LD (89.0 and 51.0%) are mainly activated during an integrated (like crossover) turn by combining twisting and rotational asymmetrically movements. Lee et al. (2006) stated that torso dynamics are influenced by recruitment co-contraction, and trunk muscle co-contraction increases trunk stiffness that would increase muscle activity. The initiation of hip flexion in rotated posture is achieved by activities of the contralateral EO and ipsilateral LD followed by the ES (Kumar et al., 2002a). ES muscles are one of the strongest and most often recruited muscles in exertions starting from bending postures and capable of producing more of a twisting moment when the torso is flexed (Marras et al.,1998). In addition, Kumar (2010) mentioned that ES activity was highest at 40° flexion, due to the greater mechanical disadvantage and having not reached the state of flexion–relaxation. On the contrary, LD and EO muscles reduce their activities once the twisting motion is performed in an asymmetric posture (Marras et al., 1998).

Table1. Medians (and standard deviations of means) of iEMG in rotation and push-off phases of four backstroke to breaststroke turning techniques.

Turns	Phases	RA	EO	LD	ES	BF	VL	TA	GM
Open	Rotation 	49.60 (31.15)	11.60 (11.63)	7.90 (8.45)	52.50 (0.00)	48.50 (29.48)	36.30 (12.78)	8.45 (3.58)	8.30 (0.00)
	Push-off 	22.40 (20.45)	0.80 (5.42)	15.25 (4.08)	42.80 (1.95)	29.80 (11.40)	60.70 (6.90)	62.60 (21.75)	77.70 (67.61)
Somersault	Rotation 	25.20 (19.93)	9.60 (24.30)	8.40 (3.15)	48.20 (23.00)	29.15 (29.80)	42.00 (33.25)	23.90 (12.45)	38.80 (24.30)
	Push-off 	22.20 (32.83)	0.45 (2.70)	1.60 (0.63)	32.40 (13.05)	48.80 (34.65)	60.40 (66.13)	66.10 (42.95)	92.70 (80.73)
Bucket	Rotation 	50.30 (18.35)	2.55 (2.85)	7.90 (1.68)	77.70 (0.00)	44.00 (10.73)	37.40 (2.38)	12.90 (2.03)	29.20 (5.18)
	Push-off 	16.90 (22.05)	0.60 (2.63)	3.40 (0.35)	54.90 (13.12)	43.50 (32.6)	32.30 (37.47)	67.20 (99.70)	76.05 (92.5)
Crossover	Rotation 	41.00 (14.25)	31.00 (10.25)	51.00 (37.75)	89.00 (0.00)	41.00 (14.75)	42.00 (0.00)	36.00 (0.00)	46.00 (5.00)
	Push-off 	28.80 (6.98)	4.30 (2.10)	32.40 (0.83)	63.90 (10.50)	35.80 (9.83)	39.30 (25.90)	55.20 (41.15)	118.25 (69.55)

Considering the biarticular muscles (BF, GM) contribution during explosive movements of the push-off phase, that store and transfer mechanical energy by redistributing mechanical energy generated by concentric action of mono articular muscles (VL, TA), for optimal performance of explosive leg extension movements (Umberger, B.1998). Agonist GM and antagonist TA muscles were mostly activated during push-off phase in crossover turn (118.25%, 55.20%), somersault turn (92.70%, 66.10%), open turn (77.70%, 62.60%) and bucket turn (76.05%, 67.20%), respectively. This was already expected, because of their main role as ankle and knee extensors, respectively (Pereira et al., 2015). The great activation of antagonist TA during push-off can be explained by muscle co-contraction due to a stretch shortening cycle (SCC) action

(Lyttle et al., 1999) and kinetic link by the action of biarticular muscles contributes from proximal (hip) to distal (ankle) joints during explosive leg extensions. Moreover, the body has a unique mechanism for providing more power to the distal joints to compensate for the reduced muscle mass (Umberger, B.1998).

CONCLUSION: This study is the first to investigate neuromuscular activation between different backstroke to breaststroke turning techniques, particularly in age-group swimmers. It provides valuable mechanistic insights into swimming turns, particularly for movement economy and efficiency improvements through the correct use of muscle of lower and core body muscles in rotation and push-off phase, which are influenced by recruitment co-activation. We believe that further analyses, combining biomechanical and neuromuscular contributions to rotation and push-off efficiency in determining turning performance, could provide a better support for the determination of the most efficient backstroke to breaststroke turning technique.

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