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Review

Electromyography in the four competitive swimming strokes: A systematic review

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ABSTRACT

The aim of this paper is to give an overview on 50 years of research in electromyography in the four competitive swimming strokes (crawl, breaststroke, butterfly, and backstroke). A systematic search of the existing literature was conducted using the combined keywords "swimming" and "EMG" on studies published before August 2013, in the electronic databases PubMed, ISI Web of Knowledge, SPORT discus, Academic Search Elite, Embase, CINAHL and Cochrane Library. The quality of each publication was assessed by two independent reviewers using a custom made checklist. Frequency of topics, muscles studied, swimming activities, populations, types of equipment and data treatment were determined from all selected papers and, when possible, results were compared and contrasted. In the first 20 years of EMG studies in swimming, most papers were published as congress proceedings. The methodological quality was low. Crawl stroke was most often studied. There was no standardized manner of defining swimming phases, normalizing the data or of presenting the results. Furthermore, the variability around the mean muscle activation patterns is large which makes it difficult to define a single pattern applicable to all swimmers in any activity examined.

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1. Introduction

Between the publication of Cureton's *Mechanics and kinesiology of swimming* in 1930 (Cureton, 1930) and 1964, numerous attempts have been made to describe anatomical function and muscle involvement in human swimming. Muscle involvement is, however, only one element. The muscle use pattern within a complex rhythmical swimming movement is a more important consideration. Such information cannot be obtained by functional anatomical deduction (Clarys, 1983a). Therefore, more than 50 years ago, researchers began to examine the potential to study muscle activation patterns using electromyography (EMG).

The primary means of communication on swimming research in general and in particular EMG has been via abstracts and congress proceedings, in particular the quadrennial symposium on Biomechanics and Medicine in Swimming. This unfortunately has repercussions for the quality and completeness of some publications as well as their availability in online databases. Nevertheless, the pioneering work presented over the years in this area deserves mention as do the 15 narrative reviews or overviews that have been written on this topic. They represented the state of the art at the time and usually give a narrative summary of articles, sometimes focused on one theme, without quality assessment of study design and presentation of information. Most are not complete, nor claim to be. Seven reviews and overviews focused purely on swimming (Clarys, 1983a, 1988, 1996; Birrer, 1986; Pink and Tibone, 2000; Rouard, 2010; Clarys and Rouard, 2011). In eight others, swimming is mentioned as one of a number of sports reviewed (Moynes et al., 1986; Clarys, 1987, 2000, 2006; Clarys et al., 1988a; Bradley and Tibone, 1991; Glousman, 1993; Clarys and Cabri, 1993). While reviews on particular aspects of swimming, such as fatigue (Rouard, 2010), or injuries (Pink and Tibone, 2000) were made, a complete systematic review on the muscle activity in the four competitive strokes (crawl, breaststroke, butterfly and backstroke) has never been published. The 50th anniversary of the first study on EMG in swimming is the ideal pretext for this systematic review which aims to give a comprehensive overview of 50 years of electromyographic research in swimming of the four competitive swimming strokes, to assess the quality of each publication and to summarize and analyze the topics, population and muscles studied and equipment used. In this way the gaps in research still existing in this field can be clearly identified.

To guide this review of EMG in swimming the following research questions were examined:

1. What is the methodological quality of publications on EMG in swimming?
2. What were the main purposes and most frequent topics examined?
3. Which muscles have been investigated?
4. Which swimming activities and populations have been studied?
5. What types of equipment were used and how was data treated?

2. Methods

A systematic search of the existing literature was conducted using the combined keywords "swimming" and "EMG" on studies published before August 2013, in the electronic databases PubMed, ISI Web of Knowledge, SPORT discus, Academic Search Elite, Embase, CINAHL and Cochrane Library. Furthermore, proceedings from the following congresses were systematically scanned for relevant papers: the quadrennial congress of Biomechanics and Medicine in Swimming (starting in 1971 following the first congress of 1970), the biannual congress of Biomechanics (starting in 1968, following the first congress in 1967) and the annual congress of the International Society of Biomechanics in Sports (starting in 1983). In addition to the electronic databases and congress proceedings, the reference lists of all articles found were examined to finalize the search. The inclusion criteria were: (1) studies containing EMG data on at least one of the four competitive swimming strokes, (2) swimmers of all performance levels, sexes and ages and (3) articles written in English. The exclusion criteria were: (1) EMG studies on animals, (2) studies on swimming

Table 1
10 Items of the quality assessment checklist.

1.	Question/objective sufficiently described?	0, 1, or 2
2.	Study design evident and appropriate?	0, 1, or 2
3.	Connection to a theoretical framework/wider body of knowledge?	0, 1, or 2
4.	Subject characteristics sufficiently described?	
	4.1. Age (average and standard deviation)	0, 1, or 2
	4.2. Gender	0 or 2
	4.3. Swimming/activity level of the participants	0, 1, or 2
5.	Data collection methods clearly described and systematic?	
	5.1. Research (swimming) protocol	0, 1, or 2
	5.2. Type of EMG system	0, 1, or 2
	5.3. Studied muscles	0, 1, or 2
	5.4. Uni or bilaterality	0, 1, 2 or NA
6.	Data analysis clearly described and systematic?	
	6.1. EMG filters	0 or 2
	6.2. Normalization method	0, 1, or 2
	6.3. Data processing protocol	0, 1, or 2
7.	Some estimate of variance is reported for the main results	0, 1, 2 or NA
8.	Conclusions supported by the results	0, 1, or 2
9.	Number of participants sufficient to draw conclusions	0, 2, 4 or 6
10.	Statistical analysis is described and appropriate	0, 1, 2 or NA