THE HISTORY OF SWIMMING RESEARCH

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ABSTRACT

The aim of the present paper was to survey the emergence and the state of the literature in swimming research through the last centuries. Before 1970, the date of the first International symposium on biomechanics and medicine in swimming, scientific research in swimming was poor and anecdotal, and the improvements of performance were linked firstly to the swimmer’s experience and secondly as the result of a permanent research for speed. Before and after the Second World War, scientific studies were conducted by pioneers and marked the beginning of research in stroke mechanics and swimming physiology exercise. Today and as illustrated and highlighted in this book, the body of knowledge available for the improvement of sports coaching and training practice in swimming, seems to be relevant, numerous, and diversified enough to help swimming coaches to bridge the gap between theory and practice.

1. INTRODUCTION

Between 1538, the date of the first book specifically dedicated to swimming, written by Wynmann, and 1970, the date of the first International Symposium on Biomechanics and Medicine in Swimming (organized by J. Lewillie and JP Clarys in Brussels), the art of swimming can be described as both the result of the swimmer’s experience and technical aspects discovered and/or developed by scientists. From 1970 up to 2009, as the level of national and international swimming has become more competitive and professional, sport practitioners turned to science to help deciding which methods are more effective than others. Today, and specifically highlighted in this book, human swimming is an important topic of scientific research. Thus, the purpose of this non exhaustive historical review was to analyze the emergence, the evolution and the state of swimming science and research from 1538 up to 2008.
2. FROM 1538 TO 1970

Numerous written works and swimming films tried to explain technical and teaching concepts relevant to practitioners [20]. The different texts available changed from a gymnastic, military and utilitarian form of swimming, up until the First World War, to a more swimming sport form thereafter. Swimming has become an important cultural phenomenon where teaching is complex and differs relatively to the biomechanical concepts predominant in the same period. Among the different authors and more specifically in France, one can differentiate:

- The humanist instructors [23], [9], [22]: They were clerics, intellectuals and professionals. Swimming assumes a utilitarian and educational form. The objectives are a complete education and an adaptable swimmer.
- The military [6]: Swimming is considered as a strategic weapon. Two aspects are pursued: a hygienic and a disciplined activity.
- The "Gymnasiarque" [10], [25]: Swimming is a gymnastic art. It consisted of learning positions in a group activity involving discipline [2].
- The engineers: Technology and the use of devices were more important than technical solutions themselves. Floating and propelling devices (from the stool to the swimming-teaching machine) involved a real educational renunciation.
- The doctors [21]: Swimming was an additional aid to health promotion and also include the beneficial effects of baths and physical exercise.
- The swimming teachers [4], [2]: They had commercial ambitions and published progressive learning strategies in order to obtain an institutional recognition.
- The sportsmen [2], [8]: They appeared at the beginning of the XX\textsuperscript{th} century with the sports phenomenon. The goal was new: competition.

Moreover, the evolution of biomechanical knowledge and regulation constraints were put forward to explain balance, breathing and propulsion changes in the modern swimming strokes [20]. In the past 100 years, and in relation to the development of competition, swimming strokes have been greatly refined because swimmers throughout history have experimented how to swim faster through different ways.

On the one hand, swimmers experimented by trial and error, and watching others, including human swimmers, and also animals, but few champions have the background necessary to explain the mechanical action of the strokes they perform. The evolution of technical solutions in swimming has been the result of a permanent research for speed. From 1850 to 1910, the most decisive landmark was when the first competitors swapped from breast stroke to front crawl. In 1902, Richard Cavill set the world record of the 100 yards by swimming the whole distance in front crawl. On this date, crawl became the fastest stroke. The front crawl stroke is very efficient because the streamlined position of the body and arm recoveries out the water, decrease the drag resistance and the alternative arm actions guarantee the continuity of the propulsive forces. Between 1912 and 1932 the evolution comes from balance and particularly breathing changes, which mainly explain the improvement of performances. At the Olympic Games in Stockholm in 1912, Duke Kahanamoku adopted a streamlined position and in Paris (1924) Johnny Weissmuller broke
the mythical one minute for the 100 m distance. In his book [26], he explained that "The instinctive thing for a beginner to do is to hold his breath. As soon as he learns to overcome this, half his fight is won, and he is ready for the finer points of swimming." and "After improving my breath control,..., where a mile a day had exhausted me completely, I began to do a mile and a half a day with greater ease". In 1926, Gertrude Ederle broke the record of the crossing of the Channel, performing the crawl stroke over the complete distance. On this date, crawl became accepted as the most economical stroke, which was demonstrated only in the seventies [15] and confirmed much later for swimming pool conditions [1].

On the other hand, the first scientific analysis conducted by Dubois-Reymond, in 1905 and 1927 [10, 11], and Cureton in 1930 [7] has helped to produce more varied strokes, greater speeds, and a better understanding of propulsion through water. This marked the beginning of research into stroke mechanics and swimming exercise physiology, together with Karpovitch, in 1933 [17], and some others. In 1928, Armbruster first filmed swimmers underwater to study stroke’s technique. The Japanese also photographed and studied world-class swimmers, using their research to produce a swim team that dominated the 1932 Olympic Games. Then, researchers [19], [16], such as Dr. James Edward Counsilman [5] focused both on the forces that act on a body moving through the water, and on the exercise physiology applied to swimming, to better define training programs. Owing to their pioneering and painstaking work, they revolutionized stroke mechanics and teaching and training methods in swimming.

3. FROM 1970 UP TO 2009

Today, the science of swimming is highly developed and helps coaches to improve swimmers' performances in competition. In this second part of this paper, the purpose of this historical review was to analyze the evolution and state of scientific swimming research. From 1970 up to 2009, the level of national and international swimming has become more competitive and professional, and swimming science has become one of the keys of swimming success. Nevertheless, scientific studies have led to high levels of frustration among coaches due to both: (i) the inability of a single approach such as physiological, biomechanical, psychological, ..., to provide the required answer for each practical problem, and (ii) the difficulty to produce relevant results in a sufficiently short period to allow a profitable interaction with practice. However, determining the most correct answer in the training process is dependent upon the weight of the scientific background available at a specific moment. The results from the scientific studies along with results from practical experiences can help to determine the best answer as shown by Troup [24] through the concept of the learning continuum:

<table>
<thead>
<tr>
<th>Scientific results</th>
<th>Applications</th>
<th>Evaluation</th>
<th>Improved training</th>
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</table>

Nevertheless, the scientific process is simultaneously and mainly influenced by the quality of the experimental design, the status of the experimental and control groups, and the specificity of the test markers affecting training and performance or experimental results.
Following a similar approach to Troup [24], three degrees of control can be distinguished in the current contents of publication:

1. Basic studies and applied studies, where interventions on animal or swimming material are tested with a lack of external influencing factors. These papers are found in the most respected peer reviewed journals with impact factor higher than 4. However, they are very difficult to numerate because they do not correspond to specific keywords such as swimming or training.

2. Descriptive studies where characteristic and typical responses during swimming exercise in humans are scientifically measured and are mostly published in scientific journals with an impact factor lower than 3.5.

3. Practical and field studies where findings emerge from a practical and useful point of view, while still maintaining scientific integrity and controls. Nevertheless, the results are more often linked to a specific context of training and population. They cannot be extended to general and scientific concepts, and are published in professional national or international journals applied to swimming. Indeed, these studies do not tightly control confounding factors, such as compliance between coach and athlete, but provide practical information derived from level 1 and 2 of scientific knowledge. These publications are very often written in different national languages and are difficult to innumerate.

The first two levels of publications are today very large and diversified. Clarys, in 1996 [3], reported that by the mid 1990’s there were 685 peer reviewed papers on swimming and Keskinen in 2006 [18] using EBSCOhost Research Databases and Sport Discus observed 16067 papers with swimming, when the time line was kept unlimited (but excluding animal experiments). Over the last decades, the increase in these publications (essentially level 2) reflects the growing interest of researchers to carry out studies in situ and can also indicate that these researchers are in part solicited and financed by the national swimming federations. For most of the great nations, the later have developed their own research structures or partnerships with private or university laboratories.

Figure 1. Evolution of specific papers related to swimming and referenced in PUBMED data base from 1970 to 2005
Indeed, we can notice on figure 1 the increase of the number of scientific papers (level 1 and 2) published during the last four decades related to swimming performance in humans. Systematic literature searches were performed through the years 1970-2005 and calculated every four years utilizing Pubmed databases and introducing specific keywords such as swimming, performance, human and competition and excluding papers about pregnant women, toddlers, scuba diving, infections, therapeutic properties of water, … and triathlon, water polo, synchronized swimming and diving not specifically related to swimming.

Moreover, and as shown in figure 2, the different scientific fields investigated in the specific 182 papers related to swimming and referenced in PUBMED data base from 2005 to 2008 are very diversified and can be classified in Biomechanics, Physiology, Technique, EMG, Medical, Psychology, Sociology and History, Learning, Technology and Methodology, Training, and Anthropometry areas.

These three levels of swimming research and publications are complementary and necessary to improve the training process, and provide a service to coaches and swimmers. In fact, an appropriate balance of the three levels of swimming research can lead to the enhancement of a scientific approach of swimming teaching and training process. The different national and international congresses such as those of the World Congress of Medical and Scientific Aspects in Aquatic sports (FINA), and particularly the most well-known by the swimming scientific community, the International Symposiums on Biomechanics and Medicine in Swimming (BMS), can give us a wealth of research unique and unprecedented in the world of sports. Table 1 illustrates the evolution of different fields of studies during the first ten International Symposiums on Biomechanics and Medicine in Swimming Papers. Further than the relative relevance of the different areas of research interest, it is important to note, from Table 1, the progressive and steady growth of the number of published papers, starting with 24, in 1970, and temporarily finishing with 144 in 2006; this was a 600% increase in the publishable volume, accomplished in 36 years and 10 editions of the Symposium.
Table 1. Evolution of the different fields of studies (expressed in %) during the 10 International Symposium on Biomechanics and Medicine in Swimming. Papers (n) can be related both to one, two or three different domains of investigation.

<table>
<thead>
<tr>
<th>Olympic Games</th>
<th>BMS</th>
<th>Biomechanics</th>
<th>Physiology</th>
<th>Technique</th>
<th>EMG</th>
<th>Medical</th>
<th>Psychology</th>
<th>Sociology / History</th>
<th>Learning</th>
<th>Technology/Methodology</th>
<th>Training</th>
<th>Anthropometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968 Mexico</td>
<td>1970 – BMS I Brussels (Belgium) n=24</td>
<td>11.4</td>
<td>34.3</td>
<td>28.6</td>
<td>11.4</td>
<td>5.7</td>
<td>2.9</td>
<td>2.9</td>
<td>0</td>
<td>2.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1972 Munich</td>
<td>1974 – BMS II Brussels (Belgium) n=37</td>
<td>9.8</td>
<td>32.8</td>
<td>23</td>
<td>1.6</td>
<td>3.3</td>
<td>1.6</td>
<td>0</td>
<td>8.2</td>
<td>13.1</td>
<td>1.6</td>
<td>4.9</td>
</tr>
<tr>
<td>1976 Montreal</td>
<td>1978 – BMS III Edmonton (Canada) n=31</td>
<td>5.6</td>
<td>38.9</td>
<td>25.9</td>
<td>5.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.8</td>
<td>3.7</td>
<td>13</td>
<td>5.6</td>
</tr>
<tr>
<td>1980 Moscou</td>
<td>1982 – BMS IV Amsterdam (Holland) n=50</td>
<td>25.7</td>
<td>31.4</td>
<td>11.4</td>
<td>4.3</td>
<td>4.3</td>
<td>1.4</td>
<td>2.9</td>
<td>0</td>
<td>4.3</td>
<td>8.6</td>
<td>5.7</td>
</tr>
<tr>
<td>1984 Los Angeles</td>
<td>1986 – BMS V Bielefeld (Germany) n=44</td>
<td>20.5</td>
<td>30.8</td>
<td>17.9</td>
<td>9</td>
<td>2.6</td>
<td>2.6</td>
<td>0</td>
<td>3.8</td>
<td>1.3</td>
<td>5.1</td>
<td>6.4</td>
</tr>
<tr>
<td>1988 Seoul</td>
<td>1990 – BMS VI Liverpool (UK) n=59</td>
<td>25.8</td>
<td>20.4</td>
<td>16.1</td>
<td>3.2</td>
<td>6.4</td>
<td>3.2</td>
<td>0</td>
<td>2.1</td>
<td>0</td>
<td>14</td>
<td>8.6</td>
</tr>
<tr>
<td>1992 Barcelona</td>
<td>1994 – BMS VII Atlanta (USA) n=35</td>
<td>22.6</td>
<td>33.4</td>
<td>19.3</td>
<td>3.2</td>
<td>4.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.6</td>
<td>11.3</td>
<td>3.2</td>
</tr>
<tr>
<td>1996 Sidney</td>
<td>1998 – BMS VIII Jyvaskyla (Finland) n=95</td>
<td>18.4</td>
<td>33.3</td>
<td>14.9</td>
<td>1.4</td>
<td>2.1</td>
<td>0.7</td>
<td>0</td>
<td>3.5</td>
<td>5.7</td>
<td>14.9</td>
<td>5</td>
</tr>
<tr>
<td>2000 Atlanta</td>
<td>2002 – BMS IX Saint Etienne (France) n=98</td>
<td>21.5</td>
<td>25.9</td>
<td>29.9</td>
<td>0.7</td>
<td>3</td>
<td>1.5</td>
<td>0.7</td>
<td>3</td>
<td>5.2</td>
<td>5.2</td>
<td>4.4</td>
</tr>
<tr>
<td>2004 Athènes</td>
<td>2006 – BMS X Porto (Portugal) n=144</td>
<td>20.1</td>
<td>26.3</td>
<td>21.1</td>
<td>1</td>
<td>3.1</td>
<td>1</td>
<td>0.5</td>
<td>4.6</td>
<td>12.4</td>
<td>7.2</td>
<td>2.6</td>
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</table>
The 11th Biomechanics and Medicine in Swimming conference will celebrate its 40th anniversary, in 2010 (Oslo, Norway). The topics which will be covered are not only biomechanics and medicine, but cover many more aspects of swimming science:

- Biological and Physical Science of Swimming: physiology, biomechanics, anatomy, electromyography, anthropometry, body composition, physics, bioenergetics, ergonomics;
- Medical Science of Swimming: clinical medicine, public health, injury prevention;
- Educational Science of Swimming: pedagogy, didactics, motor learning;
- Social Science of Swimming: psychology, sociology, anthropology, history, philosophy.

4. CONCLUSION

Science plays an important role in the understanding and development of swimming performance. Swimming research can play an important role in indentifying factors of performance and developing methods to improve them. The added benefit of research results is the information that can enhance the educational and training materials and programs. Moreover, a practical sport science program can also be the background topic of research designed to model and evaluate new concepts in training. Swim researchers also contribute to initiating new techniques, drills, and teaching and training methods based on scientific principles. Furthermore, it must be understood by both the scientist and the swimming coach that today, research study and swimming success are linked and dependant on a scientific continuum. The greatest nations, vying for places on the swimming podiums at the highest level, have understood and financed research structures and athlete study centers, allowing coaches and researchers to work together in a fruitful way.

REFERENCES

Want to know more about Swimming? Since its history, rules, how it is practiced, etc. Click here and know this and more!

Swimming is a sport that consists of swimming and aims to travel a certain distance in the least possible time and may have to use a specific swimming style. Table of Contents: History of Swimming. Swimming Styles. Breaststroke. Crawl. Backstroke.