Biomechanics and Medicine in Swimming XI

Per-Ludvik Kjendlie, Robert Keig Stallman, Jan Cabri (eds)
**Scientific Committee**

Kjendlie, Per-Ludvik, NOR, (Chair)
Stallman, Robert, NOR, (Chair)
Cabri, Jan, NOR, (Chair)

Alves, Francisco (POR)
Arellano, Raul (ESP)
Aspenes, Stian (NOR)
Barbosa, Tiago (POR)
Castro, Flavio (BRA)
Chatard, Jean Claude (FRA)
Chollet, Didier (FRA)
Clarys, Jan Pieter (BEL)
Costill, David (USA)
da Silva, Antonio (POR)
Daly, Dan (BEL)
Dekerle, Jeanne (FRA)
Dopsaj, Milivoj (SRB)
Esser-Noethlics, Marc (NOR)
Fernandes, Ricardo (POR)
Hollander, Peter (HOL)
Issurin, Vladimir (ISR)
Jürimäe, Toivo (EST)
Keskinen, Kari (FIN)
Langendorfer, Steven (USA)
Lemure, Nicolas (NOR)
Mason, Bruce (AUS)
Millet, Gregoire (SUI)
Moran, Kevin (NZL)
Nomura, Teruo (JPN)
Ogita, Futoshi (JPN)
Onodera, Sho (JPN)
Payton, Carl (GBR)
Pendegast, David (USA)
Prins, Jan (USA)
Psychariakis, Stelios (GBR)
Pyne, David (AUS)
Rejman, Marek (POL)
Rodrigues, Ferran (ESP)
Sanders, Ross (GBR)
Seifert, Ludovic (FRA)
Stager, Joel (USA)
Swaine, Ian (GBR)
Toussaint, Huub (HOL)
Ungerechts, Bodo (GER)
Vikander, Nils (NOR)
Vilas-Boas, João Paulo (POR)
Wakayoshi, Kohji (JPN)
Zamparo, Paola (ITA)

**BMS International Steering Group**

Kari Keskinen, Finland (Chair)
Jan Pieter Clarys, Belgium
Bodo Ungerechts, Germany
João Paulo Vilas-Boas, Portugal

**Local Organizing Committee**

Robert Stallman (Chair)
Per-Ludvik Kjendlie (Chair)
Cabri, Jan (Chair)

Bakke, Tom Atle
Caspersen, Cecilie
Dahl, Dugmar
Keskinen, Kari (intn. advisor)
Midun, Ingvild Riise
Olstad, Bjørn Harald
Steinbekken, Karoline
Vilas-Boas, João Paulo (intn. advisor)

**Sponsors**

The publishing of this book was supported by:

- World Commission for Sport Sciences
- The Norwegian School of Sport Sciences
- Department of Physical Performance
- Norwegian Research Centre for Training and Performance
- Norwegian Swimming Federation
- Norwegian Life Saving Society
- Norwegian Rheumatism Association

- AP Lab
- Coaches Infoservices
- Cortex Biophysik GmbH
- Hector Engineering Inc.
- Ide AS
- Klubben AS
- Nespresso
- Pahlen Norge
- Sensorize Srl
- Sport-Thieme GmbH
- Tine AS
- Vita
- Voss Water
# Table of Contents

## Preface

Chapter 1. Invited Lectures


Applying a Developmental Perspective to Aquatics and Swimming - Langendoerfer, S.J. 20

The Psycho-Physiology of Overtraining and Athlete Burnout in Swimming - Lemyre, P.-N. 22

Biomechanical Services and Research for Top Level Swimming: the Australian Institute of Sport Model - Mason, B.R. 25

Aquatic Training in Rehabilitation and Preventive Medicine - Prins, J. 28

Training at Real and Simulated Altitude in Swimming: Too High Expectations? - Rodriguez, P.A. 30

Muscle Fatigue in Swimming - Rouboa, A.H. 33

Inter-Limb Coordination in Swimming - Seifert, L. 35

Chapter 2. Biomechanics


Effect of Stroke Drills on Intra-cycle Hip Velocity in Front Crawl - Arcellano R., Dominguez-Castelli R., Perez-Infantes E., Sanchez E. 45

The Usefulness of the Fully Tethered Swimming for 50-m Breaststroke Performance Prediction - Barbosa A.C. Milicevic Dopsaj M.2, Okici T, Andrias Junior O. 47


Do Fastskin Swimsuits Influence Coordination in Front Crawl Swimming and Glide? - Chollet, D., Chevaillard, F., Seifert, L., Lemaitre, F. 55

The Effect of Wearing a Synthetic Rubber Suit on Hydrostatic Lift and Lung Volume - Cortez, M., Zamparo, P., Tam, E., Da Boit, M., Gatta, G. 57

The Development of a Component Based Approach for Swim Start Analysis - Cessor, J.M., Lawson, S.E.1, Justham, L.M., Conway, B.P.2, West, A.A. 59


Pulling Force Characteristics of 10 s Maximal Tethered Eggbeater Kick in Elite Water Polo Players: A Pilot Study - Dopsaj, M. 69

Motor Coordination During the Underwater Undulatory Swimming Phase of the Start for High Level Swimmers - Elipot, M., Houel, N., Hellard, P., Distich, G. 72


Measuring Active Drag within the Different Phases of Front Crawl Swimming - Fornaes, J., Mason, B.R. & Burkett, B.J. 82

The Mechanical Power Output in Water Polo Game: a Case Report - Gatta, G., Pantozzi, S., Cortez, M., Patti, F., Bonfazi, M. 84

Comparison of Combinations of Vectors to define the Plane of the Hand in order to calculate the Attack Angle during the Sculling Motion - Gomes, L.E.1, Mello, M.O.1, La Torre, M. 1, Lou, J.F. 86


Relationship between Eggbeater Kick and Support Scull Skills, and Isokinetic Peak Torque - Homma, M. 91


Comparison of Front Crawl Swimming Drag between Elite and Non-Elite Swimmers Using Pressure Measurement and Motion Analysis - Ichikawa, H., Mirwa, T., Takeda, T., Takagi, H., Tsukahimoto, S. 100

Whole Body Observation and Visualized Motion Analysis of Swimming - Ito, S., Okuno, K. 102

A Full Body Computational Fluid Dynamic Analysis of the Freestyle Stroke of a Previous Sprint Freestyle World Record Holder - Keys, M.J.1, Lyttele, A., Blanksby, B.A.J & Cheng, L. 105

An Analysis of an Underwater Turn for Butterfly and Breaststroke - Kitshimoto, T., Takeda, T., Sugimoto, S., Tsukahimoto, S.2 and Takagi, H. 108

Heart Rate Responses During Gradually Increasing and Decreasing Exercise in Water - Nishimura, K., Noie, Y., Yoshioka, A., Kawanou, H., Onodera, S., Takamoto, N. 208
Effects of Recently Developed Swimwear on Drag During Front Crawl Swimming - Ogita, F., Huang, Z., Karobe, K., Otsava, G., Taguchi, T., Tanaka, T. 211
Relationship between Heart Rate and Water Depth in the Standing Position - Onodera, S., Yoshioka, A., Matsumoto, N., Takahara, T., Noie, Y., Hirao, M., Seki, K., Nishimura, K., Baik, W., Hara, H., Murakawara, T. 213
Hormonal, Immune, Autonomic and Mood State Variation in the Initial Preparation Phase of a Winter Season, in Portuguese Male Swimmers - Rama, L., Alves, F., Teixeira, A. 217
Oxygen Uptake Kinetics and Performance in Swimming - Reis, J.F., Alves, F.B. 220
Maximum Blood Lactate Concentration after Two Different Specific Tests in Freestyle Swimming - Rozi, G., Thanopoulos, V., Dopsaj, M. 222
Can Blood Glucose Threshold be Determined in Swimmers Early in the Swimming Season? - Sengoku, Y., Nakamura, K., Takeda, T., Nabekura, Y., Tsukimoto, S. 224
The Effects of Rubber Swimsuits on Swimmers Using a Lactic Acid Curve Test - Shiraki, T., Wakayoshi, K., Hata, H., Yamamoto, T., Tomikawa, M. 226
Some Factors Limiting Energy Supply in 200m Front Crawl Swimming - Strumbelj, B., Usaj, A., Kapus, J., Rednarik, J. 228
Lactate Comparison Between 100m Freestyle and Tethered Swimming of Equal Duration - Thanopoulos, V., Rozi, G., Platanou, T. 230
Blood Lactate Concentration and Clearance in Elite Swimmers During Competition - Vescevi, J.D., Faleznuk, O., Wells G.D. 233
Determination and Validity of Critical Velocity in Front Crawl, Arm Stroke and Leg Kick as an Index of Endurance Performance in Competitive Swimmers - Wakayoshi, K., Shiraki, T., Ogita, F., Kitajima, M. 236
Differences In Methods Determining The Anaerobic Threshold Of Triathletes In The Water - Zoretic, D., Wertheimer, V., Leko, G. 238

Chapter 4. Training and Performance 241
Physiological Responses and Performance Characteristics of 200m Continuous Swimming and 4x50m “Broken Swimming” with Different Rest Intervals - Beidar, N., Bottini, P. and Platanou, T. 242
General Indexes of Crawl Swimming Velocity of Junior Water Polo Players in a Match - Bratusa, F.Z., Perissi, S.M., Dopsaj, J.M. 245
Bench Press and Leg Press Strength and its Relationship with In-Water Force and Swimming Performance when Measured in-season in Male and Female Age-group Swimmers - Carl, D.L., Leslie, N., Dickerson, T., Griffin, B., Marksteiner, A. 247
Effect of Start Time Feedback on Swimming Start Performance. - de la Fuente, B. and Arellano, R. 249

Predictors of Performance in Pre-Pubertal and Pubertal Male and Female Swimmers – Doada, H.T., Touiliski, A.G., Georgiou, Ch., Gourgoulis, V. and Tekaikiadis, S.P. 252
Changes of Competitive Performance, Training Load and Tethered Force During Tapering in Young Swimmers - Dressou, E., Touiliski, A.G., Gourgoulis, V., Thomaidis, S., Doada, H., Tekaikiadis, S.P. 254
Perceived Exertion at Different Percent of The Critical Velocity in Front Crawl - Franken, M., Dieffenbacher, F., de Souza Castro, F.A. 257
Talent Prognosis in Young Swimmers - Hofmann, A., Steidel, I. 262
Determination of Lactate Threshold with Four Different Analysis Techniques for Pool Testing in Swimmers; Competitive Systematisation in Age-group Swimming; An Evaluation of Performances, Maturational Considerations, and International Paradigms - Kojima, K. and Stager, J.M. 267
Effects of Reduced Knee-bend on 100 Butterfly Performance: A Case Study Using the Men’s Asian and Japanese Record Holder - Ide, T., Yoshihima, Y., Kawanari, K., Takisi, S., Kawai, T. 270
Effect of Subjective Effort on Stroke Timing in Breaststroke Swimming - Obba, M., Sato, S., Shimoyama, Y., Sato, D. 274
A Markov Chain Model of Elite Water Polo Competition – Pfiffer, M., Hofmann, A., Siegel, A., Böhnlein, S. 278
Throwing Accuracy of Water Polo Players of Different Training Age and Fitness Levels in a Static Position and after Previous Swimming - Platanou, T. and Botonis, P. 281
The Effect of Cognition-Based Technique Training on Stroke Length in Age-Group Swimmers – Schmidt, A.C., Ungerechts, B.E., Buss, W.J., & Schack, T. 283
Assessing Mental Workload at Maximal Intensity in Swimming Using the NASA-TLX Questionnaire – Schnitzler, C., Seifert, L., Chollet, D. 286
Does the Y-Intercept of a Regression Line in the Critical Velocity Concept Represent the Index for Evaluating Anaerobic Capacity? – Shimoyama, Y., Oikita, K., Baba, Y., Sato, D. 288
Identification of a Bias in the Natural Progression of Swim Performance – Stager, J.M., Brammer, C.L., Tänner, D.A. 294
Blood Lactate Responses During Interval Training Corresponding to Critical Velocity in Age-Group Female Swimmers – Tsali, G., Touiliski, A.G., Michailidou, D., Gourgoulis, V., Doada, H., Tekaikiadis, S.P. 299
Chapter 5. Education, Advice and Biofeedback


Quantitative Data Supplements Qualitative Evaluations of Butterfly Swimming - Becker, T.J., Havriluk, R. 314

The Effect of Restricting the Visual Perceptual Task in the Temporal Organization of Crawl Swimming: Surface Characteristics - Brito, C.A.F., Belvisi, W.C., Oliveira, M. 2 317

Analyses of Instruction for Breath Control While Swimming the Breaststroke - Haro, H., Yoshioka, A., Matsunaga, N., Nose, Y., Watanabe, R., Shibata, Y., Onodera, S. 319

Performance Level Differences in Swimming: Relative Contributions of Strength and Technique - Havriluk, R. 321

Evaluation of Kinaesthetic Differentiation Abilities in Male and Female Swimmers - Invernizzi, P.L., Longo, S., Scurati, R., Michielon, G. 324

Swimming in Eyesight Deprivation: Relationships with Sensory-Perception, Coordination and Laterality - Invernizzi, P.L., Longo, S., Tudini, F., Scurati, R. 326

Progression in Teaching Beginning Swimming: Rank Order by Degree of Difficulty - Junge, M., Blixt, T., Stallman, R.K., 329

The Construct Validity of a Traditional 25m Test of Swimming Competence - Junge, M., Blixt, T., Stallman, R.K. 331

Using a Scalogram to Identify an Appropriate Instructional Order for Swimming Items - Langendorfer, S.J., Chaya, J.A. 333


The Effect of a Target Sound made by a Model Swimmer’s Dolphin Kick Movement on Another Swimmer’s Dolphin Kick Performance - Shimojo, H., Ikihara, H., Tsukahimoto, S., Takagi, H. 341

Tendencies in Natural Selection of High Level Young Swimmers - Timakova TS, Klyuchnikova M.V. 343

The Cognitive Interplay Between Sensory and Biomechanical Features While Executing Flip Turns Wearing Different Swim Suits - Vieluf, S., Ungerechts, B.E., Toussaint, H.M., Lex, H. 1, Schach, T. 346

The Role of Verbal Information about Sensory Experience from Movement Apparatus in the Process of Swimming Economization - Zaton, K. 349

Chapter 6. Medicine and Water Safety

Crucial Findings from the 4W Model of Drowning for Practical and Teaching Applications - Avramidis, S., McKenna, J., Long, J., Butterly, R., Llewellyn, J.D. 353


Analysis of Aerobic/Aerobic Performance in Functionally Disabled Swimmers: Low Classes vs High Classes - De Aymerich, J., Benavent, J., Tella, V., Colado, J.C., Gonzalez, L.M., Garcia-Masó, X. 2, Madera, J. 359

Athletic Rehabilitation of a Platform Diver for Return to Competition after a Shoulder Dislocation - Fujinawa, O., Kondo, Y., Tachikawa, K., Jigami, H., Hirose, K., Matsunaga, H. 362


Real and Perceived Swimming Competency, Risk Estimation, and Preventing Drowning among New Zealand Youth - Moran, K. 368

Keeping the Safety Messages Simple: The International Task Force on Open-Water Recreational Drowning Prevention - Quan, L., Bennett, E., Moran, K. (co-chairs) 371


A Conceptual Paper on the Benefits of a Non-Governmental Search and Rescue Organization - Wengelin, M., de Wet, T. 384

Author Index 0
The Evolution of Swimming Science Research: Content analysis of the “Biomechanics and Medicine in Swimming” Proceedings Books from 1971 to 2006

Barbosa, T.M.1,4, Pinto, E.1, Cruz, A.M.1,4, Marinho, D.A.2,4, Silva, A.J.1,4, Reis, V.M.1,4, Costa, M.J.1,4, Queirós, T.M.1

1 Polytechnic Institute of Bragança, Bragança, Portugal
2 University of Beira Interior, Covilhã, Portugal
3 University of Trás-os-Montes and Alto Douro, Vila Real, Portugal
4 Research Centre in Sports, Health and Human Development, Vila Real, Portugal

The aim of this study was to analyze the evolution of swimming science research based on the content analysis of the “Biomechanics and Medicine in Swimming” Proceedings book series from 1971 to 2006 (i.e., a total of 622 full papers). There was an increasing number of papers published within the period of time analyzed (ranging from 23 papers in 1971 to 145 manuscripts in 2006). Comparing the sub-categories related to “Aquatic activity” most research done was clearly on “competitive swimming”. In the last decade there is a slight but increasing interest in “head-out aquatic exercises”. Analyzing the main “scientific area” of study, “Biomechanics” was the most often assessed area, followed by “Physiology”. Since 2003 an increasing trend in “interdisciplinary assessment” manuscripts was verified.

Key words: research, content analysis, aquatic activities, sport sciences,

INTRODUCTION

Swimming seems to be one of the most studied sports within the Sport Sciences research community. More than a decade ago, Clarys (1996) conducted an analysis about swimming research. The author analyzed the content of 685 papers related to swimming based on 12 knowledge areas. The scientific area with most papers was “Biomechanics” representing 20 % of total manuscripts, followed by “Physiology” representing 18 %, “Medicine/Clinics” representing 16 %, “Hydrodynamics” representing 9 % and “Electromyography” representing 8 %.

In these last 14 years there have been several developments in the aquatic activities domain. It was hypothesized that the Clarys (1996) report could be updated. New highlights and technologic evolutions were introduced in “swimming science”. Major updates happened in the “state of the art” of swimming. In the past, “swimming research” was dedicated almost exclusively to competitive swimming. Nowadays there are several other aquatic activities being practiced in aquatic centres, such as “head-out aquatic exercises”, aquatic rehabilitation and infant swimming. Swimming research is also dedicated to analyze and understand all these aquatic activities. Moreover, characterizing the evolution of research in these different aquatic activities has never been attempted.

The “International Symposium on Biomechanics and Medicine in Swimming” (BMS) is a scientific meeting of aquatic activities researchers. The symposium happens every 4 years and is supported by UNESCO, among other organizations, gathering all main research groups dedicated to these sports. The first meeting was held in 1970 (Brussels, Belgium) and titled “1st International Symposium of Biomechanics in Swimming”. In 1986 (Bielefeld, Germany) the definitive name of “International Symposium on Biomechanics and Medicine in Swimming” was adopted. All main conferences, oral communications and poster presentations are collected, reviewed and published in a proceeding book that nowadays is titled “Biomechanics and Medicine in Swimming”. In this sense, BMS can be considered as representative of the work conducted by the main groups dedicated to aquatic activities research in a given historic time frame.

The aim of this study was to analyze the evolution of “swimming science” research in the last decades based on the BMS proceedings books.

METHODS

The content of all the 622 papers published in the proceedings books of the “International Symposium on Biomechanics and Medicine in Swimming” series edited from 1971 to 2006 were analyzed. An observation grid for the manuscript analysis was developed. This instrument was composed by observational categories previously defined by the researchers. Two main categories were defined: (i) the “aquatic activity” studied in each paper analyzed and; (ii) the main “scientific area” applied for the assessment.

The main category “aquatic activity” included the following sub-categories: (i) Competitive swimming; (ii) Water Polo; (iii) Synchronized Swimming; (iv) Diving; (v) Hydrotherapy; (vi) Infant Swim; (vii) Head-out Aquatic Exercises; (viii) Fin Swimming and; (ix) others. The main “scientific area” included the following sub-categories (adapted from Clarys, 1996): (i) Biomechanics; (ii) Psychology; (iii) Sociology; (iv) Pedagogy/Teaching; (v) Biochemistry; (vi) Physiology; (vii) Thermoregulation; (viii) Hydrodynamics; (ix) Electromyography; (x) Anthropometry; (xi) Equipment/Methodology; (xii) Clinical Medicine/Traumatology and; (xiii) Interdisciplinary assessment.

For identification of each sub-category the following steps were used: a) read the abstract, identifying the aquatic activity studied, as well, the scientific area of assessment; b) whenever necessary or appropriate read the full paper; c) if the paper was not able to be inserted in any of the sub-categories defined for the main category “aquatic activity” it would be identified as “others” (e.g., life saving, recreational games, etc).

The absolute frequency for the number of papers in each edition of the proceeding s was registered. Relative frequency for each sub-category in a given edition and for full period of time between 1971 and 2006 was considered.

RESULTS

Figure 1 presents the number of papers published between 1971 and 2006. There was an increasing number of papers published within the period of time analyzed (ranging from 23 papers in 1971 to 145 manuscripts in 2006). The only exception to the increasing trend was the 1996 edition.

![Figure 1. Evolution in the number of papers published between 1971 and 2006.](image)
FIGURE 3 presents the evolution in the relative frequency of each subcategory within the 1971-2006 time frame. About the “scientific area” it is possible to verify that at any given moment there is a major interest about one or a couple of specific issues, besides “Biomechanics” and “Physiology”. For example, in 1983 there were several papers published about “Hydrodynamics”, in 1988 “Biochemistry”, in 1992 “Anthropometry” and in 2006 “Interdisciplinary assessment”. For the “aquatic activity” “Competitive swimming” was always on top. However, starting in 1999 there was an increasing interest for “Head-out aquatic exercises” and “Fin swimming”.

**DISCUSSION**

There was an increasing number of papers published within the period of time analyzed (ranging from 23 papers in 1971 to 145 manuscripts in 2006). So, “swimming science” seems to be increasing since 1971, as the number of research groups focused in this sport is increasing, as well as, the number of research projects developed by each group. The 1996 book was the only one that did not present a greater number of papers in comparison to the previous edition. From the 80 studies presented at the VII Symposium on Biomechanics and Medicine in Swimming, only 36 were selected to be published. This means that from the 1992 edition (with 64 papers published/presented) to the 1996 edition there was actually an increase in the number of studies presented.

Comparing the sub-categories related to “Aquatic activity” the one with most research conducted was clearly “Competitive swimming” (ranging from 78.8% in 1971 to 100% in 1996). In the last decade there is a slight but increasing interest in “Head-out aquatic exercises” (e.g., the second most studied aquatic activity in 2006 with 6.9%). Aquatic activity was for a long time synonymous with swimming. Added to this, “Water polo” was also specially under the BMS scope, as is verified by the name of the 1971 proceeding book: “First International Symposium on Biomechanics in Swimming, Water Polo and Diving”. Nowadays “Head-out aquatic exercises” are gathering a large part of the persons practicing physical activity in aquatic centres. Indeed, these facilities provide services that are complementary to “traditional” competitive sports, such as “Head-out aquatic activities”. This is related to the increasing importance of aquatic activity for health. Starting in 1999 there was also an increasing interest in “Fin swimming”. “Fin swimming” now has a more consistent position among the aquatic competitive sports. “Fin swimming” has competitions at all levels, including international and media attention is increasing in some countries.

Analyzing the main “scientific area” of study, “Biomechanics” was the most common area (ranging from 27.3% in 1988 to 60% in 1979), followed by “Physiology”. As “Biomechanics” and “Physiology” were within the origins of this scientific meeting, it is logical that they are the largest sub-categories. It is consensual that biomechanical and physiological profiles of a swimmer are determinant factors for his/her performance enhancement. Since 2003 an increasing trend in “Interdisciplinary assessment” manuscripts is verified. There is now a trend to understand not only how each scientific area determines performance, but also how they interplay. At certain periods of the history of BMS the major area of interest in addition to “Biomechanics” and “Physiology” (e.g., in 1983 the “Hydrodynamics”, in 1988 the “Biochemistry”, in 1992 the “Anthropometry” and in 2006 the “Interdisciplinary assessment”). It seems there are some topics that are deeply explored in a given moment by several research groups.

**CONCLUSION**

As a conclusion, there is a significant increase in scientific production regarding aquatic activities throughout the 1971-2006 period. Concerning the scientific area the main interests are related to “Biomechanics” and “Physiology”. Recently there is a trend in “Interdisciplinary assessment”. “Competitive swimming” is the main aquatic activity studied. In the last proceedings, the tendency for a higher interest in “Head-out aquatic activities” was verified.

**REFERENCES**


**ACKNOWLEDGMENTS**

Ana M. Cruz would like to acknowledge the Portuguese Science and Technology Foundation (Research Integration Grant BII - CIDESD/UTAD).