



Biomechanics and Medicine in Swimming XI

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



Biomechanics and Medicine in Swimming XI

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



Bibliographic information:
Biomechanics and Medicine in Swimming XI.

Proceedings of the XIth International Symposium for Biomechanics
and Medicine in Swimming, Oslo, 16th -19th June 2010

Per-Ludvik Kjendlie, Robert Keig Stallman and Jan Cabri (Eds)
Published by the Norwegian School of Sport Science, Oslo, 2010

ISBN 978-82-502-0438-6 (printed)
ISBN 978-82-502-0439-3 (electronic / pdf version)

Printed by Nordbergtrykk as

Front cover photos © by Per Eide / Innovation Norway and
Per-Ludvik Kjendlie
Front Cover Graphics by Beta Grafisk AS

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)
Lemyre, Nicolas (NOR)
Mason, Bruce (AUS)
Millet, Gregoire (SUI)
Moran, Kevin (NZL)
Nomura, Teruo (JPN)
Ogita, Futoshi (JPN)
Onodera, Sho (JPN)
Payton, Carl (GBR)
Pendergast, 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, Dagmar
Keskinen, Kari (intrn. advisor)
Midtun, Ingvild Riise
Olstad, Bjørn Harald
Steinbekken, Karoline
Vilas-Boas, João Paulo (intrn. 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

Biomechanics and Medicine in Swimming; 40 Years of Swimming Science.	4
--	---

Chapter 1. Invited Lectures

The Leon Lewillie Memorial Lecture: Biomechanics and Medicine in Swimming, Past, Present and Future - <i>Vilas-Boas, J.P.</i>	11
Applying a Developmental Perspective to Aquatics and Swimming - <i>Langendorfer, S.J.</i>	12
The Psycho-Physiology of Overtraining and Athlete Burnout in Swimming - <i>Lemyre, P.-N.</i>	20
Biomechanical Services and Research for Top Level Swimming: the Australian Institute of Sport Model - <i>Mason, B.R.</i>	22
Aquatic Training in Rehabilitation and Preventive Medicine - <i>Prins, J.</i>	25
Training at Real and Simulated Altitude in Swimming: Too High Expectations? - <i>Rodríguez, F.A.</i>	28
Muscle Fatigue in Swimming - <i>Rouard, A.H.</i>	30
Inter-Limb Coordination in Swimming - <i>Seifert, L.</i>	33

Chapter 2. Biomechanics

Comparison of Manikin Carry Performance by Lifeguards and Lifesavers When Using Barefoot, Flexible and Fiber Fins - <i>Abraldes, J.A., Soares, S.2, Lima, A.B., Fernandes, R.J. Vilas-Boas, J.P.</i>	41
Effect of Stroke Drills on Intra-cycle Hip Velocity in Front Crawl - <i>Arellano R., Domínguez-Castells R., Perez-Infantes E., Sánchez E.</i>	45
The Usefulness of the Fully Tethered Swimming for 50-m Breaststroke Performance Prediction - <i>Barbosa A.C. Milivoj Dopsaj M.2, Okic T. Andries Junior O.</i>	47
Joint Torque Request for Different Fin Uses - <i>Gouvernet, G., Rao, G., Barla, C. 1, Baly, L., Grélot, L., Berton, E.</i>	50
3D Computational Fluid-structure Interaction Model for the Estimation of Propulsive Forces of a Flexible Monofin - <i>Bideau, N., Razafimahery, F., Monier, L., Mahiou, B., Nicolas, G., Bideau, B., Rakotomanana, L.</i>	52
Do Fastskin Swimsuits Influence Coordination in Front Crawl Swimming and Glide? - <i>Chollet, D., Chavallard, F., Seifert, L., Lemaitre, F.</i>	55
The Effect of Wearing a Synthetic Rubber Suit on Hydrostatic Lift and Lung Volume - <i>Cortesi, M., Zamparo, P., Tam, E., Da Boit, M., Gatta, G.</i>	57
The Development of a Component Based Approach for Swim Start Analysis - <i>Cossor, J.M., Slawson, S.E. 2, Justham, L.M., Conway, P.P. 2, West, A.A.</i>	59
Hydrodynamic Characterization of the First and Second Glide Positions of the Underwater Stroke Technique in Breaststroke - <i>Costa, L.; Ribeiro, J.; Figueiredo, P.; Fernandes, R.J.; Marinbo, D.; Silva, A.J., 4; Rouboa, A., 4; Vilas-Boas, J.P.1; Machado, L.</i>	62

Biomechanical Characterization of the Backstroke Start in Immersed and Emerged Feet Conditions - <i>De Jesus, K., De Jesus, K., Figueiredo, P., Gonçalves, P., Pereira, S.M., Vilas-Boas, J.P. Fernandes, R.J.</i>	64
Tethered Force Production in Standard and Contra-standard Sculling in Synchronized Swimming - <i>Diogo, V., Soares, S., Tourino, C., Abraldes, J.A., Ferragut, C., Morouço, P., Figueiredo, P., Vilas-Boas, J.P., Fernandes, R.J.</i>	67
Pulling Force Characteristics of 10 s Maximal Tethered Eggbeater Kick in Elite Water Polo Players: A Pilot Study - <i>Dopsaj, M.</i>	69
Motor Coordination During the Underwater Undulatory Swimming Phase of the Start for High Level Swimmers - <i>Elipot, M., 2, Houel, N. 2, Hellard, P. 2, Dietrich, G.</i>	72
Relationship between Arm Coordination and Energy Cost in Front Crawl Swimming - <i>Fernandes, R.J., Morais, P., Keskinen, K.L., Seifert, L., Chollet, D., Vilas-Boas, J.P.</i>	74
Evaluation of the Validity of Radar for Measuring Throwing Velocities in Water Polo - <i>Ferragut, C., Alcaraz, P.E.1, Vila, H., Abraldes, J.A., Rodriguez, N.</i>	77
Biophysical Analysis of the 200m Front Crawl Swimming: a Case Study - <i>Figueiredo, P., Sousa, A.1; Gonçalves, P., Pereira, S.M., Soares, S., Vilas-Boas, J.P., Fernandes, R.J.</i>	79
Measuring Active Drag within the Different Phases of Front Crawl Swimming - <i>Formosa, D. P., Mason, B.R. & Burkett, B. J.</i>	82
The Mechanical Power Output in Water Polo Game: a Case Report - <i>Gatta, G., Fantozzi, S., Cortesi, M., Patti, F., Bonifazi, M.</i>	84
Comparison of Combinations of Vectors to define the Plane of the Hand in order to calculate the Attack Angle during the Sculling Motion - <i>Gomes, L.E.1, Melo, M.O.1, La Torre, M. 1, Loss, J.F.</i>	86
The Acute Effect of Front Crawl Sprint-resisted Swimming on the Direction of the Resultant Force of the Hand - <i>Gourgoulis, V., Aggeloussis, N., Mavridis, G., Boli, A., Toubekis, A.G., Kasimatis, P., Vezos, N., Mavrommatis, G.</i>	89
Relationship between Eggbeater Kick and Support Scull Skills, and Isokinetic Peak Torque - <i>Homma, M.</i>	91
A Biomechanical Comparison of Elite Swimmers Start Performance Using the Traditional Track Start and the New Kick Start - <i>Honda, K.E., Sinclair, P.J., Mason, B.R. & Pease, D.L.</i>	94
Kinematic Analysis of Undulatory Underwater Swimming during a Grab Start of National Level Swimmers - <i>Houel N., Elipot M., Andrée F., Hellard H.</i>	97
Comparison of Front Crawl Swimming Drag between Elite and Non-Elite Swimmers Using Pressure Measurement and Motion Analysis - <i>Ichikawa, H., Miwa, T., Takeda, T., Takagi, H., Tsubakimoto, S.</i>	100
Whole Body Observation and Visualized Motion Analysis of Swimming - <i>Ito, S., Okuno, K.</i>	102
A Full Body Computational Fluid Dynamic Analysis of the Freestyle Stroke of a Previous Sprint Freestyle World Record Holder - <i>Keys, M.1; Lyttle, A.2; Blanksby, B.A.1 & Cheng, L.</i>	105
An Analysis of an Underwater Turn for Butterfly and Breaststroke - <i>Kishimoto, T., Takeda, T., Sugimoto, S., Tsubakimoto, S.2 and Takagi, H.</i>	108
Mechanical and Propulsive Efficiency of Swimmers in Different Zones of Energy Supply - <i>Kolmogorov, S.V., Vorontsov, A.R., Rummyantseva, O.A., Kochergin, A.B.</i>	110

Prediction of Propulsive Force Exerted by the Hand in Swimming - <i>Kudo, S. and Lee, M.K.</i>	112	Identifying Determinant Movement Sequences in Monofin Swimming Technique - <i>Rejman, M. & Staszkievicz, A.</i>	160
Arm Coordination, Active Drag and Propelling Efficiency in Front Crawl - <i>Seifert, L., Schnitzler, C., Alberty, M., Chollet, D. 1, Toussaint, H.M.</i>	115	Evaluation of the Gliding Capacity of a Swimmer - <i>Roig, A.</i>	163
Modelling Arm Coordination in Front Crawl - <i>Seifert, L., Chollet, D.</i>	117	Effects of a Blueseventy™ Bodysuit on Spatial-temporal and Coordinative Parameters During an All-out 50-m Front Crawl - <i>Silveira, R.P., Kanefuku, J.Y., Moré, F.C., Castro, F.A.S.</i>	165
Different Frequential Acceleration Spectrums in Front Crawl - <i>Madeira, J., González, L.M., Garcia Massó, X., Benavent, J., Colado, J.C., Tella, V.</i>	119	Fatigue Analysis of 100 Meters All-Out Front Crawl Using Surface EMG - <i>Stirn, I. Jarm, T., Kapus, V., Strojnik, V.</i>	168
The Gliding Phase in Swimming: The Effect of Water Depth - <i>Marinho, D.A., Barbosa, T.M., Mantripragada, N., Vilas-Boas, J.P., Rouard, A.H., Mantha, V.R., Roubao, A.I., Silva, A.J.</i>	122	Comparison Among Three Types of Relay Starts in Competitive Swimming - <i>Takeda, T., Takagi, H., Tsubakimoto, S.</i>	170
A Method to Estimate Active Drag over a Range of Swimming Velocities which may be used to Evaluate the Stroke Mechanics of the Swimmer - <i>Mason, B.R., Formosa, D.P., Toussaint, H.M.</i>	124	A Study About the 3D Acceleration in Front Crawl and its Relation With Performance - <i>Tella, V., Madeira, J., Colado, J.C., Mateu, J., Garcia Massó, X., González, L.M.</i>	173
50m Race Components Times Analysis Based on a Regression Analysis Model Applied to Age-Group Swimmers - <i>Morales, E., Arellano, R., Femia, P., Mercade, J., Haljand R.</i>	127	Aquatic Space Activities – Practice Needs Theory - <i>Ungerechts, B., Klauck, J².</i>	175
Regression Analysis Model Applied to Age-Group Swimmers: Study of Stroke Rate, Stroke Length and Stroke Index - <i>Morales, E., Arellano, R., Femia, P., Mercade, J.</i>	130	Analysis of Swim Turning, Underwater Gliding and Stroke Resumption Phases in Top Division Swimmers using a Wearable Inertial Sensor Device - <i>Vannozi, G., Donati, M., Gatta G. & Cappozzo, A.</i>	178
Advanced Biomechanical Simulations in Swimming Enabled by Extensions of Swimming Human Simulation Model “SWUM” - <i>Nakashima, M., Kiuchi, H., Maeda, S., Kamiya, S., Nakajima, K., Takagi, H.</i>	132	Influence of Swimming Start Styles on Biomechanics and Angular Momentum - <i>Vantorre, J., Seifert, L., Bideau, B., Nicolas, G., Fernandes, R.J., Vilas-Boas, J.P., Chollet, D.</i>	180
Influences of the Back Plate on Competitive Swimming Starting Motion in Particular Projection Skill; Kinematical Characterisation of a Basic Head-out Aquatic Exercise during an Incremental Protocol - <i>Oliveira, C., Teixeira, G., Costa, M.J., Marinho, D.A., Silva, A.J., Barbosa, T.M.,</i>	137	The Validity and Reliability of a Procedure for Competition Analysis in Swimming Based on Individual Distance Measurements - <i>Veiga, S., Cala, A., González Frutos, P., Navarro, E.</i>	182
Influence of Swimming Speed on the Affected- and Unaffected-Arm Stroke Phases of Competitive Unilateral Arm Amputee Front Crawl Swimmers - <i>Osborough, C.D., Payton, C.J., Daly, D.J.</i>	140	An Analysis of the Underwater Gliding Motion in Collegiate Competitive Swimmers - <i>Wada, T., Sato, T., Ohishi, K., Tago, T., Izumi, T., Matsumoto, T., Yamamoto, N., Isaka, T., Shimoyama, Y.</i>	185
Co-ordination Changes during a Maximal Effort 100 m Short Course Breaststroke Swim - <i>Oxford, S., James, R., Price, M., Payton, C.</i>	142	Head Out Swimming in Water Polo: a Comparison with Front Crawl in Young Female Players - <i>Zamparo, P., Falco, S.</i>	187
The Effect of Angle of Attack and Depth on Passive Drag - <i>Pease, D.L. 1, Vennell, R.</i>	145	Chapter 3. Physiology and Bioenergetics	191
Graphic Removal of Water Wave Impact in the Pool Wall during the Flip Turn - <i>Pereira, S.M., Gonçalves, P., Fernandes, R.J., Machado, L., Roesler, H., Vilas-Boas, J.P.</i>	148	Models of Vertical Swimming Abilities in Elite Female Senior Water Polo Players - <i>Dopsaj, M.</i>	192
Extending the Critical Force Model to Approach Critical Power in Tethered Swimming, and its Relationship to the Indices at Maximal Lactate Steady-State - <i>Pessôa Filho, D.M., Denadai, B.S.</i>	151	Critical Velocity and the Velocity at Maximal Lactate Steady State in Swimming - <i>Espada, M.A., Alves, F.B.</i>	194
Preliminary Results of a “Multi-2D” Kinematic Analysis of “Straight- vs. Bent-arm” Freestyle Swimming, Using High-Speed Videography. - <i>Prins, J.H., Murata, N.M., & Allen, J. S. III.</i>	154	Modelling the VO ₂ Slow Component in Elite Long Distance Swimmers at the Velocity Associated with Lactate Threshold - <i>Hellard, P., Dekerle, J., Nesi, X., Toussaint, J.F., Houel, N., Hausswirth, C.</i>	196
Biomechanical Factors Influencing Tumble Turn Performance of Elite Female Swimmers - <i>Puel, F., Morlier, J., Cid, M., Chollet, D., Hellard, P.</i>	155	The Impact of Tension in Abdominal and Lumbar Musculature in Swimmers on Ventilatory and Cardiovascular Functions - <i>Henrich, T.W., Pankey, R.B. Soukup, G.J.</i>	199
Front Crawl and Backstroke Arm Coordination in Swimmers with Down Syndrome - <i>Querido, A., Marques-Aleixo, I., Figueiredo, P., Seifert, L., Chollet, D., Vilas-Boas, J.P., Daly, D.J., Corredeira, R., Fernandes, R.J.</i>	157	Relationship between Propelling Efficiency and Swimming Performance in Elite Swimmers. - <i>Huang, Z., Kurobe, K., Nishiwaki, M., Ozawa, G., Tanaka, T., Taguchi, N., Ogita, F.</i>	201
		Effect of Increasing Energy Cost on Arm Coordination at Different Exercise Intensities in Elite Sprint Swimmers - <i>Komar, J.I, Leprêtre, P.M.2, Alberty, M.3, Vantorre, J.1, Fernandes, R.J.4, Hellard, P.6, Chollet, D.1, Seifert, L.</i>	204
		Swimming and Respiratory Muscle Endurance Training: A Case Study - <i>Lemaitre, F., Chavallard, F., Chollet, D.</i>	206

- Heart Rate Responses During Gradually Increasing and Decreasing Exercise in Water - *Nishimura, K., Nose, Y., Yoshioka, A., Kawano, H., Onodera, S., Takamoto, N.* 208
- Effects of Recently Developed Swimwear on Drag During Front Crawl Swimming; - *Ogita, F., Huang, Z., Kurobe, K., Ozawa, 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., Nose, Y. 1, Hirao, M., Seki, K., Nishimura, K., Baik, W., Hara, H., Murakawa, T.* 213
- Oxygen Uptake Kinetics Around the Respiratory Compensation Point in Swimming - *Pessôa Filho, D.M., Reis, J.F., Alves, F.B., Denadai, B.S.* 215
- 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., Tsubakimoto, 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., Bednarik, 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 - *Vescovi, J.D., Falenchuk, 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 - *Zoretić, 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 - *Beidaris, N., Botonis, P. and Platanou, T.* 242
- General Indexes of Crawl Swimming Velocity of Junior Water Polo Players in a Match - *Bratusa, F.Z., Perisic, 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 - *Douda, H.T., Toubekis, A.G., Georgiou, Ch., Gourgoulis, V. and Tokmakidis, S.P.* 252
- Changes of Competitive Performance, Training Load and Tethered Force During Tapering in Young Swimmers - *Drosou, E., Toubekis, A.G., Gourgoulis, V., Thomaidis, S., Douda, H., Tokmakidis, S.P.* 254
- Perceived Exertion at Different Percents of The Critical Velocity in Front Crawl - *Franken, M., Diefenthaler, F., de Souza Castro, F.A.* 257
- Ventilatory and Biomechanical Responses in Short vs. Long Interval Training in Elite Long Distance Swimmers. - *Hellard, P., Deckerle, J., Nesi, X., Toussaint, J.F., Houel, N.1, Hauswirth, C.* 259
- Talent Prognosis in Young Swimmers - *Hohmann, A.1, Seidel, I.* 262
- Determination of Lactate Threshold with Four Different Analysis Techniques for Pool Testing in Swimmers; Competitive Systematization 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., Yoshimura, Y., Kawamoto, K., Takise, S., Kawakami, T.* 270
- Stability and Prediction of 100-m Breaststroke Performance During The Careers of Elite Swimmers - *Costa, M.J.; Marinho, D.A., Reis, V.M., Silva, A.J., Bragada, J.A., Barbosa, T.M., 4* 272
- Effect of Subjective Effort on Stroke Timing in Breaststroke Swimming - *Ohba, M., Sato, S., Shimoyama, Y., Sato, D.* 274
- Models for Assessing General Horizontal Swimming Abilities of Junior Water Polo Players According to Playing Position - *Özkol, Z., Dopsaj, M., Thanopoulos, V., Bratusa, Z.* 276
- A Markov Chain Model of Elite Water Polo Competition - *Pfeiffer, M., Hohmann, 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.1 & 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., Okita, K., Baba, Y., Sato, D.* 288
- Evaluation of Force Production and Fatigue using an Anaerobic Test Performed by Differently Matured Swimmers - *Soares, S., Silva, R., Aleixo, I., Machado, L., Fernandes, R.J., Maia, J., Vilas-Boas, J.P.* 291
- Identification of a Bias in the Natural Progression of Swim Performance - *Stager, J.M., Brammer, C.L., Tanner, D.A.* 294
- Tethered Swimming as an Evaluation Tool of Single Arm-Stroke Force - *Toubekis, A.G., Gourgoulis, V., Tokmakidis, S.P.* 296
- Blood Lactate Responses During Interval Training Corresponding to Critical Velocity in Age-Group Female Swimmers - *Tsalis, G., Toubekis, A.G., Michailidou, D., Gourgoulis, V., Douda, H., Tokmakidis, S.P.* 299

Monitoring Swim Training Based on Mean Intensity Strain and Individual Stress Reaction of an Elite Swimmer - <i>Ungerechts, B.E., Steffen, R., and Vogel, K.</i>	302	Chapter 6. Medicine and Water Safety	353
Accelerometry as a Means of Quantifying Training Distance and Speed in Competitive Swimmers. - <i>Wright, B.V., Hinman, M.G., Stager, J.M.</i>	305	Crucial Findings from the 4W Model of Drowning for Practical and Teaching Applications - <i>Avramidis, S., McKenna, J., Long, J., Butler, R., Llewellyn, J.D.</i>	354
Critical Swimming Speed Obtained by the 200-400 Meters Model in Young Swimmers - <i>Zacca, R., Castro, F.A.S.</i>	307	Swimming, Cycling, Running and Cardiovascular Health - <i>Bagheri, A.B., Mobebebi, H.D., Azizi, M.H., Saiiari, A.R.</i>	357
Chapter 5. Education, Advice and Biofeedback	311	Analysis of Aerobic/Anaerobic Performance in Functionally Disabled Swimmers: Low Classes vs High Classes - <i>De Aymerich, J., Benavent, J., Tella, V., Colado, J.C., González, L.M., García-Massó, X. 2., Madera, J.</i>	359
The Evolution of Swimming Science Research: Content analysis of the "Biomechanics and Medicine in Swimming" Proceedings Books from 1971 to 2006 - <i>Barbosa, T.M., Pinto, E., Cruz, A.M., Marinbo, D.A., Silva, A.J., Reis, V.M., Costa, M.J., Queirós, T.M.</i>	312	Athletic Rehabilitation of a Platform Diver for Return to Competition after a Shoulder Dislocation - <i>Fujinawa, O., Kondo, Y., Tachikawa, K., Jigami, H., Hirose, K., Matsunaga, H.</i>	362
Quantitative Data Supplements Qualitative Evaluations of Butterfly Swimming - <i>Becker, T.J., Havriluk, R.</i>	314	Comparisons of Water- and Land-based Physical Activity Interventions in Japanese Subjects with Metabolic Syndrome - <i>Hanaei, A. and Yamatsu, K.</i>	364
The Effect of Restricting the Visual Perceptual Task in the Temporal Organization of Crawl Swimming: Surface Characteristics - <i>Brito, C.A.F., Belvis, W.C., Oliveira, M. 2</i>	317	Estimation Method for Energy Expenditure by Acceleration of Human Head during Water Walking - <i>Kaneda, K., Ohgi, Y., Tanaka, C.</i>	366
Analyses of Instruction for Breath Control While Swimming the Breaststroke - <i>Hara, H., Yoshioka, A., Matsumoto, N., Nose, Y., Watanabe, R., Shibata, Y., Onodera, S.</i>	319	Real and Perceived Swimming Competency, Risk Estimation, and Preventing Drowning among New Zealand Youth - <i>Moran, K.</i>	368
Performance Level Differences in Swimming: Relative Contributions of Strength and Technique - <i>Havriluk, R.</i>	321	Keeping the Safety Messages Simple: The International Task Force on Open-Water Recreational Drowning Prevention - <i>Quan, L., Bennett, E., Moran, K. (co-chairs)</i>	371
Evaluation of Kinaesthetic Differentiation Abilities in Male and Female Swimmers - <i>Invernizzi, P.L., Longo, S., Scurati, R., Michielon, G.</i>	324	Immune Status Changes and URTI Incidence in the Initial 7 Weeks of a Winter Training Season in Portuguese Swimmers - <i>Rama, L., Alves, F.B., Rosado, F., Azevedo, S., Matos, A., Henriques, A., Paiva, A. 3, Teixeira, A.M.</i>	374
Swimming in Eyesight Deprivation: Relationships with Sensory-Perception, Coordination and laterality - <i>Invernizzi, P.L., Longo, S., Tadini, F., Scurati, R.</i>	326	Swimming Ability, Perceived Competence and Perceived Risk among Young Adults - <i>Stallman, R.K., Dahl D.I., Moran, K., Kjendlie, P.L.</i>	377
Progression in Teaching Beginning Swimming: Rank Order by Degree of Difficulty - <i>Junge, M., Blixt, T., Stallman, R.K.,</i>	329	Movement Economy in Breaststroke Swimming: A Survival Perspective - <i>Stallman R.K., Major J., Hemmer S., Haavaag G.</i>	379
The Construct Validity of a Traditional 25m Test of Swimming Competence - <i>Junge, M., Blixt, T., Stallman, R.K.,</i>	331	Post-exercise Hypotension and Blood Lipoprotein Changes following Swimming Exercise - <i>Tanaka, H., Sommerlad, S.M., Renzi, C.P., Barnes, J.N., and Nualnim, N.</i>	381
Using a Scalogram to Identify an Appropriate Instructional Order for Swimming Items - <i>Langendorfer, S.J., Chaya, J.A.</i>	333	A Conceptual Paper on the Benefits of a Non-Governmental Search and Rescue Organization - <i>Wengelin, M., de Wet, T.</i>	384
Imagery Training in Young Swimmers: Effects on the Flow State and on Performance - <i>Scurati, R., Michielon, G., Longo, S., Invernizzi, P.L.</i>	336	Author Index	0
Shallow or Deep Water for Adjustment? A Study in Children Aged 3 to 6 Years - <i>Scurati, R., Michielon, G., Longo, S., Invernizzi, P.L.</i>	339		
The Effect of a Target Sound Made by a Model Swimmer's Dolphin Kick Movement on Another Swimmer's Dolphin Kick Performance - <i>Shimojo, H., Ichikawa, H., Tsubakimoto, S., Takagi, H.</i>	341		
Tendencies in Natural Selection of High Level Young Swimmers - <i>Timakova T.S., Klyuchnikova M.V.</i>	343		
The Cognitive Interplay Between Sensory and Biomechanical Features While Executing Flip Turns Wearing Different Swim Suits - <i>Vieluf, S., Ungerechts, B.E., Toussaint, H.M., Lex, H. 1, Schack, T.</i>	346		
The Role of Verbal Information about Sensory Experience from Movement Apparatus in the Process of Swimming Economization - <i>Zatoñ, K.</i>	349		

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.^{3,4}, Reis, V.M.^{3,4}, 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; (ii) Sociology; (iii) Pedagogy/Teaching; (iv) Biochemistry; (v) Physiology; (vi) Thermoregulation; (vii) Hydrodynamics; (viii) Electromyography; (ix) Anthropometry; (x) Equipment/Methodology; (xi) Clinical Medicine/Traumatology and; (xii) 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.

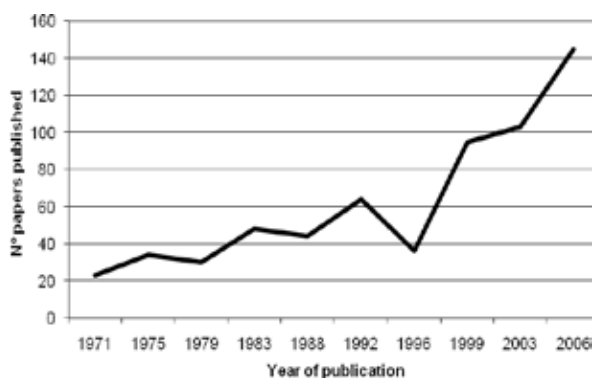


Figure 1. Evolution in the number of papers published between 1971 and 2006.

Figure 2 presents the partial contribution of each sub-category, for both main categories, in the period of time from 1971 to 2006 considering overall data. For the “scientific area”, main interest was in “Biomechanics” (37.8 %), “Physiology” (17.20 %) and “Interdisciplinary assessment” (8.52 %). Related to the “aquatic activity”, the sport with the greatest number of papers, by far, was “Competitive swimming” (87.46 %), followed by “Water polo” (3.22 %) and “Head-out aquatic activities” (2.57 %).

Figure 3 presents the evolution in the relative frequency of each sub-category 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”.

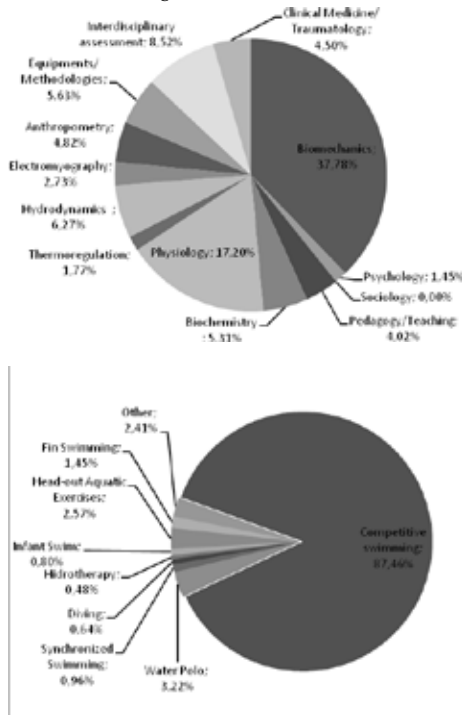


Figure 2. Partial contribution of each sub-category for “swimming science” in the period of time from 1971 to 2006.

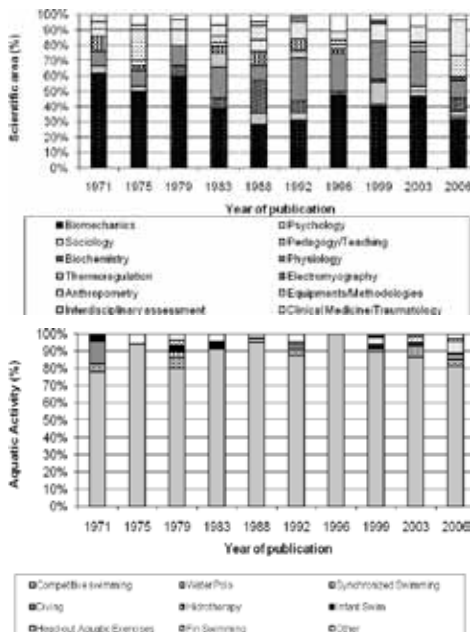


Figure 3. Evolution of sub-categories in each proceeding book edition between 1971 and 2006.

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 VIIth Symposium in 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 preceding 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

Clarys, J.P. (1996). The historical perspective of swimming science. Foreword to the Biomechanics and Medicine in Swimming VII. In: Troup J.P., Hollander A.P., Strasse D., Trappe S.W., Cappaert J.M., Trappe T.A. (eds), *Biomechanics and Medicine in Swimming VII* (pp xi-xxxiv). London: E & FN Spon.

ACKNOWLEDGMENTS

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