What can we learn from Swimming Science?

Analysis of papers presented at the XI International Symposium on Biomechanics and Medicine in Swimming – Oslo June 16 – 19, 2010

Kari L. Keskinen

To be discussed …

World Commission of Science and Sport

International Symposium Biomechanics and Medicine in Swimming

Achievements of Oslo 2010

Invitation to Altitude

World Commission of Science and Sport (www.wcss.org.uk)

- Science into Sport – Sport into Science
  - WCSS is a working group of the International Council of Sports Science and Physical Education (ICSSPE).
  - WCSS is a non-profit making organization aiming to promote application of science to sport
  - President Erich Müller, Salzburg, Austria
  - Secretary General Mark Williams, Liverpool, UK
- Steering groups organize Scientific Congresses e.g. in
  - Swimming, Ski'ing, Soccer, Cycling, Racket Sports …
- SG on Biomechanics and Medicine in Swimming
  - Chair Kari L. Keskinen (FIN); Jan P. Clarys (BEL); Bodo E. Ungerechts (GER); João Paulo Vilas-Boas (POR)

International Symposium Biomechanics and Medicine in Swimming (BMS)

- 1970 Brussels, Belgium
- 1974 Brussels, Belgium
- 1978 Edmonton, Canada
- 1982 Amsterdam, Holland
- 1986 Bielefeld, Germany
- 1990 Liverpool, UK
- 1994 Atlanta, Georgia, US
- 1998 Jyväskylä, Finland
- 2002 St. Étienne, France
- 2006 Porto, Portugal
- 2010 Oslo, Norway
  - www.nih.no/BMS2010
    - Abstracts / open access
    - Full Articles / with password
  - www.coachesinfo.com
    - Videos of the key-notes
- 2014 Canberra, Australia
  - Australian Institute of Sport (AIS)
- 2018 BMS
  - Bids are open until January 2018
    - Contacts: kari.keskinen@lts.fi

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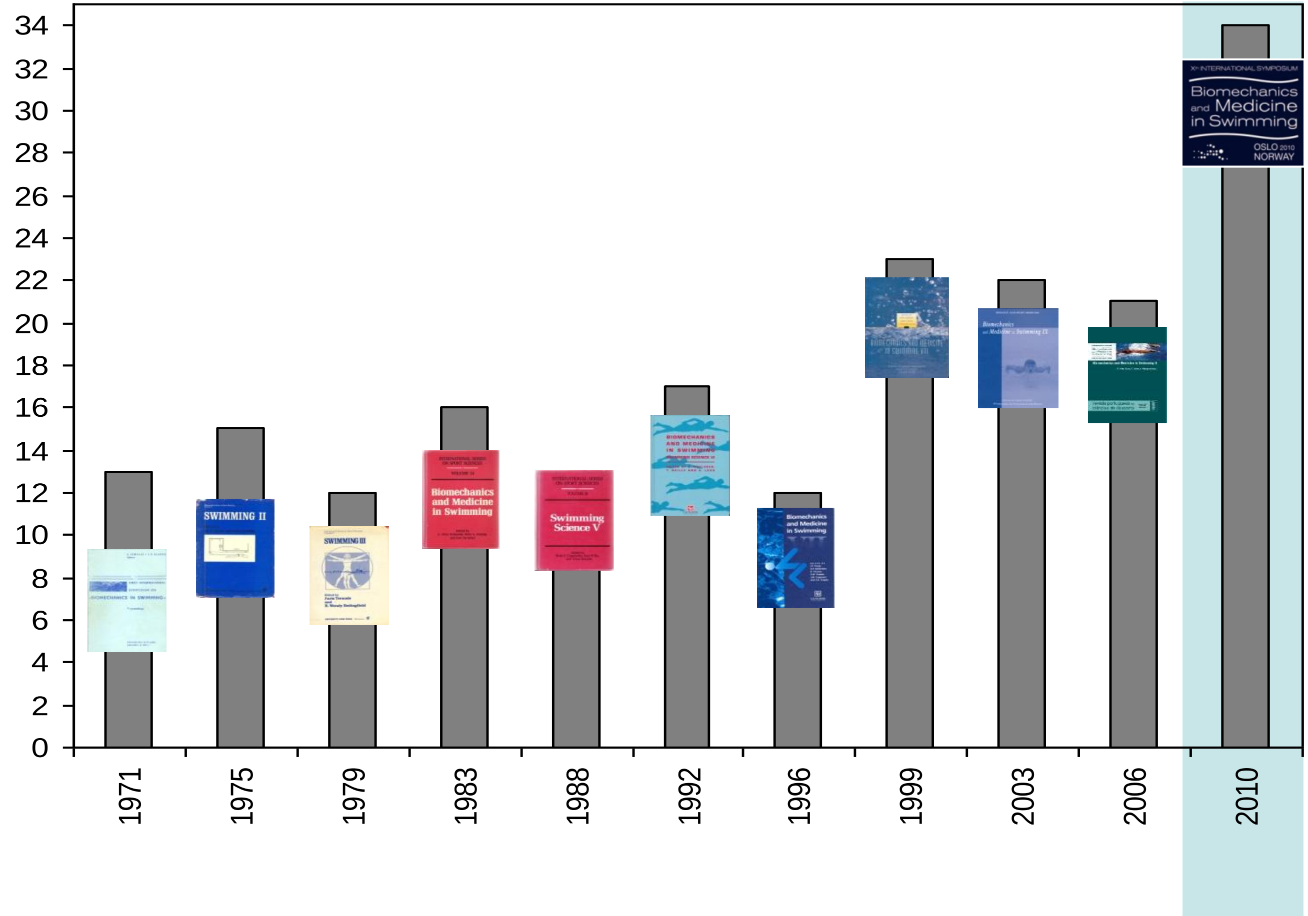
Participation: 1970 - 2010

Number of participating countries, considering the affiliation of the first author



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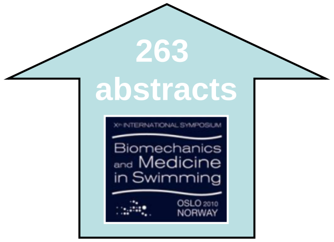
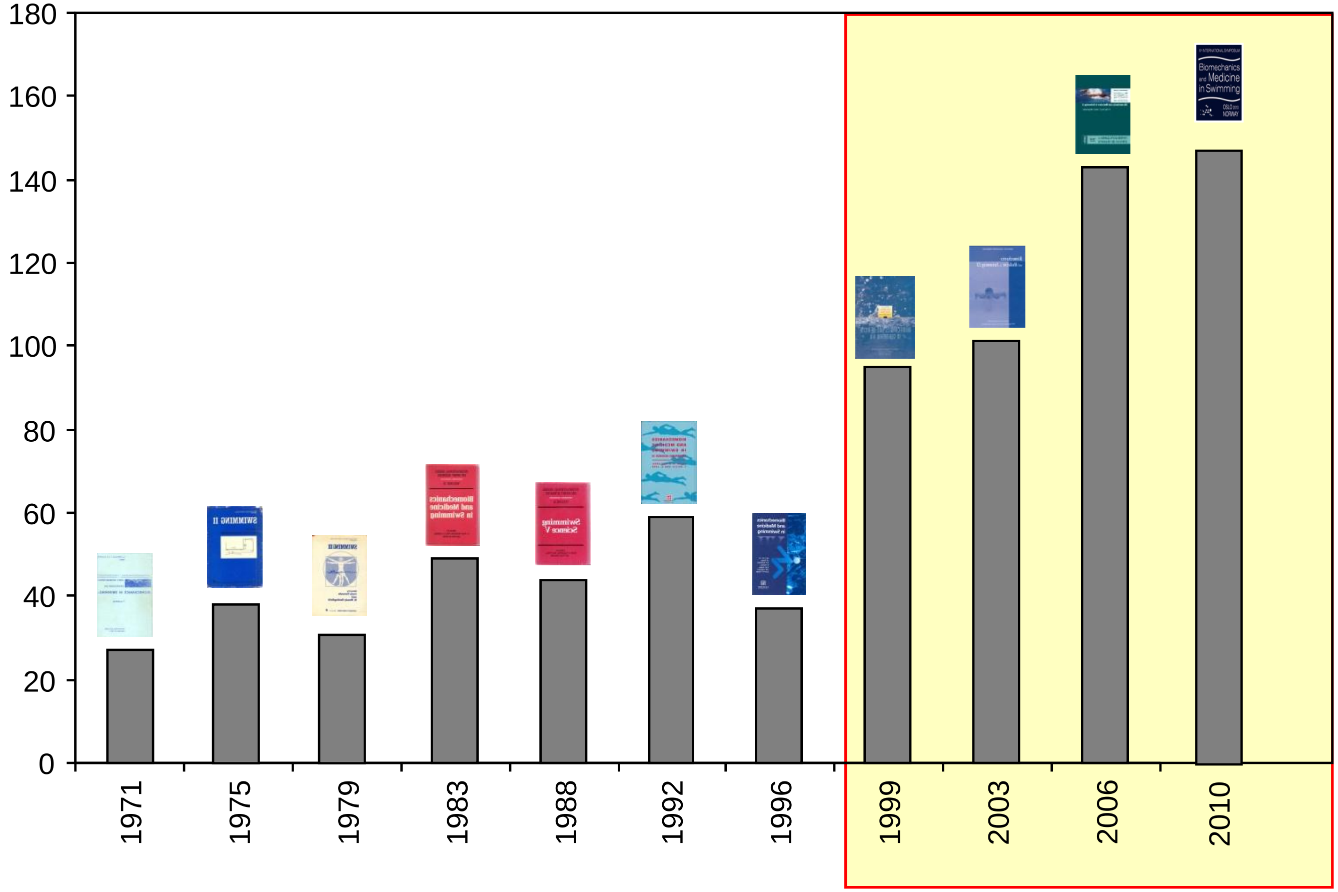
769 Published Papers: 1970 – 2010

The body of knowledge through BMS Conferences





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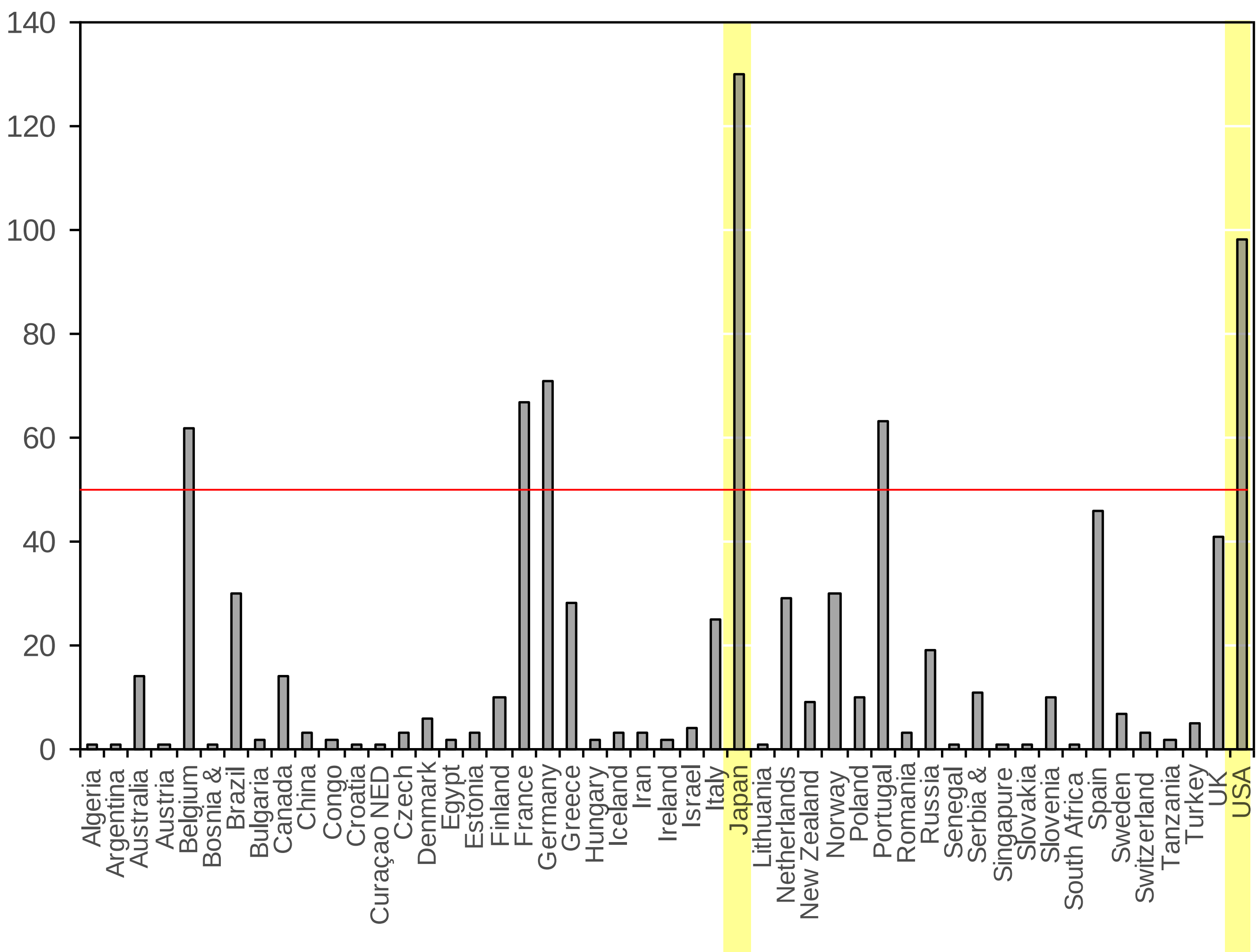
Participation Activity:

Number of contributions per country, considering the affiliation of the first author



49 Countries

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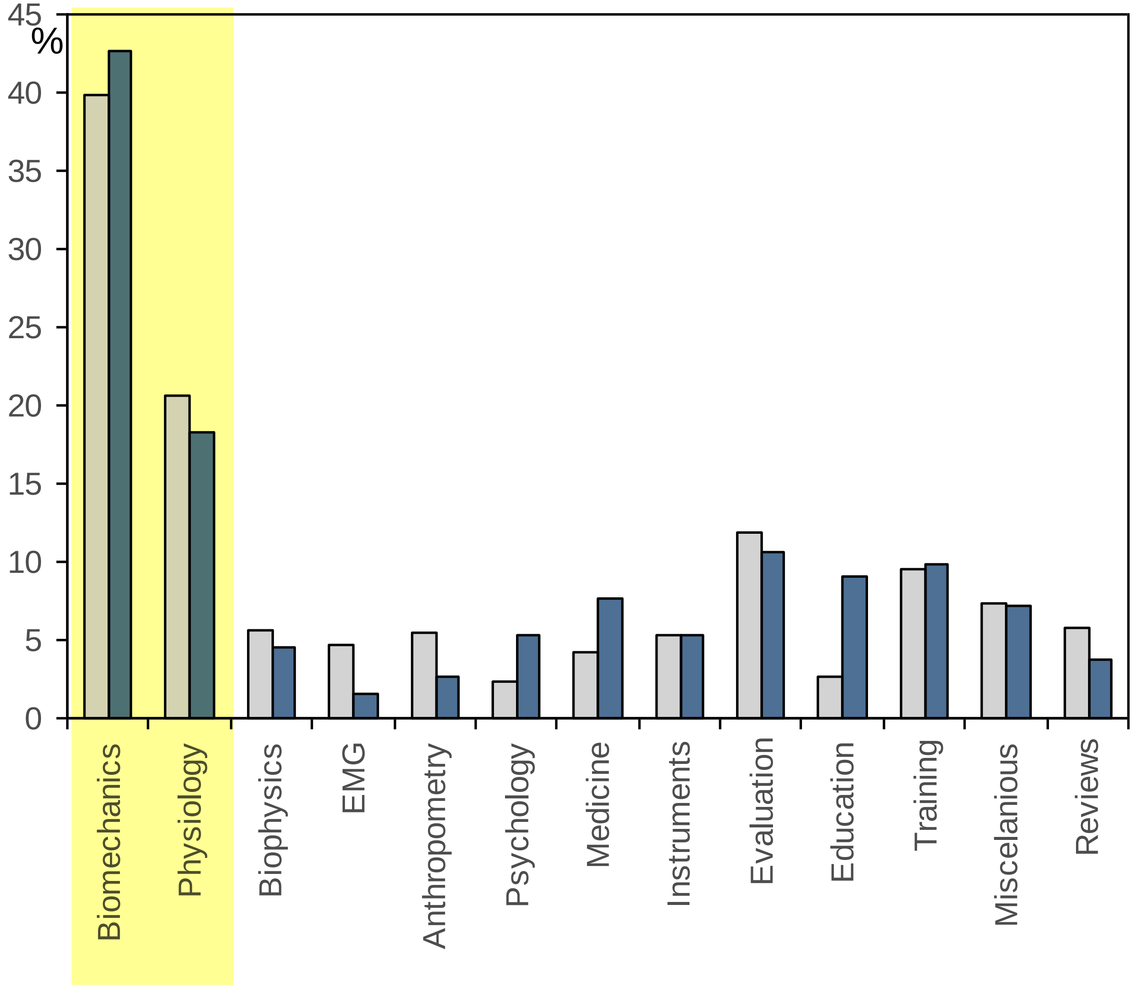
Xth INTERNATIONAL SYMPOSIUM Biomechanics and Medicine in Swimming OSLO 2010 NORWAY

Results:

Number of papers per scientific domain – *Comparison to BMS XI*



Total abstracts: 263
Total entries: 338
Multiple: 28.5%

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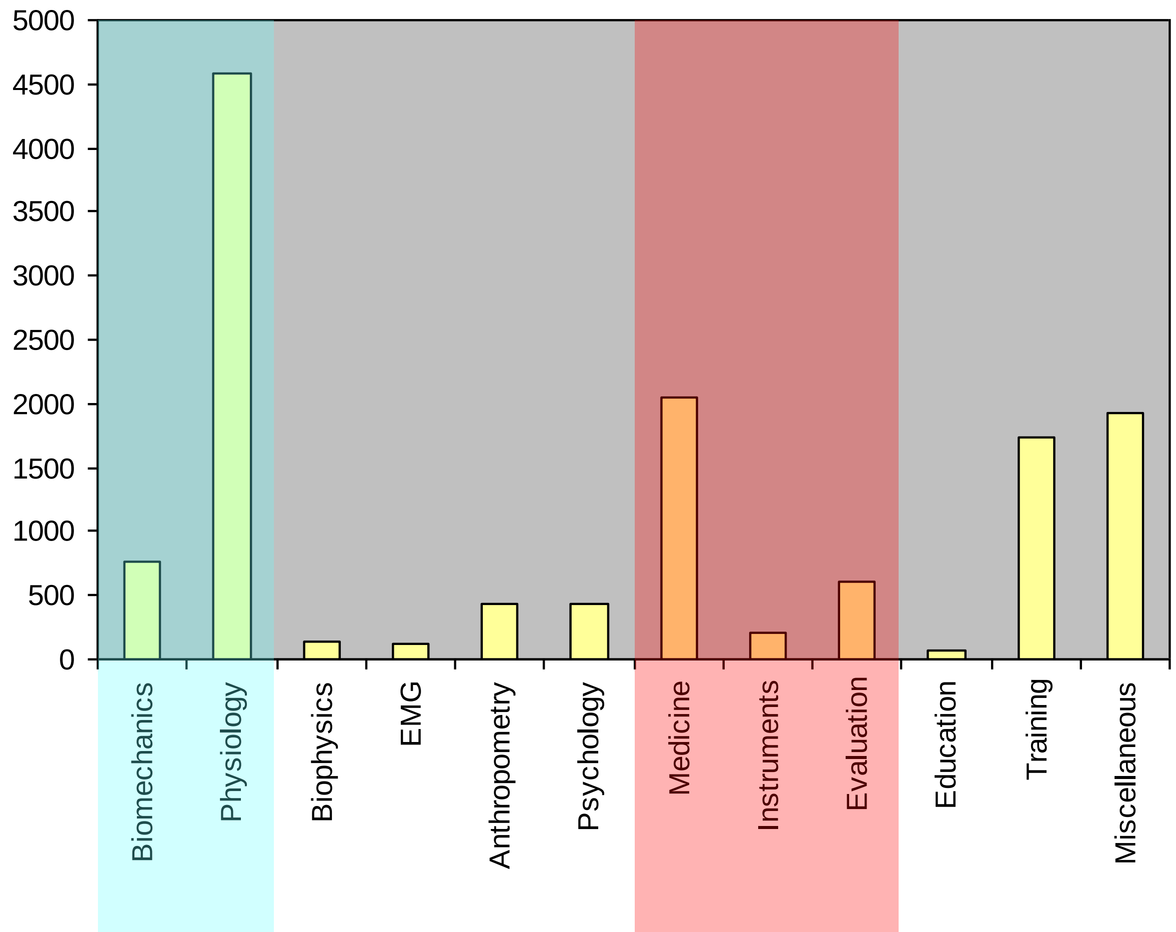
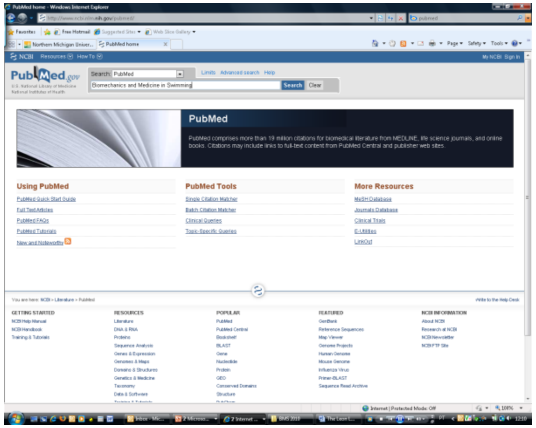
Results:

Number of papers per scientific domain in the ***PubMed***^{TM} search





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Preliminary conclusions:

BMS series is a worldwide spread and growing movement of scientists.

BMS series seem to cover a large spectrum of specific aquatics knowledge over the years, with a increased trend for interdisciplinary studies.

Despite a tendency for a change, BMS series still underlines the relevance of *Biomechanics* compared to other swimming science domains, which importance should be reinforced in the future…

…apparently, the theoretical knowledge is coming closer to practice but not yet fully achieved, in Oslo 2010 …

To stimulate general progress, it is important to emphasize both theoretical and practical relevance of that knowledge, and to enlarge its frontiers

Achievements of Oslo 2010 Focus on Teaching Techniques

Teaching and Learning Skills
Learning Straight Leg kick in Butterfly
Balances / Biomechanics and Bioenergetics
Balances / Strength and Technique

Applying a Developmental Perspective to Aquatics and Swimming. *Langendorfer SJ (USA)* *see video www.coachesinfo.com*

- Employing developmental aquatic assessment skills requires practitioners to reject the error correction model with the assumption that there is only one correct way to perform a skill and appreciate that all swimming skills change in regular, ordered sequences.

- Several developmental aquatic assessment instruments have been published using aquatic developmental sequences to identify where along a developmental continuum a swimmer's skill or stroke falls.

Langendorfer …

- Individualized instruction is needed instead of traditional teacher-centered techniques to focuse on the needs of each learner
- Learner-centered teaching allows each member to take responsibility for her or his own learning while the instructor serves as a facilitator helping each swimmer to move from where he/she is to being more advanced.
- Generally this means that a practitioner needs to employ more indirect teaching techniques such as exploration, guided discovery, or task setting
- Muska Mosston: www.spectrumofteachingstyles.org

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 (Japan)

- Bending knees in butterfly kick increase undulation (wave butterfly). Coaches teach bending the knees with the purpose of pushing the water backwards.
- Since 2006, Kawamoto was coached to change his butterfly technique towards employing a straight kick. The target was to keep the knee angle > 170 degrees to obtain horizontal stroke.
- Kawamoto's initial butterfly kick technique used a bending butterfly kick. We changed this to a straighter kick with less knee-bend by imagining to hold the water in the pool bottom

Effects of Reduced Knee-bend …

- Kohei Kawamoto, 30 years old Asian and Japanese record holder of the men's 100 meter butterfly (height; 174 cm, body weight; 64kg) volunteered to participate in this study
-
- A comparison was made of Kawamoto's performance in 2009 to his previous performance in 2005
  - 4 times 25 meter butterfly swims were filmed
  - DartTrainer was used to analyze knee angle upper body
  - A Swimming Speed Meter was used to register peak velocity

- Kawamoto's initial butterfly kick technique used a bending butterfly kick. We changed this to a straighter kick with less knee-bend (Yoshimura, 2008), which is imagined as holding the water to the bottom of the pool

Effects of Reduced Knee-bend …

- In the first step, we imagined the straighter kick on land.
  - The straight leg kick was obtained by stretching the tendon of the tibialis anterior muscle rather than using the quadriceps muscles (Huijing, 1992). When Kawamoto used this stretched tendon in a similar way in the butterfly straight leg kick, the kick frequency was much more rapid (Hosokawa, 2009).
- The second step was to utilize the straight leg kick in the pool
  - This involved slow speed drills during training. The drills involved swimming no more than 3500m. If he swam more than 3500m he had a tendency to bend the knees and move the upper body too much. Also, these sessions were performed just once a day.
- The third step was to test the technique in a minor meet.
  - After the race, we checked these techniques by the video camera. Then we would check these techniques from the minor meet and insure they are correct in preparation for the next step.
- The fourth step was the major meet
  - Olympic Trials, World Championship Trials, Japan Nationals, World Championship, East Asian Games or Japan Open. His training partner won and set a meet record at the 2009 US Junior Nationals men 100Fly.

Effects of Reduced Knee-bend …

- **CONCLUSIONS**
- This study analyzed the butterfly stroke technique of Japan's 100 meter butterfly record holder
-
- Kawamoto improved his performances, due to three possible reasons:
  - 1. increased maximum speed, 2.5m · s^{-1} to 2.7 m · s^{-1}
  - 2. increased distance per stroke, 1.89 m to 2.20 m
  - 3. Use of the straight knee dolphin kick
- Changing technique will not happen in a minute
  - – it took > 2 years to see changes happen
  - – new level of performance was obtained after delay

Biomechanics and Bioenergetics of 100-m Front Crawl Swimming in Young Male Swimmers. ***Lätt E, Jürimäe J, Mäestu J, Purge P, Rämson R, Haljaste K, Keskinen KL, Rodríguez FA, Jürimäe T (Estonia)***

- Studies are needed to investigate influence of somatic, energetic and technical parameters together to determine sprint swimming performance in boys after reaching puberty
- The aim was to analyze relationships between swimming performance, anthropometrical, physiological and biomechanical parameters in male adolescent swimmers
- The authors hypothesized that sprint swimming performance in adolescent boys could be predicted from a relatively low number of selected variables pertaining to these testing domains

Biomechanics and Bioenergetics …

- 25 male swimmers (15.2±1.9 years; 176.1±9.2 cm; 63.3±10.9 kg) performed 100m maximal front crawl swim in the 25m pool
- Oxygen consumption was measured on-line using breath by breath technology. Consequently energy cost (Cs) was calculated
- Swimming speed (V), stroke rate (SR), stroke length (SL) and stroke index (SI) were assessed
- Blood samples for lactate analysis were collected (3 / 5 min)
- Anthropometry used full scale ISEK model and body composition were taken by DXA using the DPX-IQ densitometry

Biomechanics and Bioenergetics …

- Time in 100 m was 77.6±9.1 and significantly related to somatic parameters such as height, body mass and arm span
- T100 was significantly related to biomechanical variable SL, SR and SI
- T100 was significantly related to bioenergetics such as VO^2, ΔLa and Cs measured and.
- Biomechanical factors (79%) characterized best the 100m swimming performance in these young swimmers, followed by somatic (49%) and bioenergetic factors (32%).
- Thus learning correct swimming technique from the early years of swimming training is elementary for further progress in competitive swimming.
- Cs is a key parameter to evaluate performance in swimming, but studies are few investigating determinants of swimming economy in children

Performance Level Differences in Swimming: Relative Contributions of Strength and Technique.
Havriluk R (USA)

- The purpose of this study was to compare the relative contributions of strength (measured by force, F) and technique (measured by the active drag coefficient, Cd) to swimming performance so that coaches can implement the most appropriate interventions for continued improvement.

- Swimmers from 21 teams participated in the study
- Male (n = 40) and female (n = 40) swimmers were tested with Aquanex + Video, swimming four trials (one of each stroke) over a 20 m course with the standard Aquanex testing protocol.

Performance Level Differences …

- Informed consent was obtained. Descriptive statistics for the male swimmers include: age in yrs (M = 18.0, SD = 1.3), height in cm (M = 180, SD = 7.7), mass in kg (M = 74.2, SD = 8.5) and for the females: age in yrs (M = 17.7, SD = 1.0), height in cm (M = 168, SD = 6.0), mass in kg (M = 62.1, SD = 6.5).

- Underwater video, hand force data, and swim time were collected over the last 10 m of each trial.

- The Cd was calculated as: $Cd = F/(0.5\rho X v^2)$, where F is the average normal hand force, p is the mass density of water, X is the cross-sectional area of the body, and v is swimming velocity.

- Previous research found an almost perfect correlation between normal and propulsive force ($r = .98$) with a minor over estimation (6 N) of propulsive force (Havriluk, 2006b).

Performance Level Differences …

- The magnitude of the difference between faster and slower swimmers in both F and Cd was calculated as an effect size (ES) for all 8 combinations of gender and stroke
- In 7 of 8 gender stroke combinations, the magnitude of the ES for Cd was greater than for F. The mean ES was .54σ for the F values and .90σ for the Cd values.
- Coaches can help slower swimmers improve by emphasizing technique instruction and regularly measuring their Cd. Because of the large gains in v that result from small decreases in Cd, even the fastest swimmers can continue to benefit from improving technique.
- Faster swimmers can also gain a greater advantage over slower swimmers from a more effective use of strength. With a detailed hand force analysis, a coach can identify wasted motion and force losses to provide options that increase average force and achieve maximum performance potential.

What can we learn from these four papers of Oslo 2010?

- Teaching and learning skills need individual approaches instead of simply emphasizing error correction by command style – both parties will learn when using full spectrum of teaching styles

- Learning even simple skills such as straight leg kick in Butterfly requires time and a well-defined target to be achieved

- Learning correct swimming technique from the early years of swimming training is elementary for further progress in competitive swimming – favorable somatic characteristics and well developed energetic profiles are required along with technique training

- Improvement in performance will be obtained by emphasizing technique learning and instruction over force development but both elements are necessary for balanced improvement in performance

Achievements of Oslo 2010 Focus on Critical Swimming Speed

CS versus anaerobiosis
CS versus young swimmers
CS versus lactate responces

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 (Japan)*

- A linear relationship between swimming distances (D) and their sustained times (T) is observed. In this concept, Wakayoshi et al.(1992) suggested that the slope of the linear regression line was referred to as a critical velocity (CV), and CV could be used as an index of aerobic capacity. However, research has shown that anaerobic threshold and CV do not correspond to each other
- The purpose of the present study was to investigate whether the y-intercept of a regression line between D and T could be utilized as an index for evaluating anaerobic capacity in competitive swimming.

y-Intercept of a Regression Line …

- 21 well-trained college swimmers participated in this study. They performed maximum swims in 50, 100, 200 and 400-m for CV determination
- Highest blood lactate concentration was taken after 100 and 200 m distances
- 5 x 300-m intermittent (25 min rest) progressive (60, 70, 80, 90, 100 %) swim test was performed to determine velocity at OBLA
- 30-s all-out Wingate Anaerobic Test (WAnT) with arms and legs was performed determine Anaerobic Power

y-Intercept of a Regression Line …

- The y-intercept of the D-T relationship in swimming is significantly correlated with various indices of anaerobic capacity, such as the highest [La], the mean and peak power of the WAnT.
- From these results, it is suggested that the y-intercept of a regression line in the critical velocity concept could represent a good index of anaerobic capacity, determinable without any invasive measurements.

Critical Swimming Speed Obtained by the 200-400 Meters Model in Young Swimmers. Zacca R, Castro FAS *(Brazil)*

- The primary aim of the present study was to compare CS using the 200 and 400-m race distance with 14 combinations of distances ranging from 50 m to 1500-m in young swimmers.
- The secondary aim was to compare these CS combinations with the 1500-m best performance velocity (V1500).
- 11 young sprint swimmers (male) of national competitive level (Age: 14.4 y; Body Mass: 60.6 kg; Arm Span: 182 cm; Competitive experience 5 y)
- Maximal swimming trials (front crawl) were in 50, 100, 200, 400, 800 and 1500-m distances within 16 days with a minimum of 48 hours between each trial. The order of the trials was randomized.

Critical Swimming Speed …

- 15 different combinations of distances were compared statistically with Bland & Altman agreement test. CS_{10} (200-400 m) served as a reference.
- CS_1 (50-100m) was the model that most overestimated CS_{10} (200-400m).
- CS_3 (50-400m) had the lowest error (-0.5%) in the estimation of CS_{10} and the second best was CS_7 (100-400m) with an error of 0.8%.
- CS_{10} (200-400 m) was with higher velocity than v1500 (+3.5%) with performances ranging from 19.5 to 22-min young male swimmers.
- This study showed that many different combinations of distances can be applied for CS determination. There are evident differences between those models. It is up to the coach to decide which method should be used and thereafter continue using the same method.
- OBS! CS studies numerous – be critical with the results – apply with care!

Blood Lactate Responses During Interval Training Corresponding to Critical Velocity in Age-Group Female Swimmers. Tsalis G, Toubekis AG, Michailidou D, Gourgoulis V, Douda H, Tokmakidis SP (Greece)

- It has been suggested that critical swimming velocity (CV) can be maintained for a long time without fatigue (Wakayoshi et al., 1993). In interval swimming the speed at CV will progressively increase blood lactate concentration and may lead to fatigue in less than 30 minutes during continuous or intermittent swimming
- While young swimmers may show different metabolic reaction to CV swimming this study aimed to examine the lactate responses of female swimmers of different ages during interval swimming at a velocity corresponding to CV.

CS and lactate responses …

- Three groups of female swimmers; eight children (C; age: 10.4), eleven youth (Y; age 13.1) and seven adults (A; age 10.9) were studied. The stage of biological maturation was assessed according to pubic hair and breast development

- All swimmers were timed over the distances of 50, 100, 200, 400 m and the slope of the distance vs. time relationship was calculated and identified as CV. The distances of 50 and 400 m were timed on the first day and the distances of 100 and 200 m on the second day.

- On a following day swimmers performed five repetitions of 400 m or 300 m with an interval of 30-40 s (5x400 m for Y/A; 5x300 m for C group. During the set the swimmers were guided to maintain CV.

- The 300-m distance was used for children swimmers in order to keep the duration of each repetition similar among groups. A capillary blood sample was taken from a finger-tip after each 400 or 300 m repetition.

CS and lactate responses ...

- The swimmers were in different stages of maturation (C=1; Y=3.5; A=5) and the CS was highest in A and lowest in C group.

- The CV were 96.1%, 96.5% and 96.4% of 400-m speed in C, Y and A
- All swimmers could keep their speed steady throughout the set. C group obtained 100.5%, Y group 98.3% and A group 97.8% of their CS

- Blood lactate concentration (4.1 – 5.1 mmol) during the set was not different between groups and was maintained steady during the repetitions of 300 or 400 m in all groups

- RPE was not different between groups and increased step by step

- Irrespective of the age-group, female swimmers performed at steady-state and similar blood lactate responses during intermittent swimming at a velocity corresponding to CS contrasting previous findings in males.

What can we learn from these three papers of Oslo 2010?

- Critical Speed (CS) or critical velocity (CV) is a well-known and utilized tool for training world-wide. Coaches can easily determine CS without additional equipment as part of normal training regimens

- It has been suggested that CS can be maintained for a long time without fatigue. In interval swimming the velocity at CS will progressively increase blood lactate concentration and may lead to fatigue in less than 30 minutes during continuous or intermittent swimming.

- CS corresponds to velocity which is faster than in 1500 m and lower than in 400-m swimming. This means that blood lactate concentrations will increase higher than at AnT (2-4 mmol) but will remain lower than at maximum aerobic power

- A great number of different procedures have been developed. Coaches are recommended to have their method of choice and use it systematically

Achievements of Oslo 2010
Focus on Swimming Suit

Censory and biomechanical features
Hydrostatic lift and lung volume
Passive drag
Spatial-Temporal and Coordinative prmtrs
Lactic acid curve tests
Use of different suits

A Study About the Cognitive Interplay Between Sensory and Biomechanical Features While Executing Flip Turns Wearing Different Swim Suits. *Vieluf S, Ungerechts BE, Toussaint HM, Lex H, Schack T* (Germany)

- The purpose was to study the influence of sensory effects on flip turns under two different conditions: wearing a regular or a full swim suits.
- The turns while wearing full suits are executed significantly faster (.012) so that both the approach and the gliding velocity were higher
- The technique was represented significantly different (=.52 < 0.68) mentally due to suit conditions) – feel of water was less in full suit and the sensory input was different

The Effect of Wearing a Synthetic Rubber Suit on Hydrostatic Lift and Lung Volume. *Cortesi M, Zamparo P, Tam E, Da Boit M, Gatta G (Italy)*

- In the 13th World Championships, swimmers used suits which were produced partially or entirely with industrial polymers – 43 World Records were broken.
- Average hydrostatic lift was found to be slightly smaller when the subjects were wearing a technical swimming suit. This finding could be related to the observed reduction in the chest and abdominal circumferences during maximal inspiration and expiration, as well as, to the reduction in lung volume due to a strong thoracic and/or abdominal compression caused by the technical suits.
- It must be noted that the data reported in this study indicated an effect of these suits that is opposite to the "air-trapping effect hypothesis".
- In conclusion, the improvement in performance obtained by wearing these suits is not related with better static buoyancy, even if these technical suits may make the difference in dynamic conditions.

Effects of new Hightech-Swim-Suits on Passive Drag. *Keul S, Bieder A, Wahl P* (Germany)

- Which influence do Hightech-Swim-Suits have on swimming performance was the main question during the Olympic Games 2008 and World Championships 2009. Therefore the purpose of the present study was to investigate the effects of new generation Hightech-Swim-Suits compared to conventional swimwear on passive drag.
- Under both surface and under water gliding with a Semi Tethered Machine Hightech suits reached higher velocities compared to conventional swimwear.
- The present study showed advantages in wearing tested suits while gliding through water. Even if the results cannot be transferred to a real situation of swimming, it can be expected, that long gliding phases under water after turns and wearing a new swimsuit might improve swimming performance.

Effects of a Blueseventy™ Bodysuit on Spatial-Temporal and Coordinative Parameters During an All-Out 50-M Front Crawl Stroke. *Silveira RP, Kanefuku JY, Moré FC, Castro FAS* (Brazil)

- The aim of this study was to establish the effects of using a shoulder to ankle bodysuit (BlueseventyTM) on spatial-temporal and coordinative parameters during an all-out 50m front crawl swim.
- Wearing a full bodysuit, covering from the shoulders to the ankles, from Blueseventy™, significantly improves the swimming speed during an all-out 50 m front crawl swimming trial, mostly on the second half of the test.
- When wearing the suits, the subjects showed a greater stroke length during both 25 m splits and shorter duration of the non-propulsive phase of the arm stroke during the second half of the test.

The Effects of Rubber Swimsuits on Swimmers Measured by a Lactic Acid Curve Test. *Shiraki T, Wakayoshi K, Hata H, Yamamoto T, Tomikawa M (Japan)*

- This study aimed to verify the influence of wearing a rubber swimsuit on the swimming exercise load by using a lactic-velocity curve test.
- Swimmers performed a 4 x 200 m incremental swimming protocol, the speed of the four stages set relative to the best record of 200 m race
- Four suit types were used. Three rubber suits were made of Neoprene: A was a commercially available, B was made from Neoprene and metallic minerals were contained between rubber and back fabric layers, C was made of Neoprene with titanium in bond part between rubber and back fabric layers.
- Non-significant difference was found between suits in lactates. Normal suit (10.5), A (8.7), B (9.4) and C (8.2 mmol) at highest velocity of the test. Same applied with number of strokes taken: normal suit required more strokes compared to Neoprene conditions.

13th FINA World Championships: Analysis of Swimsuits Used By Elite Male Swimmers.

Neiva HP, Vilas-Boas JP, Barbosa TM, Silva AJ, Marinho DA (Portugal)

- The purpose of this study was to verify the distribution of different swimsuits used by male swimmers during the finals at the 13th World Championships
- Male swimmers participating in the finals limited their choice to seven types of swimsuits, of four different brands.
- Male swimmers preferentially used full swimsuits, covering both the torso and legs, probably contributing for a higher drag decrease.
- We could observe a clear preference for two swimsuits types: the Powerskin X-Glide Full® and the Jaked01 Full®. These swimsuits had greater success rate for achieving podium places.

What can we learn from swimming suit papers of Oslo 2010?

- Rules can be changed rapidly
- – swimmers adapt
- – researchers are doing their homework

- Swimming suits are necessary
- – much better than without
- – rubber suits may benefit high speed training

- There is continuous work going-on
- – even better suits will be developed!

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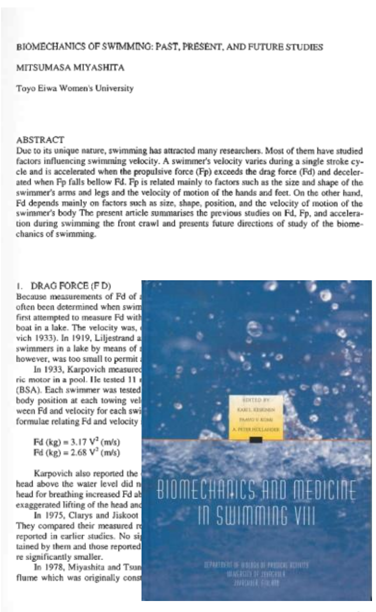
Biomechanics and Medicine in Swimming: past, present and future

M. Miyashita
(*BMS VIII*, 1999)


BIOMECHANICS OF SWIMMING: PAST, PRESENT, AND FUTURE STUDIES

MITSUMASA MIYASHITA

Toyo Eiwa Women's University

ABSTRACT
Due to its unique nature, swimming has attracted many researchers. Most of them have studied factors influencing swimming velocity. A swimmer's velocity varies during a single stroke cycle and is accelerated when the propulsive force (Fp) exceeds the drag force (Fd) and decelerated when Fp falls bellow Fd. Fp is related mainly to factors such as the size and shape of the swimmer's arms and legs and the velocity of motion of the hands and feet. On the other hand, Fd depends mainly on factors such as size, shape, position, and the velocity of motion of the swimmer's body The present article summarises the previous studies on Fd, Fp, and acceleration during swimming the front crawl and presents future directions of study of the biomechanics of swimming.

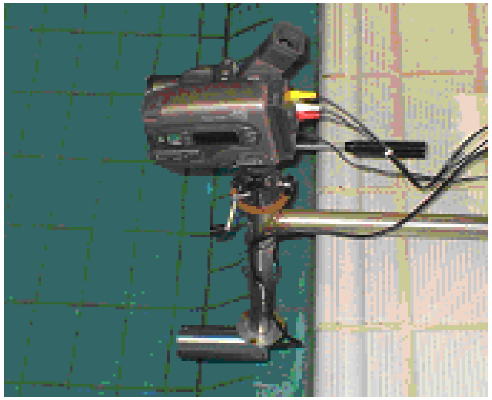
1. DRAG FORCE (F D)

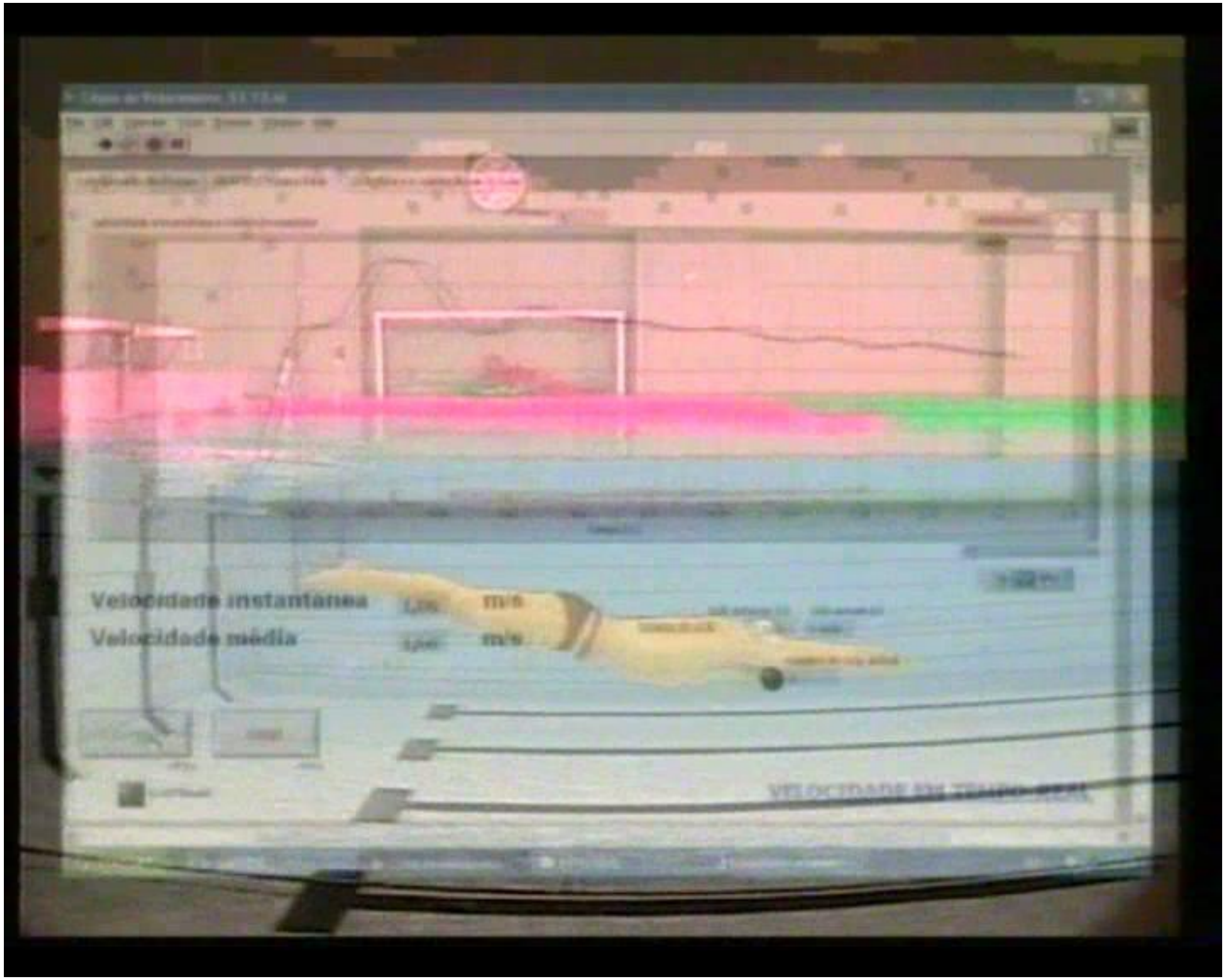
FUTURE RESEARCH DIRECTIONS (p. 6)

"(…) the mean velocity and <u>the velocity change during a stroke cycle should be investigated more in detail in relation to body position and motion of arms and legs in each individual swimmer</u>. Such studies might provide more concrete prescriptions to individual swimmers on how to modify their body position and how to move their arms and legs in each stroke phase."

Dual-media video images and velocimetric feedback in swimming

Vilas-Boas et al. (1996); Lima et al. (2006)





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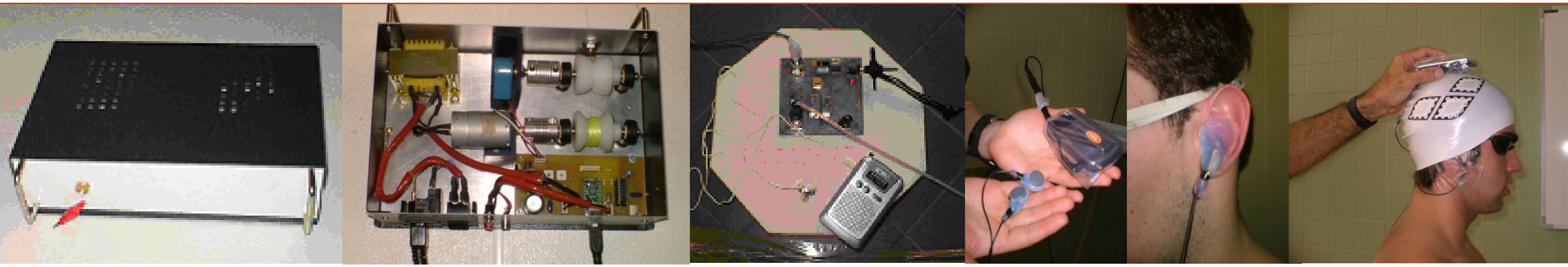
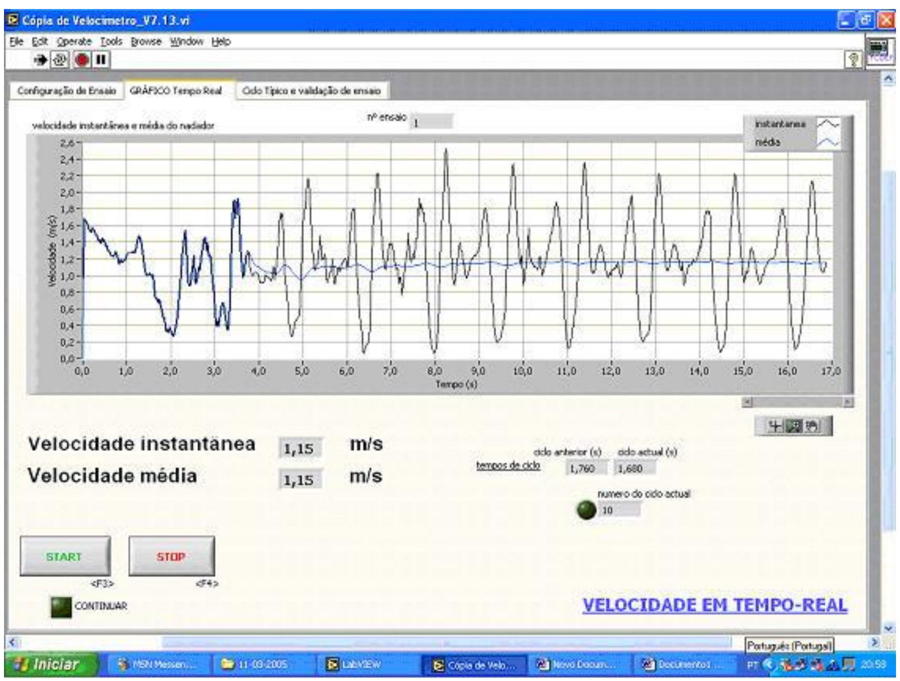
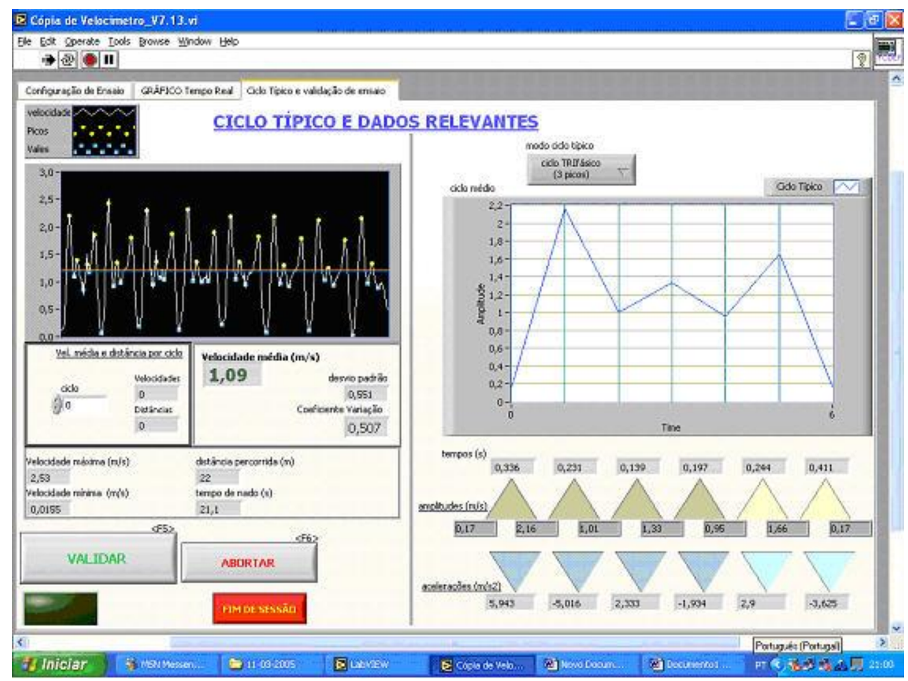


Lima, A.B.; Semblano, P.; Fernandes, D.; Gonçalves, P.; Morouço, P.; Sousa, F.; Fernandes, R.; Barbosa, T.; Correia, M.V.; Tani, G.; Vilas-Boas, J.P. (2006). *A kinematical, imagiological and acoustical biofeedback system for the technical training in breaststroke swimming*.





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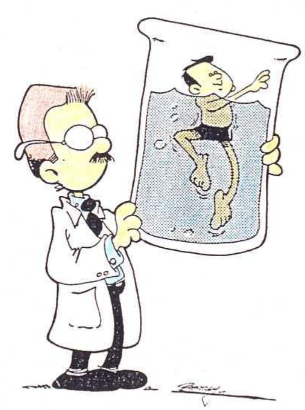
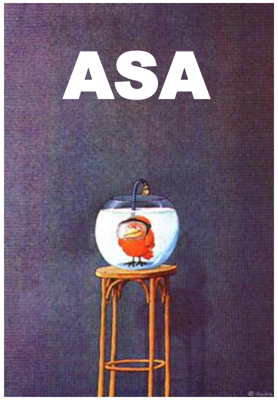
Future perspectives:

New technology

Cleaver use

Progress of knowledge ⟷ Progress of practice





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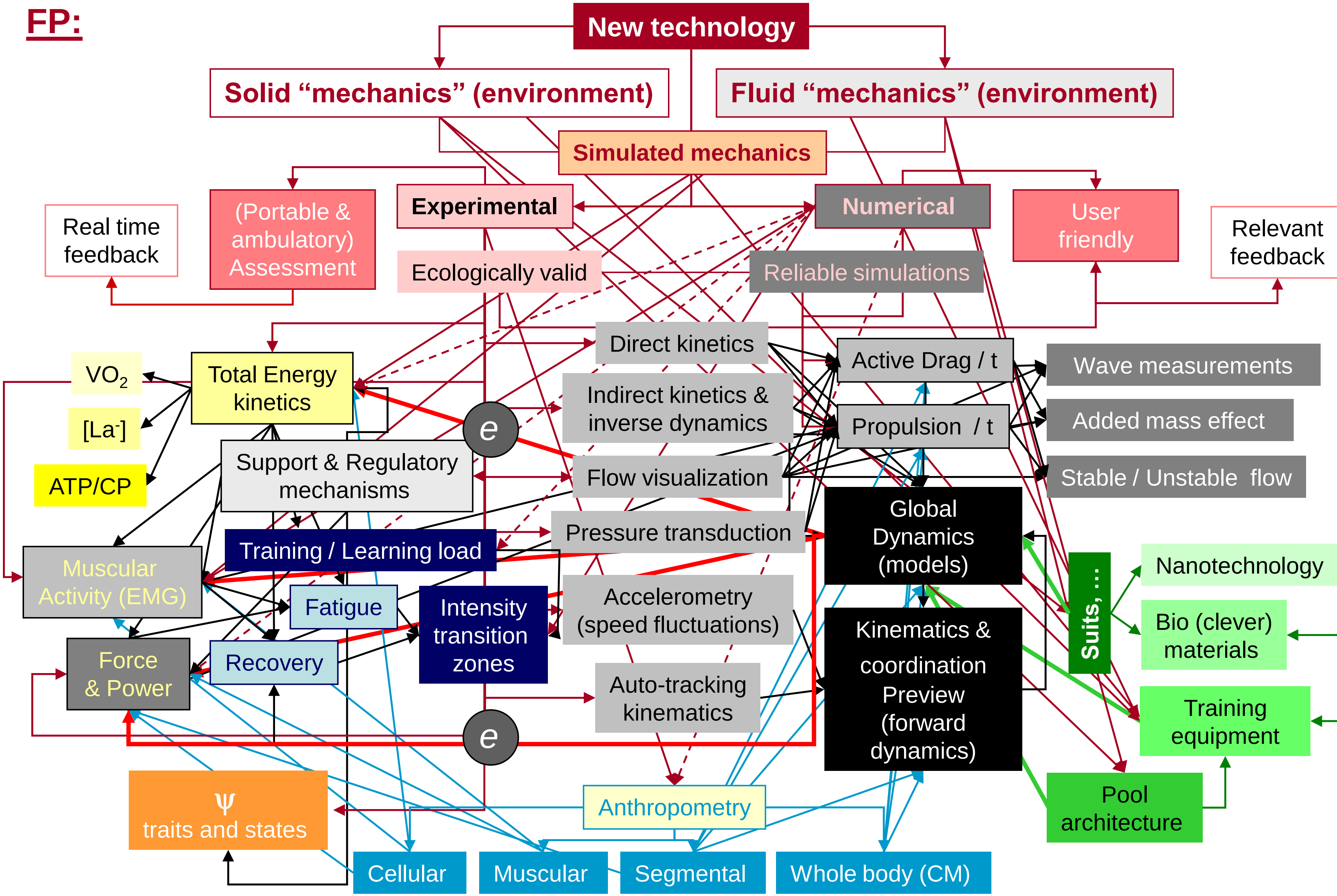

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Future perspectives:

Concluding!

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We must THINK what we are doing…

But we must also DO what we think!