Biomechanics and Medicine in Swimming XI: the 2010 International Symposium in Midsummer Oslo

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This quadrennial conference was hosted in 2010 by the Norwegian Sport University, NIH. Amongst the best performance-related presentations were a case study of a change in butterfly kicking style and large-scale longitudinal studies of talent identification and overtraining in swimmers. Novel Technologies and Analyses: pressure across the hand, active drag, computational fluid dynamics, markerless video analysis, beat the bubbles, frontal cross-sectional area, data-loggers/accelerometers, controlled trials with competitions, free simulation software. Starts and Turns: gliding, starting blocks, step starts, entry styles, underwater turn, start-time feedback, relay changeover, other starts and turns. Strokes and Kicking: limb coordination, freestyle/front crawl, butterfly. Training: reducing volume, overtraining, imagery, altitude, taper, strength. Water Polo: tests, offensive strategies. Miscellaneous: talent identification, trends and performance trajectories, skill acquisition, tests, lactate, swim suits, mushrooms.
KEYWORDS: elite athletes, psychology, skill, technology, tests, training.

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The 2010 quadrennial BMS conference in Oslo was memorable for the midnight twilight, the mainly wonderful summer weather, the nearby Nordic forests and lakes, the mayoral reception at the town hall, where one wall was a vast painting of Norwegians in an idyllic natural setting, and the amazing Vigeland Sculpture Park, featuring many more natural Norwegians. Is the Scandinavian attitude to nudity an evolutionary adaptation to the need for vitamin D? Also memorable and much appreciated was the thorough and thoughtful planning by our hosts at the Norwegian Sport University (Norges idrettshøgskolen, NIH), who provided an opening fanfare by a brass quartet of student musicians, a closing flute solo, free wi-fi, classy conference backpacks, and highest-quality espresso coffee throughout the conference.

And there were some great presentations! Here we report only on those with practical application to competitive swimming performance or to research thereon. If your interest is the clinical, safety, adapted, or educational aspects of swimming, peruse the book of abstracts (see below) to find the many relevant presentations.

Prizes for the best oral, poster and student presentation (the Archimedes Award) went to topics related to health and mechanisms. We had to wait for nearly the last poster on the last day for our choice of the best performance-related presentation: a case study by the coach of a top butterfly swimmer, who persevered with a change in kicking style for two years before his swimmer "got it" (to use his words) and went on to a personal best at age 30. See below. Runners-up were massive longitudinal studies of talent identification and overtraining.

Although this conference is focused on one sport, it is organized under the auspices of the World Commission of Science and Sports. WCSS is dedicated to bringing science to sport and to bridging gap between scientists and practitioners. There's a lot to be said for such specialty conferences, and this one was also just the right size: ~300 delegates (most of whom gave at least one presentation), nine unopposed keynote presentations, 125 oral presentations in three or four streams that didn't clash too badly, and 125 poster presentations. A real plus was having all the posters displayed throughout the conference, so there were many unopposed hours to view them. Each poster was also presented in four parallel chaired sessions, which was only partially successful, owing to the overlap of content, the crush of people, and the background noise: you had to fly backwards and forwards and make a special effort to push to the front to hear the presenter. In future we need email addresses in the abstracts so we can arrange to interact with presenters during or after the conference.

To mark the 40 years since the inception of BMS, João Paulo Vilas-Boas included in his opening address a quantitative review of the contents of the previous and current conferences. The main topics have always been biomechanics, physiology and "evaluation", with medicine and other disciplines playing roles similar to those at any sport-science conference. So whether or not you are a biomechanist or a medic, if you are interested in swimming research, come to the 2014 conference. The venue was announced at the closing ceremony: the Australian Institute of Sport, Canberra, and it will be sometime near Easter.

Videos of the **keynote presentations** are now available at the Coaches Info website. The **conference abstracts** can be downloaded as a PDF from the conference website. A welcome difference from the ACSM meeting, along with the incomparable coffee, is the availability of abstracts for *all* presentations. Even more welcome, and for the first time, the volume of **full papers** will also be available free as a 10-MB PDF, the aim being to get more recognition and citations of the published work. For access to a particular paper before the password-protection is removed from the PDF, contact us. To make the most of the abstracts, we suggest you get a small group together (no more than five) with an interest in a specific stroke or topic, set up the PDF of the abstracts on a big monitor, then use the Search window (not the Find form) to link to each abstract containing an appropriate keyword. It's great fun, and you will learn things from each other, as well as from the abstracts.

In what follows, use the code number shown in brackets (…) to search the abstracts PDF for the given abstract. Text after the number represents the first few words of the title that will take you uniquely to the paper when you search for it in the full volume. *Abstract only* implies either that the authors did not submit a full paper or that the submitted paper was rejected in the peer-review process.

In evaluating effects on performance, it's important to keep in mind the changes that will improve or impair the medal prospects of a top athlete. The smallest important such change is 0.3 of the amount of variation (expressed as a standard deviation) that a typical top athlete shows from competition to competition (Hopkins et al., 1999; Hopkins et al., 2009). An elite swimmer's time varies in this way by only 0.8% (Pyne et al., 2004), so the smallest important change in swim time is 0.3 of 0.8%, or about 0.25%. Use this value even for research on subelite competitive swimmers, in the hope that the findings will apply to elites. For research on youth swimmers aimed at team selection or talent identification, the smallest effect may be better defined via standardization: 0.20 of the between-swimmer standard deviation. See Magnitude Matters for more.

Novel Technologies and Analyses

An Italian group think they have developed the best technology yet for measuring **thrust** developed by the hand via **pressure differences** across the hand (O-002, abstract only). Another group has developed algorithms to analyze the data from 12 pressure sensors on the hand (O-005, Prediction of Propulsive…).

You can detect left-right asymmetry and wide swings in instantaneous stroke force by measuring "**active drag**": the tension in a line used to drag a swimmer through the water at slightly above maximum swimming speed while the swimmer swims all out (O-004, Measuring Active Drag…). This technique is not particularly new, and you can get the same information from an **instrumented tether**: synchronize it with video analysis and you can see what's going wrong. There was a good trade display of the latest version, the Torrent E-Rack, which for US$10,000 incorporates resisted training, assisted training, and synchronized video. The much simpler passive tether costs US$3000.

Bruce Mason gave only an average account of the biomechanics of **active drag** (O-006, A Method to Estimate Active…), but he redeemed himself completely in a keynote address about the biomechanical services provided to swimmers and their coaches at the **Australian Institute of Sport** in Canberra (KL-004, Biomechanical Services…). He presented a series of case studies of starts, turns, and strokes, where the high-tech equipment in the new pool at the AIS has been used to improve performance.

Most promising of the recent wizardry is the use of **computational fluid dynamics** (CFD) to combine the swimmer's anthropometry (from laser scan) with the swimmer's current swimming style (from video analysis) to develop a computerized mathematical model of the swimmer actively swimming through water, complete with simulations of the vortices and waves that limit speed. The model can then be used to predict ways to improve the swimmer's technique, and you try out the most promising in the pool. The method has been around for some years now, and although we got the impression that one more level of model development and computer power is needed to fully realize the potential of this approach, it was rumored that the Russians might already be there. Swimming at the next Olympics may be partly a contest between nations with the most money to spend on computers and computer programmers.

A CFD analysis of **finger positions** of an elite male swimmer reached the following conclusion (O-076, abstract only): "For hand positions in which lift force plays an important role (e.g., insweep phases), abduction of the thumb may be better, whereas at higher angles of attack… the adduction of the thumb may be preferable... Fingers [should be] slightly spread… to create more propulsive force."

Development of **markerless automated video analysis** appears to be close to practical implementation (O-050, abstract only), the main breakthrough apparently being a statistical approach to dealing with the obscuring action of **bubbles**. Another group beat the bubbles by using a regression technique to identify limb-segment midlines in an analysis of the **dive** of 16 male elite swimmers (P-014, abstract only). Faster starters used a dolphin kick and performed deeper dives.

It's now possible to get a reasonable estimate of frontal **cross-sectional area** (responsible for drag) from an analysis of movements in the sagittal plane recorded from a single side-on camera (O-053, abstract only). We're not sure how this approach will "provide new practical insights into swimming analysis protocols".

Apparently successful merging of video with the data stream from a 3-D accelerometer-gyroscope **data-logger** was made possible by addition of a **depth gauge** with a resolution of 10 cm to the device (O-055, Whole Body Observation…). "Wavelet analysis" also helped, but it was difficult to understand the presenter on this point. Another author claimed that "the feasibility to use **inertial sensors** [accelerometer-gyroscopes] to characterize turning, gliding and stroke resumption in swimming was verified" in eight elites doing various swim movements (O-123, Analysis of Swim Turning…). We are skeptical about the current practicality and bulk of these devices.

You can get a swimmer's **position** down to an accuracy of one frame of a 25-Hz video if you use 2-D **direct linear transformation** (DLT) analysis of footage from three cameras (O-056, The Validity and Reliability of a Procedure…).

If your team competes often in a season, and there are plenty of other teams in the competitions, and your coach wants to try some new strategy with the whole team, and the coach hasn't done anything else substantially different so far in the season, you can **use competition results** to estimate the effect of the strategy (O-073, abstract only). The uncertainty of the estimate is typically about one third of what you get from the usual controlled trials, and the outcome is as valid as it is possible to get: the effect on competitive performance. It's best done with mixed modeling.

It was demonstrated at the last BMS meeting, but the authors have updated their free **swimming simulation software** (Swumsuit), and it looks very cool indeed, at least for teaching (O-126, P-029, Advanced Biomechanical Simulations…) and possibly for research (P-030, abstract only). Downloads and more at the SWUM website.

Starts and Turns

Kinetic analysis of **gliding** combined with planimetry to determine cross-sectional area in six national-level males led the authors to recommend more emphasis on control of body position during the glides to reduce drag (O-078, Hydrodynamic Characterization…).

A new FINA-sanctioned **starting block** with side grips and a steeper angle (9° rather than 5°) appears to produce starts that would represent a substantial small effect for 50- and 100-m events in seven male swimmers (P-004, abstract only) and in 14 elite swimmers (O-083, A Biomechanical Comparison of Elite…). The authors of the latter study concluded that "coaches and athletes should spend time adapting to the new block and the new starting technique".

Step starts were statistically significantly faster than no-step starts in repeated trials of relay changeovers (O-084, Comparison among Three…), but this is one of those occasions where statistical significance of a trivial effect practically guarantees the effect isn't worth worrying about. The swimmers also made more "missed trials" (bad changeovers?) with step starts.

A randomized controlled trial of 5+5 elite swimmers compared outcomes of instruction on **pike vs flat entry** (O-086, abstract only). Both groups changed their entry style significantly, but whether the changes would have substantial effects on swim time was unclear.

Does a new "apnea" **underwater turn** (O-119, An Analysis of an Underwater…) offer any advantages for the butterfly and breaststroke? The mean gain in time for the 10 swimmers was 0.07 s on average, which is not worthwhile, but apparently the swimmers had practiced the turn for only a few sessions (not stated in the abstract or full paper). So it might be worthwhile with enough practice, but only for 50- or 100-m events: the presenter mentioned that the reduction in breathing would probably impair performance in races with more than one turn.

A controlled trial of the effect of giving feedback about **start times** produced a statistically significant improvement in start time in the experimental group (O-121, abstract only), but it was done with regional-level swimmers and physed students, and in any case the gains would probably translate into a trivial effect in 50-m swim time. Inferring significance apparently via a comparison of P values in the two groups is also forbidden, although the presenting author said that this was a mistake in the abstract.

In the first of two controlled trials aimed at improving **relay changeovers** (O-122, abstract only), both groups of 13 junior elites received video feedback for the 4 d of training, but one group was given additional feedback on horizontal take-off force while the other received feedback on changeover time. The group receiving force feedback made bigger reductions in changeover time that would probably translate into medals (not enough data presented to be sure), and they made less false starts. In the other trial, eight elites practiced the traditional arm-swing start while another eight learned a single-step start. Both groups improved by a similar amount, but it's unclear from the ambiguous abstract whether the step start was better.

There was no immediate application to race times, but the following analyses may be of interest nevertheless: **backstroke start** (P-009, Biomechanical Characterization…); **flat, pike or Volkov starts** (O-085, Influence of Swimming Start…); and **gliding** (P-036, Evaluation of the Gliding…) .

Several **correlational studies** of starts or turns and performance time suffered from woefully inadequate sample sizes. Unless the relationships are very strong and therefore obvious anyway (for example, when there are novice and expert swimmers in the sample), you need hundreds of subjects to do the job properly. The only way correlation can work with samples of 10-20 is when the correlated variables are change scores derived from repeated measurements, in which the subjects spontaneously vary their technique substantially and there are substantial differences in the change in performance–see, for example, the paper on effects of tapering (P-072) reported in more detail below. It's even better when you make multiple observations on each subject, derive a slope representing the relationship between the movement and performance for each subject, then process the slopes with a simple t statistic. (See within-subject modeling for more.) Anyway, here's a quick list of the studies: kinematic analysis of **grab start** in 12 national level (and this involved stepwise regression, which is right out of the question with this sample size) (P-020, Kinematics Analysis of Undulatory…); kinematic analysis of **water-entry skill** in 14 college elites (P-024, abstract only); and kinematic and kinetic analysis of **tumble turns** in eight elite females (P-033, Biomechanical Factors Influencing…).

Strokes and Kicking

In a keynote and original-research presentation on **limb coordination** (KL-002, Inter-Limb Coordination in Swimming), Ludovic Seifert mentioned *complex systems*, *dynamical system theory*, *self-organization*, and various *constraints*, although you don't have to understand these concepts to appreciate his main finding: the best swimmers achieve overlap of the propulsion phase of each arm at race pace, presumably by shortening the recovery phase of each stroke. Is there an application to performance enhancement here? Seifert also presented several original-research studies on coordination (O-044, Arm Coordination, Active Drag…; P-037, Modelling Arm Coordination…).

A string of **light-emitting diodes** down each arm facilitated automatic digitizing (P-127, Preliminary Results of…). Combined with high-speed video of four elite **freestylers**, the technique revealed that forward thrust (as determined by hip forward velocity) is maximum midway through the stroke rather than towards the end, as traditionally taught, and that these swimmers adopted an elbow angle of ~130° rather than the recommended 90°. The authors are getting a bigger sample size.

The findings were inconclusive with respect to race times, but you may have an interest in video analyses of **front-crawl** (P-005, P-035, abstracts only), and the **freestyle** in the previous paragraph.

Analysis of pressure difference across the hand combined with video of 23 varsity-level butterfly swimmers revealed **patterns of hand-force** development that led to the following conclusions: coaches can adjust entry angle to eliminate time wasted when the hands are above the shoulders, and coaches can also encourage swimmers to begin elbow flexion as soon as the entry is complete (O-111, Quantitative Data Supplements…).

The most inspirational presentation for us was the case study presented by the coach of the 100-m butterfly Asian record holder, who took two years to change his **kicking** style, then went on to set a personal best as a 30-year old (P-077, Effects of Reduced Knee-bend…). The swimmer was taught to keep his legs straight in the upbeat and to delay bending the knees until the downbeat was initiated. The presentation of the longitudinal monitoring was almost exemplary, lacking only an inferential statistic for the uncertainty in the change in performance (but the effect was so clear that it didn't matter).

Training

Continuing the long tradition initiated by Dave Costill, a group from Denmark reported on the effect of **halving training volume** and increasing training intensity for 12 weeks in a randomized controlled trial of 16+15 elite swimmers (20 male, 11 female) (O-026, P-078, abstracts only). VO2max dropped significantly by 3.8% in the experimental group compared with control. It was also apparent in the presenter's slide that performance in an all-out 200-m test also declined by about 1.5%, but it was non-significant and it was presented as no change. On the other hand, 100-m sprint performance apparently improved, but the comparison of the changes in the two groups is not in the abstract. Amazingly, the coach allowed this 12-week study to straddle the Danish national championships, but the group had not investigated the effect of the first 6 wk of the program on change in competitive performance since the previous competition. Hopefully they will, and report it using chances of benefit and harm with respect to a smallest important change of 0.25%.

In a sometimes overwhelming keynote lecture, Pierre-Nicolas Lemyre told us all about one of the biggest and best studies yet of **over-training/burnout** (KL-006, The Psycho-Physiology of Overtraining…), involving psychometrics, hormones, and double maximal stress testing of 53 elite swimmers at the easy beginning (September), very hard middle (November), and peaking end (March) of a six-month season. A measure of lack of motivation at the beginning of the season was the best predictor of level of burnout in the middle (r=0.52) and at the end (r=0.55). Change in cortisol in the stress test and several other measures were also substantial predictors of burnout, altogether giving a correlation of 0.82 in a multiple linear regression. Predictors of performance change from the previous season to the end of the monitored season were not presented in the abstract or the paper, alas, but presumably they would have been similar to the predictors of burnout. Now we need studies of interventions based on the predictors and aimed at reducing risk of burnout and enhancing performance. Let's hope you can do both in the same athlete.

There was apparently no significant effect of 3 wk of supplemental **imagery training** on performance in a controlled trial of 8+8 13-y old kids, but not even the full paper showed any data (P-107, Imagery Training in Young…).

Ferran Rodriguez presented a keynote on **altitude training** for swimmers (KL-008, Training at Real…), in which he gave credit to a recent meta-analysis of performance effects of the various kinds of hypoxic exposure (Bonetti and Hopkins, 2009), unfortunately without drawing on its findings. The forthcoming multi-center altitude study he promoted here and in an earlier presentation (O-052, abstract only) would be a good opportunity to try out the competition-based new research design (O-073, abstract only, see above).

The reduction in training load during a **taper** before a national competition in 12 age-group swimmers correlated clearly and substantially (r=0.63) with change in performance in the competition from the previous "starting list time" (P-072, Changes of Competitive Performance…). When asked, the presenter thought the correlation was due more to higher training at the start of the taper than lower training at the end; that is, those who reached a higher training load before the taper had bigger gains in performance.

Four weeks of **strength training** improved the start times of five male and two female national-level swimmers by an average of 0.07 s (P-075, abstract only), or about 0.3% in a 50-m race. Although this change is the smallest worth having, it would be important to ensure the benefit transfers to actual overall swim time.

Water Polo

Means and standard deviations were reported for a new **test battery** (P-094, abstract only), but there were no statistics for validity (e.g., correlation with ability of players) or reliability (e.g., test-retest correlation). The same group reported a correlational study of muscle strength and **throwing speed** with 15 players (O-038, abstract only). See our earlier comments about inadequate sample size.

Looking for patterns of play in games using sophisticated modeling may be the way of the future. Here a group used Markov chains to analyze **offensive play** in 11 games between the same two teams at a world league final (O-041, A Markov Chain Model). Their conclusion: fast breaks and intense activities of the back players are important.

Miscellaneous

In a spectacular study of **talent identification** (O-071, Talent Prognosis…), 21 measures of fitness and anthropometry were taken on over 700 children of age 14 ± 4 y (mean ± SD) from two elite sport schools. Swimming competition data were collected ~7 y later on the 130 male and 113 female survivors (age 21 ± 3 and 20 ± 3 y). They were divided into three talent groups (why not use percent of world record as the outcome?), then linear and neural-net models were developed to predict the talent grouping from the original test scores. The neural net worked much better than the linear model, correctly predicting the talent group for 88% of the girls and 68% of the boys compared with only 69% and 50% respectively. The linear model does manage to identify the tests that matter most (***ex***trinsic motivation–oh dear!–and a composite factor called swimming coordination), whereas a neural net is a black box that doesn't tell you what matters without extensive probing. Now what? Use the neural-net model to help filter future intakes?

Mixed modeling is the secret for analyzing **age and calendar year trends** in overall competitive performance times and for **predicting performance** of individual swimmers from their "quadratic trajectories" (O-074, abstract only). Is this the way to identify your country's strong and weak events and your promising talented individuals?

Stephen Langendorfer gave an inspirational keynote on **skill acquisition** at different stages of the lifespan (KL-007, Applying a Developmental Perspective…). But as an audience member summarized it in question time, he hijacked all the good techniques in teaching under his banner of the *developmental* view, and left all the bad things under the *error-correction* view. Perhaps he should have given some credence to this prevailing view, given that we seem to have evolved to acquire behavior and culture in this efficient manner.

Our comments about sample size in correlational studies in the section on Starts and Turns applies to a study of **field tests** in 12 swimmers (P-110, abstract only) and of **fitness tests** in 25 male adolescents (P-079, abstract only). With larger sample sizes outcomes are clearer, although hardly surprising in the study of **fitness tests** of 72 young swimmers (P-121, Predictors of Performance…).

Some of the papers relating to **lactate** measurement sported big names, but we consider these to be of marginal utility. Those interested should search the abstract PDF for *lactate*. We have adopted the same approach to the many studies of **swimsuits**.

By our calculations from the full paper, **Olympic swim times** in the 2008 games were faster than predicted from the trend over previous Olympics by a large 1.7 ± 0.7 % (mean ± SD) (P-088, Identification of a Bias…). Swimsuits were surely the main reason?

There was an intriguing abstract about beneficial effects of a **mushroom extract** on "infection, allergy and inflammation that… may improve health and training-related inflammation in elite swimmers and other athletes" (O-021, abstract only). Unfortunately the author did not turn up to present the study and to answer questions about the potentially harmful effects of anti-inflammatories and antioxidants on training adaptations. See this year's ACSM report for more on this topic.

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Reviewer's Comment

This is an excellent analysis of performance-related papers presented in BMS XI. I have noticed a trend towards more controlled trials at this conference, but sample sizes are still generally too small to study the small effects that make a difference to medal-winning. Placebo effects, both positive and negative, are also a problem in studies where swimmers cannot be blinded to the treatments. –Kari Keskinen

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