

Performance Outcomes at the XII International Symposium on Biomechanics and Medicine in Swimming

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This quadrennial conference was hosted in 2014 by the Australian Institute of Sport in Canberra, Australia. [Best presentations](#) for sport generally: extra warm-up; participation base. Best presentations for swimming: hearing pressure on the hand; coach assessment errors. [Keynotes](#): Bill Sweetenham; strength training; David Costill; immune function; computational fluid dynamics; injuries. [Workshops](#): Q&A with top swimmers; wet-plate and Kistler systems; video feedback; physiology. [Technologies and Analyses](#): pressure sensors; active drag; digitizing videos; structural equation modeling; speed oscillations; accelerometers; automated motion capture; heart-rate variability. [Starts and Turns](#): teaching and training start skills; stance; fore-aft lean; pelvic tilt; kick start; apnea turn; breaststroke turn. [Strokes and Kicking](#): coach assessments; body position; breathing; arm entry; stroke cycle; drills; dolphin kick. [Training](#): altitude; hypercapnic-hypoxic; Doc Councilman; deliberate practice; interval; resisted; high-intensity; modeling. [Synchronized Swimming](#): thrust movement; lift move; free routines. [Water Polo](#): performance analyses. [Miscellaneous](#): warm-up; participation; carbohydrate; protein; lane bias; development squad. KEYWORDS: competition, elite athletes, ergogenic aids, nutrition, performance, talent identification, tests, training.

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Similar in size to the memorable Biomechanics and Medicine in Swimming conference in [Oslo in 2010](#) (about 250 delegates), this BMS was equally worthwhile for the quality and quantity of useful presentations organized by Bruce Mason and his team at the Australian Institute of Sport. The AIS was an ideal venue: we stayed in "Ressies", the Spartan old hall of residence, we dined with athletes and visiting school children, and we were treated to an inside view of state-of-the-art swimming facilities. For one of us (WGH) there was a sense of loss: he had visited the AIS regularly during its golden age of sport research over the last 12 or so years, but now, alas, a policy of decentralization following Australia's relatively poor performance at the London Olympics has all but emptied the labs of PhD students.

Conferences focusing on a single sport can turn up novel strategies relevant to sport performance generally. Our top two from this conference: a special [extra warm-up](#) just before the event, and [more kids competing](#) means better

performances. And the two most novel swimming-specific presentations: turning pressure across the hand into [sound for instant feedback](#) on stroke technique, and major discrepancies between the [technique assessments of top coaches](#). The keynotes and symposia included summaries of [strength training](#), [altitude training](#) and [nutritional strategies](#) valuable to swimmers and non-swimmers alike.

As usual with conference reports at Sportscience, the focus here is the presentations with practical applications to training and performance. Anyone with an interest in learning to swim, lifesaving and drowning should search the volume of abstract for the half dozen or so relevant presentations by some of the experts in this field. Presentations with inconclusive findings (e.g., because of small sample size) or inadequate reporting of effects (e.g., p-value inequalities only) have been excluded. Presentations where the main outcome involved lactate concentration or oxygen consumption have also been excluded, because their large errors of

measurement make anything but obvious outcomes inconclusive for good swimmers.

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 swimmer. The smallest important 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 [Statistical Analysis and Data Interpretation](#) for more.

Conference attendees can register now at the [Clearinghouse for Sport](#) website to access the **book of proceedings**, high-quality **videos** of the keynote, biomechanics and medicine presentations that were delivered in the main lecture theatre, and most of the **slideshows** presented in the other two lecture theatres. The conference organizers have very generously offered public access via the Clearinghouse from August and to the **book of abstracts** right now via [this link](#) at SportsScience. To make the most of the abstracts, get a small group together with an interest in a specific stroke or topic, set up the PDF of the abstracts on a big monitor, then use the Advanced Search form (Ctrl+Shift+F) rather than the Find form (Ctrl+F) 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, copy exactly the author name (usually shown in brackets [...]) into the Advanced Search form to find the abstract in the abstracts PDF. If the name is shown in **bold**, there is a corresponding full article in the PDF of the proceedings.

Keynotes

Legendary coach of multiple medalists at five Olympics, **Bill Sweetenham** presented a detailed program based on improving technique at race pace. He brought a team of four support

staff to the podium to help explain the program. Some key points... He uses "stations" or steps focusing on different aspects and technique and speed, closely monitored. "Efficiency comes first": coaches should focus on adding speed and endurance to good technique, and not the other way around. If swimmers don't have the right technique, focus on improving technique at race pace. Get swimmers to do their homework on technique development before a training session, not after. He finished with the message that academics need to spend more time on pool deck to understand the sport and do meaningful research. (Bill's abstract is uninformative, but the proceedings contains his slides, which deal with some of these points.)

Robert Newton emphasized the need to build resilience in swimmers through regular **strength training**, noting that "strong athletes are hard to kill" and "don't bring a feather duster to a sword fight". He stated that strength and power training should be performed throughout all phases of the season to maintain an anabolic state, on the basis that muscle is an anabolic secretory organ. However, strength and endurance sessions tend to interfere, so there should be at least 6-9 h recovery between modes, and any high-intensity sessions should be on alternate days. The final take-home message: the last training session of the day is most important for adaptation, so the order of swim and dryland sessions should be alternated.

We were privileged indeed to have a keynote presented by one of the all-time greats, **David Costill**. He summarized his pioneering contributions to research with biopsies and on the effects of nutritional ergogenic aids. He has also been a swimming coach for more than 50 years and was one of the first to challenge the need for high training volumes. He found that training 2-3 times per week in the off-season maintained aerobic fitness at peak end-season levels in athletes with a solid endurance base. In top swimmers more time could therefore be focused on skill and technique rather than aerobic conditioning. Practising what he preaches, he confessed to training his current squad just once a day. (There is no relevant abstract or full paper.)

In his review of research on **immune function** of elite athletes at the AIS, **Peter Fricker** concluded that anti-viral drugs are ineffective for reducing the risk of upper respiratory infec-

tion associated with heavy training loads. However, modest evidence does exist for the prophylactic effects of particular strains of probiotics. Eat more good yoghurt, athletes!

Along with a keynote by Raymond Cohen, there were several original-research presentations on **computational fluid dynamics** for swimming. In summary, with further development of theoretical models and computing power, CFD will eventually be able to predict how to improve the technique of individual swimmers in a more efficient manner than the current trial-and-error approach. Watch this space.

Physiotherapist **Peter Blanch** warned about the elephant in the room: the fact that **injuries** in swimmers and many other sports are always about load. Risk factors such as training history, age, technique, flexibility, strength, injury history and genetics are only modifiers of the effect of training load on injury. Training ramped up too quickly, taken too high or maintained at monotonous levels are all related to injury, and the coach has considerable responsibility here.

Workshops

Those we attended were high points of the conference. We missed a round table and practical session on strength and conditioning chaired by Jamie Youngson of the AIS. Unfortunately you had to be there: there are no abstracts or articles in the proceedings.

In a question-and-answer session with AIS swimmers, Olympic medalist Brenton Rickard told us that he was a “numbers guy”, and that he focused on rhythm and holding a rate of 35 strokes per minute in preparing for his 200-m breaststroke races. He also worked on holding 13, 16, 16 and 18 strokes in the respective 50-m laps. Olympic medalist Alicia Coutts and young hopeful Ben Treffers mentioned the importance of the wet-plate system in their training. This system consists of cameras and force platforms built into the starting blocks and walls of the pool to provide instantaneous feedback on starts, turns and swim speed. Coutts also described how AIS swimmers filled in VARK questionnaires to establish which type of feedback best suited their individual learning styles. (VARK = visual, auditory, reading, kinesthetic. See Wikipedia's [Learning Styles](#).)

The poolside demonstrations consisted of three stations. Before demonstrating the **wet-plate system**, AIS coach John Fowlie showed

two large whiteboards with pictures of technique in elite swimmers, and he explained that he wanted to create an intrinsic learning environment. He then had Alicia Coutts and Ben Treffers perform a series of starts and turns, with the wet-plate system providing footage and performance data of angles, force and speed. John explained that it was up to the coach to select the important data. He told us how he had used the system to further the flight after leaving the start block by changing the take-off angle from -19° to -9° in one of his swimmers, to assess the best timing of the first kick for optimal speed and performance, and to evaluate the efficiency of the entry into the water. The system contained a detailed history of performances of each of his swimmers. John stressed the importance of communication and ownership with using the system, and he recommended asking the swimmer's thoughts first before giving feedback himself.

A demonstration of the **Kistler system** by company representatives was on the other side of the pool. Similar to the wet plate, this system combines force plates, cameras and sensors, to measure speed and depth of reference points at set distance intervals.

At the third station, Ben Titley (the renowned British coach now working for the Canadians) facilitated a technique session in a group of youth swimmers, using delayed **video feedback**.

The practical physiology session was a round-the-table discussion with an international group facilitated by Professor David Pyne. Attendees took turns describing their work and current projects. There was a debate around the use of conventional physiology tests, where the New Zealand physiologist (TJV) challenged the group to explain how these tests help athletes prepare for competition; he advocated performance tests specific to the goals of the program and individual.

Technologies and Analyses

Novel idea: **pressure sensors** on the hand to turn pressure differences into **sound** so the swimmer can hear the effect of modifying their technique [**Bodo E Ungerechts**]. We can't wait to hear if it helps.

Two methods for computing **active drag** via the AIS assisted towing technique were superior to a third method [Mason Bruce [sic]].

The more traditional resisted towing method

gave smaller values of **active drag** than the assisted method, for reasons as yet unclear. [Pendar Hazrati]

Adjustment to software for **digitizing videos** can save operation time by automatically acquiring body-segment parameters [Chuang-Yuan Chiu].

Various swim parameters measured during a season in 30 young talented swimmers tracked performance change over the season when analyzed with **structural equation modeling**, but the goodness of fit was not reported in a manner that allows assessment of the model's utility [Tiago Barbosa].

Oscillation in swimming speed might be a good measure for assessing swimming economy, but no supporting evidence was presented [Boris Dyshko].

Accelerometers calibrated individually for swimmers might be useful to monitor **swim speed**, if the data can be downloaded in real time [Brian Wright]. But the error of measurement (~3%, not shown in the Abstract) is probably too high. They could also be useful to quantify **inter-limb coordination** [Ludovic Seifert].

An **automated underwater motion capture** system had errors of only 1-2 mm, which is negligible [Bjørn Harald Olstad].

The French have developed software to automate the **tracking and analysis** of swimmers in competitions [Florence Garnier].

It's hard to follow the abstract and the full paper, but it looks like gains in performance of 13 elite swimmers between a time trial at the end of an overload period and a competition after a 3-wk taper were highly correlated ($r=0.80$) with increases in high-frequency and reductions in low-frequency components of **heart-rate variability**. "During taper, this method may be helpful in evaluating the optimal training load decrease and in regulating the high-intensity, low-intensity and strength training proportions." How? It's unclear. [Philippe Hellard]

Starts and Turns

A **focus on external movement outcomes** rather than internal processes is known to result in improvement in complex skills, although "elite level athletes regularly receive instructions that encourage an internal focus." Here an external focus improved mean values of various swim-start parameters in a crossover with 10

elite swimmers [Michael Maloney]. The gains in entry speed (0.6%) and 15-m time (1.6%) would have to continue to some extent through the first lap to make a substantial difference to 50-m time.

A combination of four weeks of **plyometric and auditory training** improved 15-m **start time** by ~1.0% in this uncontrolled study of eight male national-level sprint swimmers [Pierre-Marie Leprêtre]. This improvement would almost certainly translate into faster 50-m and possibly also 100-m times.

By varying the parameters of **starting stance**, it was possible to improve the start times of half of a group of 19 mainly freestyle elite swimmers [Armin Kibele].

"The optimal **fore-aft lean** [on the OSB11] is dependent on swimmer characteristics" in this study of 2-m start time in 11 elite swimmers [Andrew Dragunas].

There appeared to be a very strong correlation between **pelvic tilt and start time** in eight elite swimmers, but wait for more evidence from a larger sample size [Brett Doring].

The **kick start** on the OSB11 wedged starting blocks is clearly superior to the grab and track starts [David Burkhardt].

Teaching the **apnea turn** to 19 age-group swimmers preparing for their first national championships wasn't particularly successful: only five improved their apnea turn time compared with conventional turn time [Bodo E Ungerechts]. The apnea turn may not be for everyone, or maybe it takes a lot longer than 10 weeks to learn.

Alison Alcock was able to reduce five national-level **breaststrokers' turn time** by getting them to initiate an earlier pull-out, but she noted that the gain might be offset by the need to take more strokes.

Strokes and Kicking

Seven high-level **coaches** differed considerably in their **assessment of sprinting technique** of 12 sub-elite freestyle swimmers (FINA points 698 ± 70 , mean \pm SD), judging by the correlations between their ratings and the swimmers' performance (ranging from 0.68 down to an unstated negative correlation) [Gina Sacilotto]. The Cronbach alpha of 0.62 for the mean of the coaches' ratings translates into an average correlation between individual coaches of only 0.23, which also indicates that most coaches must be making serious mistakes in

their assessments. Yikes!

When four expert and four developing coaches viewed 20 5-s clips of freestyle swimmers (10 above and 10 below water), the experts not surprisingly made more technical comments. More interestingly, recordings of eye movements showed that the experts fixated mostly on the hips, whereas the developing coaches fixated mostly on the arms. Conclusion: "**body position** is a key area of importance." [Amy Walters]

Ten male competitive front-crawl sprinters swam 3% faster over 25 m without **breathing**. "It is recommended that sprinters limit the number of breaths taken without physiological compromise" [Carla McCabe]. Are top sprinters already taking the optimum number of breaths?

Bilateral **breathing** resulted in less hip-roll asymmetry in 20 provincial and national freestyle swimmers, but effects on performance weren't reported [Mike Barber].

"Females [need to] improve their **arm entry** to minimize time of exposure to shoulder stress and to maximize the force-generation overlap" in this study of 40 university-level swimmers doing freestyle at unstated intensity [Rod Havriluk, presenting for Ted Becker].

Expert breaststrokers are more stable than novices and intermediates at key points in the **stroke cycle** [John Komar].

Muscle activation patterns of some **drills** of a world-champion breaststroke swimmer differed from those of the free-swimming stroke [Bjørn Harald Olstad]. Does that make the drills good or bad?

In a study of 15 experienced male swimmers, those who performed the underwater **dolphin kick** faster had a more symmetrical kick resulting from a better upkick [Ryan Atkison].

Training

Laura Garvican gave a succinct overview of optimizing the **altitude camp**. Assuming that the effects are mediated by—or at least associated with—the increase in circulating erythropoietin (EPO) that occurs with exposure to hypoxia, she identified the following factors that impair the EPO response and therefore potentially reduce the benefit of altitude training: low iron status, illness, injury, stress, and intake of anti-inflammatory drugs (use paracetamol rather than ibuprofen). These factors may explain why altitude training doesn't always work with a given athlete. The live-high train-low camp

should last for 2-3 wk at 3000 m (or its equivalent in an altitude house) for at least 14 hours per day. Athletes have to eat more to stay in energy balance with the 10-15% increase in basal metabolic rate that occurs at altitude. They should also drink more to remain euhydrated and consider supplementing with iron, folic acid, and vitamins B12 and D.

Ferran A Rodriguez presented the results of the **altitude-training** study that he had already presented at last year's ECSS conference (see the [summary](#) in my report). The fact that he has presented the full paper in the proceedings here suggests that he has had difficulty publishing it elsewhere, possibly because the swimmers weren't randomized to the treatment groups and the training wasn't controlled. Anyway, by 2-4 weeks after a 3- to 4-week training camp, swimmers who had lived and trained high (2300 m) improved to the same extent (~3%) as those who had lived and trained low (sea level), while those who had lived high and trained high but did some of their training low (690 m) swam another ~3% faster. At least some but probably not all of that difference could be explained by a difference in the training of the high-high-low group. If you're going to invest in an altitude camp, make it one where you can train low.

It's hard to understand this abstract, but it looks like **hypercapnic-hypoxic training** (no details of protocols) enhanced 100-m freestyle performance by an unstated amount in a controlled trial of 26 top swimmers [Dajana Zoretic].

The legendary coach **Doc Councilman** changed his training programs "from few but intense sessions in the 60s, to greater distance in the 70s, and finally to a more moderate approach with less physiological stress in the 80s." See the full paper for details. [Masataka Ishimatsu]

Deliberate practice emphasizes quality of training, so it should be a no-brainer for improving performance compared with traditional high-volume swim training. But when 11 male and 8 female national-level swimmers tried it for a month, their swimming speed fell by ~1%. The effect was apparently non-significant, but that doesn't mean "the swimmers were able to swim as fast", as claimed by the presenter [Rod Havriluk], who enthused instead about a reduction in active drag coefficient. There was also a

reduction in hand force, so it would appear the losses outweighed the gains. Conclusion: the presenter's recommendation to include this program of deliberate practice with top swimmers is premature.

High-intensity interval training taken to an extreme (five 5-s all-out bouts with 10-s rests, twice per session, five sessions a week for 4 wk, with no other training) produced a 2% enhancement in 50-m freestyle time of 11 college-level swimmers [**Futoshi Ogita**]. But there was no control group to compare the effects of more reasonable high-intensity training, and a non-significant impairment in swimming economy (0.8%) is consistent with some harm to technique.

"Ten weeks of **resisted swim training** is not any more effective than traditional non-resisted sprint training" in this randomized controlled trial of 18 age-group well trained swimmers. The increase in 50-m freestyle speed was 3.8% and 3.9% in resisted and sprint groups respectively [**Kosuke Kojima**].

In an 18-week controlled trial with 20 (elite?) swimmers, the group doing **high-intensity training** in Weeks 9-14 increased their critical velocity by 6.7% in Week 18 (after the taper), while the usual high-volume group improved by 5.2%. No details of the swimmers, the training program and the tests were given [Gustavo Antonio Meliscki].

Marta Avalos and colleagues investigated several sophisticated **models** relating training to performance of 138 professional French swimmers between 1991 and 2011. Presentation of the prediction error in percent units would have allowed better evaluation of the models, but it was reasonably clear that none was any good. Possible reasons: errors in the quantification of training load, and unrealistic models.

Synchronized Swimming

This biomechanical study of 9 elite female synchronized swimmers established that "important techniques to improve peak height in **thrust movement** are to unroll with a shorter time, not to have low arms at the beginning of the thrust movement, and to turn arms rapidly and catch the water closer to the surface" [**Miwako Homma**]. An unstated number of thrust movements was performed by each swimmer, so the simple analysis of correlations was not appropriate.

The swimming human simulation model

SWUM was used to show that jump height in the **lift move** is sensitive to the timing of motion of the middle and upper swimmers in the group of four [**Motomu Nakashima**].

It was an unnecessarily complicated analysis, but it looks like scores in the **free routines** had clear relationships with the total number of patterns, the number of surface changes, and the performance time of layout positions, while relationships with number of movements and movement times were less clear [Haruka Fujishima].

Water Polo

The two noteworthy presentations were both on **performance analysis** at the 2013 world championships. Successful teams were better at counter attacks in offence and defence, were better at preventing opponents shots, better at action shots, center shots and counter shots, and had better goal keepers [**Itaru Enomoto**]. Compared with the two finalists (Hungary and Montenegro), the eighth-placed Australian team had less dry passes and more water passes leading into a goal shot, more men-up plays, and lower throwing efficacy [Ricardo Fernandes].

Miscellaneous

The transition period between the warm-up and the start of a race is long enough for some of the benefit of the warm-up to be lost. So Courtney McGowan and colleagues did a crossover with 16 age-group swimmers at national level to compare the effects of three additional **warm-up strategies**. Compared with the usual condition of waiting around in a tracksuit for ~30 min, there were enhancements in 100-m freestyle performance time of 0.7% with an electrically heated tracksuit, 1.1% with a normal tracksuit plus 5 min of extra exercise, and 1.8% with the combination of heated tracksuit and extra exercise. Even if a placebo effect is involved, it's worth investing in a heated tracksuit and other suitable apparel to use in conjunction with the right kind of potentiating exercise.

"Increasing **participation** in the target activity is one viable strategy for improving regional performance"—that's the conclusion from an analysis of correlations between number of age-group participants and best 50-yard freestyle swim time in the given age group in the 59 US swimming communities between 2005 and 2010. The mean of the 168 correlations (one for each combination of age, sex and year) was

0.64 [Andrew Cornett]. Conclusion: money spent on grass-roots participation as well as high-performance athletes should reap more medals.

Louise Burke summarized the current status of **carbohydrate** for swimmers and athletes generally. Training on a low-carb high-fat diet and competing on high carb looked promising a few years ago, but it turns out not to enhance endurance, and it impairs the sprint to the finish ("loss of top gear"). So, a high-carb diet is still the best strategy, but the focus is now on the best times to have high-carb feedings in relation to training sessions. Low glycogen following a training session is a stimulus to adaptation, and the stimulus may be reduced if you feed up on carbs straight after training. Delaying replenishment of carbohydrate until the next morning ("train-high sleep-low") may therefore be a good strategy.

Greg Shaw focused on **dietary protein**. There was nothing particularly new here: muscle is sensitized to the anabolic effects of protein feeding for a day following a training session; leucine is the most important amino acid in protein, and it's highest in milk (whey protein) and eggs (egg albumin); and you should consume protein every 4 h or so at the rate of 0.3 g per kg per day (~20 g per day).

There was clear **lane bias** in the performance of 50-m swimmers at the 2013 world championships in Barcelona. The bias must have arisen from a current in the pool. [Chris Brammer]

An Australian **high-performance development squad** selected on the basis of current performance and age would need to have hundreds of swimmers several years out from the Olympic trials to ensure 90% of eventual qualifiers were included in the squad. Targeting resources towards such a large group might further improve those swimmers who would otherwise end up qualifying without the benefit of being in the current smaller squad [Sian

Allen].

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Reviewer's Comment

The BMS conference has a long history in the swimming-research community, celebrated in the opening lecture by **João Paulo Vilas-Boas**. The four-day program provided plenty of opportunities for research updates and the usual networking over morning and afternoon tea. Fortunately the conference program had generous breaks, which was great for catching up with old and new colleagues. There was enough new material, or new insights on traditional questions, at the BMS to make it worthwhile for attendees. This conference report is another comprehensive and informative summary of key presentation themes and outcomes. As usual, Hopkins and colleagues have cast a keen eye on performance outcomes, mechanisms and potential applications of the latest swimming research. The decision to omit discussion of abstracts dealing with lactate or VO₂ measurements is understandable. Emerging and established researchers should focus on projects that could have a substantial impact on performance or provide useful insights into mechanisms, rather than addressing esoteric or academic questions.

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