## Global trends on sports science contribution to elite sports

Iñigo Mujika
PHYSIOLOGY & TRAINING

## The art *vs*. science dilemma

## Is training an art or a science?

- "Training is principally an act of faith" Franz Stamfl, coach of Sir Roger Bannister
- "The training of athletes for strenuous physical activity today is much an art and less of a science" Forbes Carlile, legendary Australian swimming coach
- "Successful training is intelligent training. Intelligent training is knowing the why of an exercise, as well as the what and how" Arthur Lydiard, New Zealand running coach
- "The most important factor in coaching is to be yourself. A lot of coaches try to copy other coaches and other programs. There's a lot of discussion of whether a coach should be scientific or whether one should coach as if it's an art. Every coach should find a personal way of coaching... the way that is best for oneself, because, first of all, coaching is the art of communication " Gennadi Touretski, Coach of Alexandre Popov

Hawley & Burke, *Peak Performance*, 1998

## Is training an art or a science?

- "So much coaching is hit and miss, coaches giving you sessions without knowing why. Everything should have a reason, a scientific base. Every time I went out the door, the session had a purpose, a means to an end. That is where so many get it wrong" Wendy Sly, 1984 Olympics silver medallist
- "The thinking must be done first, before training begins" Peter Coe, Coach and father of Sebastian Coe
- "A systematic approach to training is one of the key factors in becoming a successful athlete. It is not enough to know how to do something, you must know why you are doing it " Greg LeMond, 3-time winner of the Tour de France

Hawley & Burke, *Peak Performance*, 1998

## Where do I stand?

My background

Sports scientist | Laboratory rat | Coach



## This is where I stand

- "Several widely accepted training principles have evolved which are common to most sports and have been studied extensively by sports scientists. When these basic principles are combined with the practical, field-based observations of many coaches, they can provide a framework on which to base more precise and comprehensive sports-specific training recommendations" Hawley and Burke, *Peak Performance*, p. 18, 1998
- The more scientific information you can deal with and make sense of, the bigger the chance of success, but the coaching of athletes to prepare for competition will never be a total science and will always remain an art
- The coach as a "chef"

## What is sports science?

- "Sport science is a multi-displinary field concerned with the understanding and enhancement of human sporting performance. Sport science can be thought of a scientific process used to guide the practice of sport with the ultimate aim of improving sporting performance" Bishop et al., *Int. J. Sports Physiol. Perform.* 1: 161-168, 2006

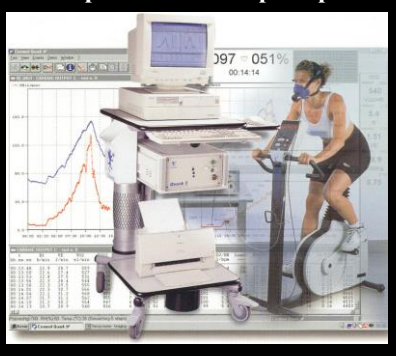
- Sports physiology
- Sports nutrition
- Biomechanics
- Sports psychology
- Sports medicine
- Physiotherapy
- Recovery
- Skill acquisition
- Etc.

→ Athletes' Performance

## Dr. David T. Martin's "Jane Goodall analogy" prior to the Sydney 2000 Olympic Games


- Early genuine interest
- Formal academic training
- Established mentor
- Oportunity to work in the field
- Patient persistence (not productive early on)
- Accepted into the group
- Careful observations
- Made mistakes (altruistic behavior)
- Research not accepted by academics at first
- Influenced but not limited by basic science
- Eventually knowledge makes positive impact

## The sports scientists' perception



## Sport science and coaching

International Journal of Sports Science & Coaching Volume 1 · Number 1 · 2006 77

Exercise Science and Coaching: Correcting Common Misunderstandings About Endurance Exercise

**Andrew N. Bosch, PhD**
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Sports science knowledge has progressed tremendously in the last 20 years in terms of the understanding of many of the underlying concepts in exercise physiology and human performance. Many coaches, however, have failed to take cognisance of the new information and still believe in old and out-dated concepts, many of which frankly are wrong. And it is this incorrect understanding that is then applied to the coaching of athletes.

**Bosch, *Int. J. Sports Sci. Coaching* 1: 77-87, 2006**

## Growth of sport science research

*Journal of Sports Sciences*, January 1st 2008; 26(1): 1–2

EDITORIAL

**The growing trend of scientific interest in sports science research**

Table I. Trends in impact factor for journals indexed in the "Sports Sciences" subject category of the ISI database, 2003–2006.

| Year | Journals (*n*) | Articles (*n*) | Total cites | Median impact factor | Aggregate impact factor | Aggregate cited half-life |
|---|---|---|---|---|---|---|
| 2003 | 71 | 4934 | 102 040 | 0.835 | 1.371 | 8.2 |
| 2004 | 71 | 5067 | 110 966 | 0.861 | 1.373 | 8.2 |
| 2005 | 70 | 5243 | 124 262 | 0.955 | 1.559 | 8.1 |
| 2006 | 73 | 5536 | 135 671 | 1.099 | 1.640 | 8.1 |

The growing trend of scientific interest in sports science journals clearly attests that sports science is facing a new paradigm shift, moving towards a new system based on a real scientific background, solid professional competences, and expanded horizons.

**Lippi et al., *J. Sports Sci.* 26: 1-2, 2008**

## The sports scientists' perspective on their contribution

*Journal of Sports Sciences*, February 15th 2008; 26(4): 413–426

**Twenty-five years of sport performance research in the *Journal of Sports Sciences***

ALAN NEVILL[1], GREG ATKINSON[2], & MIKE HUGHES[3]

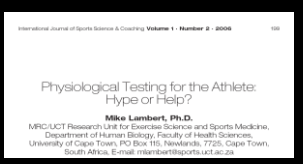
[1]*School of Sport, Performing Arts and Leisure, University of Wolverhampton, Walsall,* [2]*Institute of Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, and* [3]*Sport and Physical Education, University of Wales Institute, Cardiff, UK*

Sports scientists, coaches, and athletes are continuously looking for ways to provide a slight, legal advantage in athletic performance. Over the past 25 years, the Sports Performance section of the *Journal of Sports Sciences* has provided athletes and their coaches with valuable insights on how they can obtain such an advantage.

**Nevill et al., *J. Sports Sci.* 26: 413-426, 2008**

## The coaches' perception

## Physiological testing and sports performance



International Journal of Sports Science & Coaching Volume 1 · Number 2 · 2006 199

Physiological Testing for the Athlete: Hype or Help?

**Mike Lambert, Ph.D.**
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The aim of this paper is to examine the process of gathering relevant information from the athlete from the perspective of using that information to optimise performance. This focus is pertinent as, unfortunately, some scientists have tried to contribute and make an improvement to sports performance by random physiological testing, based on the assumption that any information gathered can be interpreted and used by the coach. In many cases this testing does little to contribute to improving performance as it has either been for research purposes or has been done without a clear goal. This type of testing usually generates results that cannot be applied by the coach and increases the credibility gap that exists between the coaches and scientific/medical support staff.

**Lambert, *Int. J. Sports Sci. Coaching* 1: 199-208, 2006**

## Knowledge transfer between sport scientists and coaches

International Journal of Sports Science & Coaching Volume 3 · Number 3 · 2008 319

Knowledge Transfer: How do High Performance Coaches Access the Knowledge of Sport Scientists?

**Ian Reade, Wendy Rodgers and Nathan Hall**
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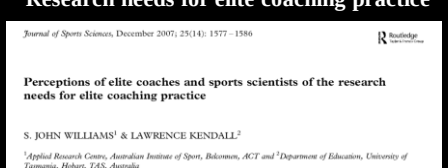
E-mail: ian.reade@ualberta.ca

Gaps exist between what coaches are looking for and the research that is being conducted, especially in the area of tactics and strategies. Coaches are most likely to consult other coaches, or attend coaching conferences to get new information. Sport scientists and their publications were ranked very low by the coaches as a likely source of sport science information. The barriers to the coaches' access to sport science are the time required to find and read scientific journals, and lack of direct access to a sport scientist. Strategies to remove the barriers could include rewarding sport scientists for successful transfer of their knowledge to practice through direct communication with coaches.

**Reade et al., *Int. J. Sports Sci. Coaching* 3: 319-334, 2008**

## Research needs for elite coaching practice



*Journal of Sports Sciences*, December 2007; 25(14): 1577 – 1586

Routledge

**Perceptions of elite coaches and sports scientists of the research needs for elite coaching practice**

S. JOHN WILLIAMS[1] & LAWRENCE KENDALL[2]

[1]*Applied Research Centre, Australian Institute of Sport, Bokomen, ACT and* [2]*Department of Education, University of Tasmania, Hobart, TAS, Australia*

Targeting research to enhance athletic performance is one-half of the research process. The other (from an athletic performance perspective) is to disseminate findings appropriately to those who will implement those findings in the preparation of athletes. Coaches and researchers agreed research findings need to be translated into easily understood language, supporting claims made in the literature (Sands, 1998; Thompson, 1982) regarding the need to disseminate research more directly to coaches.

**Williams & Kendall, *J. Sports Sci.* 25: 1577-1586, 2007**

## Sporting legends, coaching gurus and sport science geeks

| Name | Sport | Income |
|---|---|---|
| Tiger Woods | Golf | $110 M |
| Kobe Bryant | Basketball | $45 M |
| Michael Jordan | Basketball | $45 M |
| Kimi Raikkonen | Formula 1 | $45 M |
| David Bekham | Football | $42 M |

| Name | Sport | Income |
|---|---|---|
| Luiz F. Scolari | Football | $24 M |
| Jose Mourinho | Football | $16 M |
| Fabio Capello | Football | $13 M |
| Phil Jackson | Basketball | $10 M |
| Alex Ferguson | Football | $10 M |

| Position | Industry | Income |
|---|---|---|
| Sport scientist | Private sector | $300 K |
| Sport Scientist | Pro team | $100-250 K |
| Sport scientist | Sport Institute | $60-100 K |
| Sport scientist | University | $60-120 K |

## Bridging the gap

## Applied research model for the sport sciences

REVIEW ARTICLE

An Applied Research Model for the Sport Sciences

*David Bishop*

Faculty of Motor Science, University of Verona, Verona, Italy

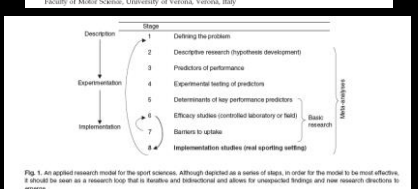



Fig. 1. An applied research model for the sport sciences. Although depicted as a series of steps, in order for the model to be most effective, it should be seen as a research loop that is iterative and bidirectional and allows for unexpected findings and new research directions to emerge.

**Bishop, *Int. J. Sports Sci. Coaching* 1: 89-100, 2006**

## Merging sports science and coaching to enhance performance

International Journal of Sports Science & Coaching Volume 1 · Number 1 · 2006 89

Enhancing Sport Performance: Merging Sports Science with Coaching

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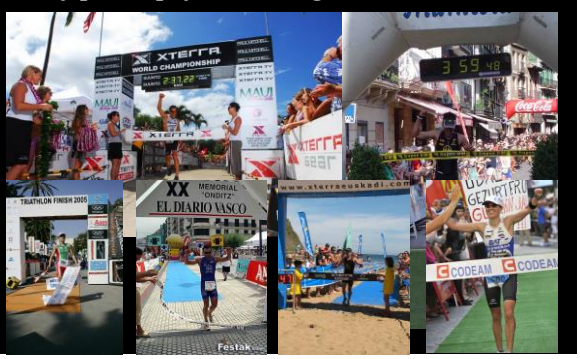
Just as a puzzle is made up of many pieces, a successful merger of sport science and coaching involves many components. To ensure a successful outcome, communication, organization, attention to detail, adopting a comprehensive outlook, and proper habituation of athletes should be kept at the forefront. Coaches, athletes, and especially the sport science professionals should be on the same page. Sport skill assessments should be selected that are pertinent to the sport, player position, and skill level, and that the tests are properly conducted by qualified staff. Pay attention to details and stay consistent, but flexible, with interpretation and utilization of available sport science information and norms. Scientific information and standards are constantly changing, serve only as guidelines, and must be realistically adapted to the athlete's specific training environment.

**Meyers, *Int. J. Sports Sci. Coaching* 1: 89-100, 2006**

## My philosophy of working with elite athletes




## Sport Scientist

## Research built around sport training and performance

➡ Swimming


## Research built around sport training and performance

➡ Cycling

## Research built around sport training and performance

**Running**


## Research built around sport training and performance

**Football**


## Research built around sport training and performance

**Water polo**


## Research built around sport training and performance

**Rowing**

## Research built around sport training and performance

- Tennis

Caffeine, Carbohydrate, and Cooling Use During Prolonged Simulated Tennis

Fatigue in Tennis
Mechanisms of Fatigue and Effect on Performance

ORIGINAL ARTICLE
An integrated physiological and performance profile of professional tennis

## Training quantification

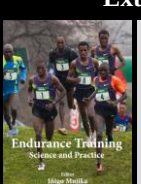
## The alphabet of sport science research starts with Q

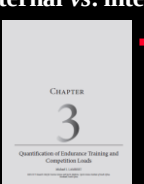
The Alphabet of Sport Science Research Starts With Q

- "I still consider the quantification of training a cornerstone of athletic preparation for competition and a key issue when it comes to good sports science research."
- "It is not possible to identify the effects of training without a precise quantification of the workload."
- "Without precise, thorough and in-depth information about training, the findings of a training study are of very little or no value."

**Mujika, *Int J Sports Physiol Perform*. 8: 465-466, 2013**

## External *vs.* internal training load



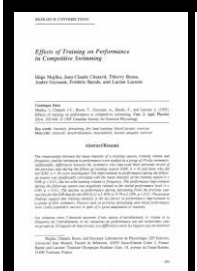




- "The external training load is an objective measure of the work that an athlete completes either during training or competition and is measured independently of the internal workload."
- "The internal workload is the biological stress imposed by the training session and is defined by the disturbance in homeostasis of the physiological and metabolic processes during the exercise training session."
- "The external training load does not measure the biological stress imposed by the training session."

**Lambert. In: *Endurance Training – Science and Practice*, 21-28, 2012**

## Relating external load and performance in swimming


## Swimming research based on quantification of the external load and performance



*Effects of Training on Performance in Competitive Swimming*

Modeled responses to training and taper in competitive swimmers

Use of swim-training profiles and performance data to enhance training effectiveness

Mujika et al., *Can J Appl Physiol.* 20: 395-406, 1995

Mujika et al., *Med Sci Sports Exerc.* 28: 251-258, 1996

Mujika et al., *J Swimming Research* 11: 23-29, 1996

## Training intensity distributions in elite swimmers

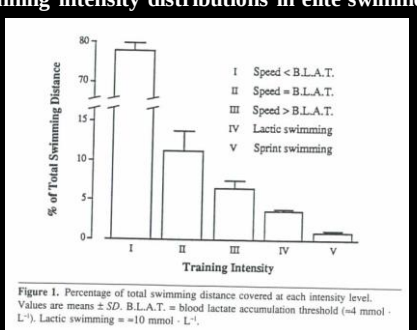



**Figure 1.** Percentage of total swimming distance covered at each intensity level. Values are means ± *SD*. B.L.A.T. = blood lactate accumulation threshold (≈4 mmol · $L^{-1}$). Lactic swimming = ≈10 mmol · $L^{-1}$.

Mujika et al., *Can. J. Appl. Physiol.* 20: 395-406, 1995

## Training intensity and performance gain in elite swimmers

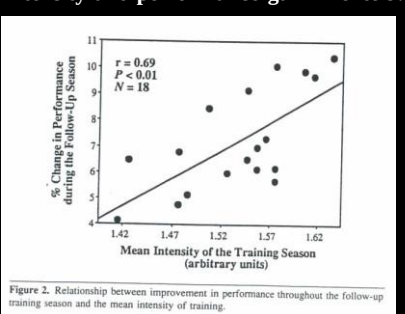
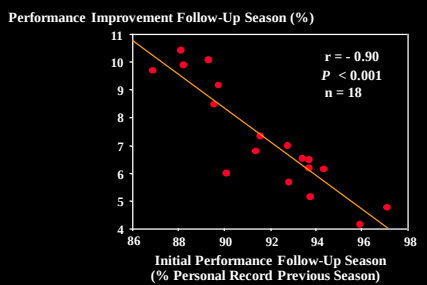



**Figure 2.** Relationship between improvement in performance throughout the follow-up training season and the mean intensity of training.

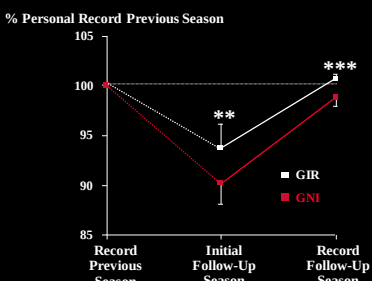
Mujika et al., *Can. J. Appl. Physiol.* 20: 395-406, 1995

## Initial level – Performance relationship



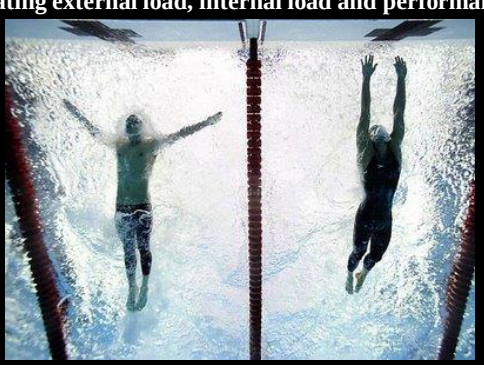

Mujika et al. *Can. J. Appl. Physiol.* 20: 395-406, 1995

## Comparison GIR - GNI




Mujika et al. *Can. J. Appl. Physiol.* 20: 395-406, 1995

## Relating external load, internal load and performance



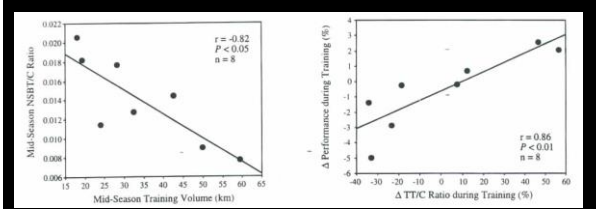
## Swimming research based on quantification of the external load, internal load and performance

Mujika et al., *Eur J Appl Physiol.* 74: 361-366, 1996

Mujika et al., *Int J Sports Med* 17: 213-217, 1996

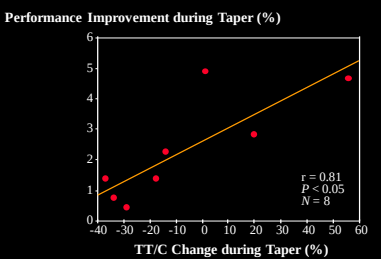
Mujika et al., *Arch Physiol Biochem.* 105: 379-385, 1997

## T/C ratio, training volume, performance relationship



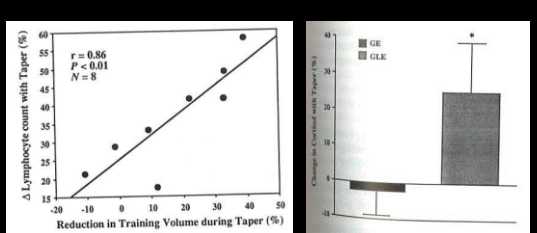

Mujika et al. *Eur. J. Appl. Physiol.* 74: 361-366, 1996

## TT/C ratio-Performance relationship



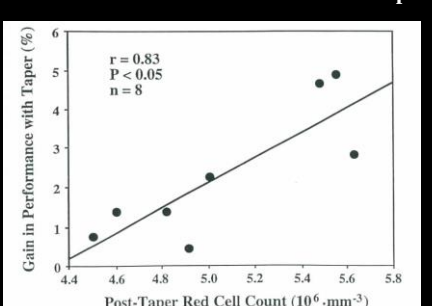

Mujika et al. *Eur. J. Appl. Physiol.* 74: 361-366, 1996

## Lymphocytes, cortisol, training volume, performance relationships



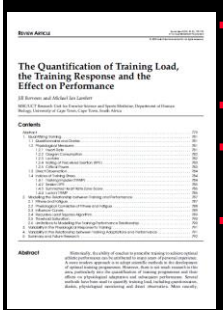

Mujika et al. *Int. J. Sports Med.* 17: 213-217, 1996

## Red cell count-Performance relationship




Mujika et al. *Arch. Physiol. Biochem.* 105: 379-385, 1997

## The quantification of training load, the training response and the effect on performance



The Quantification of Training Load, the Training Response and the Effect on Performance

- "There is currently no accurate quantitative means with which to describe the pattern, duration and intensity of exercise required to produce specific physiological adaptations."
- "Added to this is the fact that individuals adapt differently to the same exercise stimulus."
- "Despite years of research, no single physiological marker has been identified that can quantify the fitness and fatigue responses to exercise or predict performance with accuracy."
- "Thus, more emphasis needs to be directed towards the measurement of markers that reflect an individual's global capacity to respond or adapt to training, rather than an absolute measure of the changes in physiological variables in response to exercise."

Borresen & Lambert, *Sports Med.* 39: 779-795, 2009

## In the age of technology, Occam's Razor still applies

In the Age of Technology, Occam's Razor Still Applies

- "Whilst we must continue to encourage innovation, we must also maintain effective industry practices and protect the integrity of our discipline."
- "We should avoid the temptation to overutilize the technology and all its data, before proof of concept and validity and reliability trials are completed."
- "Without the ability to separate the signal and noise in the measures, we cannot make meaningful inferences on practice."
- "We should also look to establish parsimonious systems that are both cost- and time-effective."
- "This scientific approach will alow us to take advantage of the recent technological advancements and best position us to have a positive impact on elite sporting performance."

Coutts, *Int J Sports Physiol Perform.* 9: 741, 2014

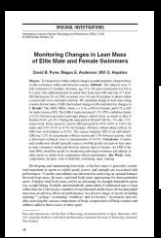
## Scientific follow-up of elite swimming

## Body composition, hydration status, blood lactate testing and altitude training

## Body composition and swimming performance

"The best single predictor of competition performance was skinfolds for females (r = -0.53)"

Anderson et al. *J. Sports Sci.* 26: 123-130, 2008



77 elite swimmers from the A.I.S.

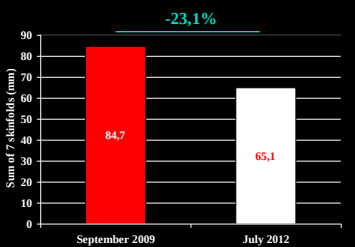
Table 1 Descriptive Statistics for the Participants

| Parameter | Females (n = 31) Mean ± SD | Range | Males (n = 46) Mean ± SD | Range |
|---|---|---|---|---|
| Number of tests | 24 ± 27 | 3–106 | 29 ± 27 | 4–120 |
| Starting age (y) | 18.2 ± 2.7 | 14.7–25.5 | 19.7 ± 2.4 | 15.6–23.5 |
| Time in program (y) | 3.0 ± 2.5 | 0.2–9.2 | 3.5 ± 2.2 | 0.4–9.0 |
| Mean mass (kg) | 64.9 ± 9.0 | 51.4–78.1 | 82.1 ± 7.9 | 66.1–99.6 |
| Mean skinfolds (mm) | 87.6 ± 12.0 | 49.0–100.5 | 49.2 ± 9.0 | 32.8–86.6 |
| Mean lean-mass index | 32.8 ± 2.8 | 26.5–37.7 | 48.2 ± 4.5 | 36.8–59.4 |

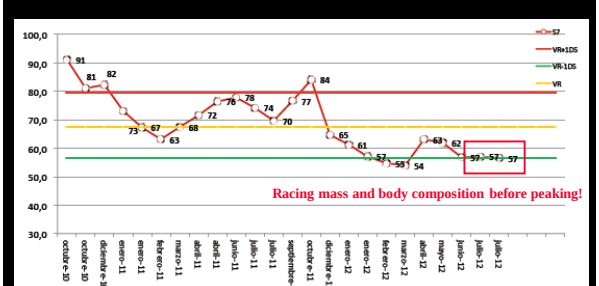
Pyne et al. *Int. J. Sports Physiol. Perform.* 1: 14-126, 2006

## Skinfold measurements Spanish swim team

- ≈ 300 Σ of 7 skinfold measurements September 2009- July 2012
- Σ of 7 skinfolds Spanish swim team (females)




## Σ of 7 skinfolds Mireia Belmonte




Racing mass and body composition before peaking!

## Hydration status Spanish swim team

- ≈ 500 U.S.G. measurements September 2009- July 2012
- Educate the athletes on the importance of hydration

## Blood lactate testing Spanish swim team

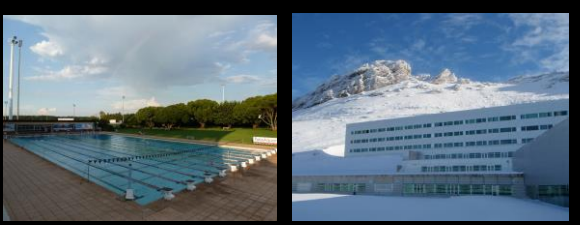
Anderson et al. *Eur. J. Sport Sci.* 6: 145-154, 2006

**"While routine testing offers insight into the training process, the relationship between testing and competitive performance in international swimmers remains uncertain and needs to be addressed."**

- Testing during standardised training sets
- Testing "à la carte" (i.e. on coaches' request)

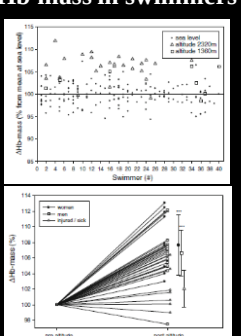
## Altitude training with Mireia Belmonte 2011-2012

- October 2011: 4 weeks in Sierra Nevada (2320 m)
- January 2012: 2 weeks in Pretoria (1500 m)
- February 2012: 4 weeks in Sierra Nevada (2320 m)
- June 2012: 4 weeks in Sierra Nevada (2320 m)



## Altitude training and Hb mass in swimmers

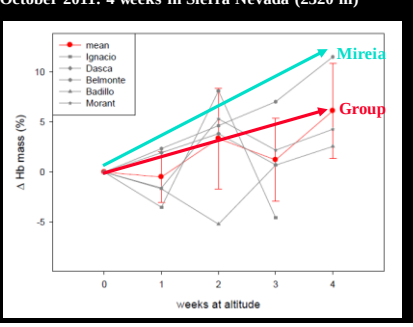
The effects of classic altitude training on hemoglobin mass in swimmers




Wachsmuth et al. *Eur. J. Appl. Physiol.* 113: 1199-1211, 2013

## Δ Hemoglobin Mass C.N. Sabadell October 2011

- October 2011: 4 weeks in Sierra Nevada (2320 m)



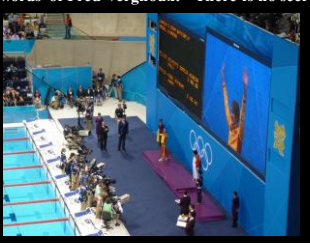
## Altitude training with Mireia Belmonte June 2012

4 weeks in Sierra Nevada (2320 m) → 447 km + 48 h dryland training


3 weeks in simulated altitude (3200 m)

## Training summary of Mireia Belmonte's Olympic season

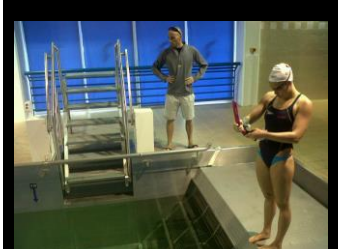
- 50 weeks of training divided in two macrocycles (33 + 17 weeks)
- Mean weekly swimming volume: 84 km
- Mean daily training: 5 hours swimming + 2 hours dryland
- In the words of Fred Vergnoux: "There is no secret!"

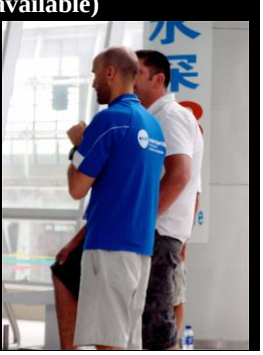


## Recommendatios for athletes and coaches

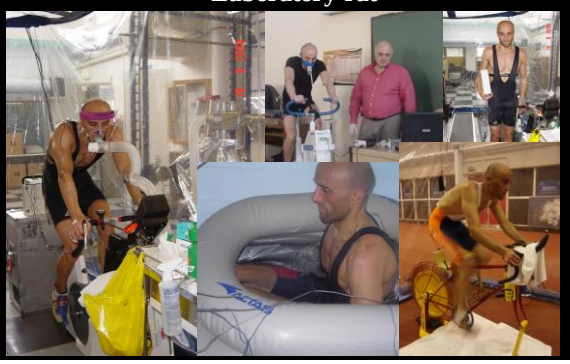
- Recommendations on nutrition
  - Early season
  - Intensive training
  - Recovery
  - Tapering
  - International travel
  - Nutritional ergogenic aids
  - Olympic village
- Optimizing body composition
- Proactive recovery protocols
- Managing time zone changes in international competition
- Minimizing the risk of infection

## "Face time" (i.e. be there for athletes and coaches, make yourself available)





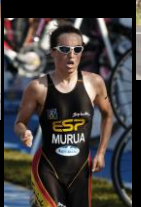
## Laboratory rat



## Coach


## Coaching style must be adapted to the individual athletes

Hektor Llanos




Ainhoa Murua

Eneko Llanos

Virginia Berasategui

## Communication

## Listening to your athletes

Some experienced athletes know exactly what they need

•2005, week 36: 2nd XTerra Spain
•"I need leg strength after all this IM training"
•Weeks 37-47: 20 sessions 2-3x8@75-80%1RM

•2005, week 40: Winner XTerra US Championships Lake Tahoe

•2005, week 43: 2nd XTerra World Championships Maui, after riding 50% of the bike leg on a flat tire

•2005, week 48: 2nd Ironman Western Australia, Busselton

## Friendship

## ESKERRIK ASKO!
## ("Thank you very much!" in Basque Language)

Iñigo Mujika
PHYSIOLOGY & TRAINING