ADVANCED SPORT TECHNOLOGIES: Enhancing OLYMPIC PERFORMANCE

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INTRODUCTION: In the extremely demanding environment of Olympic sport, the difference between standing on the podium and finishing "in the pack" can often be fractions of a percentage point. Coaches and athletes are thus constantly striving to find effective ways to improve sport performance. Biomechanists, physiologists, sport psychologists, strength and conditioning specialists, engineers, and computer scientists offer coaches and athletes an integrated, coordinated approach that is specifically designed to unlock each athlete's ultimate performance capability.

As athletes enter their final preparation phases for major competitions, skill refinement, effective equipment integration, visualization, and strategic planning become important goals. Although in-depth biomechanical analyses provide relevant background information useful in achieving these goals, rapid performance feedback systems are emerging as the coach's choice when crunch time arrives. In particular, coaches are now less tolerant of the months, weeks, and even days they often have to wait for test results and data interpretation. As such, novel and rapid performance measurement and feedback tools are becoming more pervasive in the training environment.

The USOC Coaching and Sport Sciences Division has developed and integrated rapid performance feedback systems into several Olympic sport programs. In many cases, the systems represent novel applications of emerging technologies to Olympic sport. In others, the systems simply capitalize on today's high computational speeds to accelerate data processing and thus feedback. This presentation provides Olympic sport program examples in which advanced technologies have been used to enhance performance.

Video-Overlay Feedback System - Boxing

Since 1998, USA Boxing has been using a specially designed instrumented boxing bag as part of their training and competition preparation. The instrumented bag was developed by biomechanists and engineers in collaboration with USA Boxing coaches to assess punching performance of the athletes.

The bag is part of a system that combines microsensors with video technologies. Minute accelerometers are positioned deep within the bag. The accelerometers measure movements of the bag in response to a boxer's punch. Since the mass of the bag is known, Newton's Second Law allows the impact force to be calculated. This information, along with other timing and motion data, is combined with video of the boxer (via a process called *video-overlay*) to create a graphic that combines qualitative technique analysis with quantitative punch analysis (Figure 1). The graphic is videotaped as the boxer performs a simulated round (usually 3 minutes in duration), and can be reviewed by the athlete and coach immediately after the completion of the performance. Since video, punch forces, and punch timing are displayed together, the coach and athlete can quickly see the impact of technique modifications on punch effectiveness. Similar video-overlay systems have been developed for bobsled, luge, shooting, and speedskating.

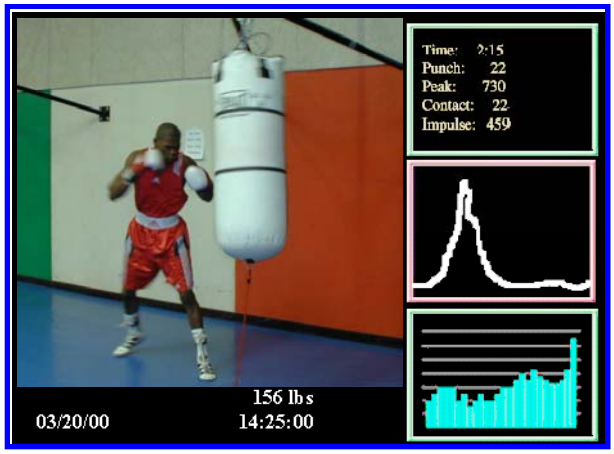

Figure 1 - USOC boxing analysis system. Video information is combined with processed force and timing data in a single presentation. Information is viewed by the coach during data collection, while being simultaneously transferred to videotape for subsequent review with the athlete.

Immediate Feedback to Coaches – Rowing

In 1994, the USOC launched its Rowing Data Acquisition System (DAS), designed to provide on-water biomechanical analyses of rowing technique. The US National Teams used the system in preparation for the 1996 Atlanta Olympic Games, and the women continued to incorporate the Rowing DAS into their training programs leading to Sydney.

Specialized sensors measure oar bending and oar position (in the horizontal plane), and boat velocity. Data are measured on four rowers simultaneously, processed on-board, and transmitted to a receiver located on the coach's launch. As the athletes row, the coach views individualized (rower-specific) rowing "style," evaluates crew synchronicity and uniformity, examines relationships between rowing technique and boat response, and provides immediate verbal feedback to the crew.

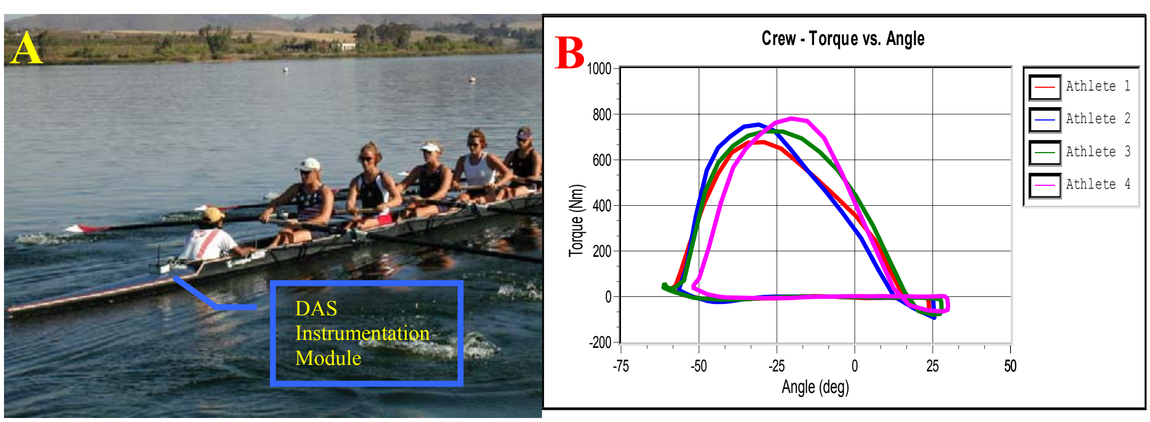

Figure 2 - The on-board module (on the boat deck in Panel A) collects biomechanical data (oar bending and oar angle) from four rowers, plus boat velocity, and transmits it to the coach's launch. Rowing power curves in Panel B depict oar torque versus oar angle. The area within the torque/angle envelope is the work performed by each rower.

Rowing data is also post-processed after a training session to perform more in-depth analyses of rowing technique. These analyses address coach's questions such as:

- How much power does each athlete produce during a given training effort?
- How do stroke rate, stroke length, and oar geometry (blade shape, rigging) affect rower power delivery and boat performance?
- Which rowers waste oar motion at the catch (blade entry) and/or finish (blade exit) of the stroke?

Real-Time Feedback – Cycling

Evaluations of pedaling mechanics have been performed on junior and national team cyclists at the USOTC since 1989. The primary tool used for these evaluations is a set of dual-piezoelectric force pedals. The pedals (Figure 3A) contain two force transducers which measure applied forces in the normal (straight into the surface), medial-lateral (side-to-side) and shear (fore-aft) directions. Additionally, the location (side-to-side) of the applied load and any torque developed between the cycling shoe and the pedal (about a vertically oriented axis) are measured. Digital encoders measure pedal orientation with respect to the crank, and crank orientation with respect to the bicycle.

New specialty software provides rapid feedback of critical pedaling technique variables. Pedaling mechanics data are collected in the laboratory during controlled bouts of pedaling on a bicycle mounted to a fixed-frame trainer. Data describing several pedal revolutions are collected and graphically displayed on a computer screen (Figure 3B). The data may be displayed in *real-time* (as the cyclist is pedaling) or in summary fashion (whereby multiple pedaling cycles are averaged to describe the cyclist's typical pedaling technique). Furthermore, verbal and written feedback describing critical findings may be given to coach and athlete in report form following the test session. With real-time feedback, cyclists have the opportunity to practice technique modifications and view the results while they pedal, developing and reinforcing motor patterns that produce more effective pedaling.

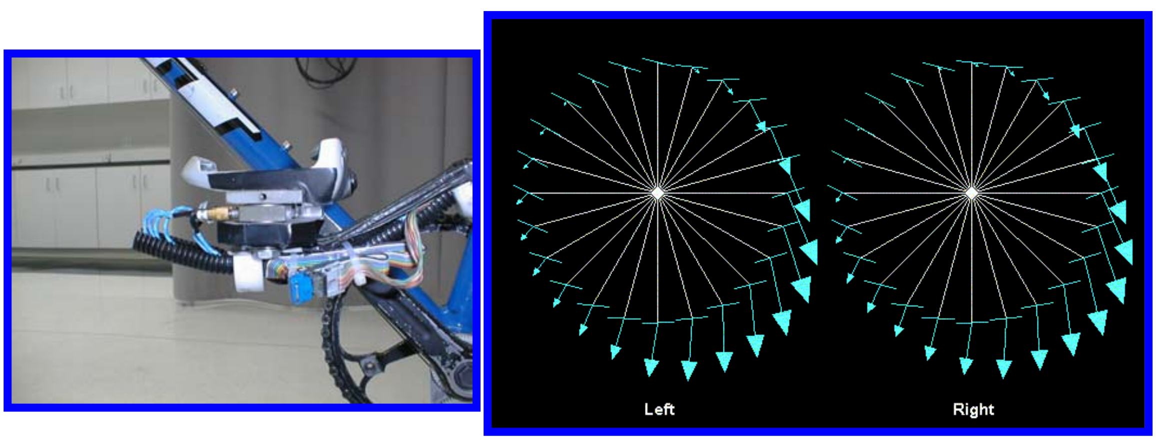

Figure 3 - Instrument bicycle pedal used for pedaling mechanics evaluations (left panel). Clock diagrams (right panel) showing magnitude and direction of applied forces for a national team rider pedaling at 300 watts, 100 rpm. These diagrams are usually displayed during real-time feedback.

Movement Analysis Using Timing Systems – Volleyball Block Jumping

A volleyball jump analysis program was initiated in 1998 to characterize Women's National Team jump performance. Maximal countermovement jumps, with and without the arms, were performed on a Kistler 90 cm x 60 cm force platform. *Jump height* and *propulsion time* were determined. *Jump height* was calculated from the ground reaction force versus time, and *propulsion time* represented the elapsed time from when the athlete was at the lowest point of the countermovement (maximum knee and hip flexion) to takeoff. Other variables (e.g., peak power, peak force) were calculated and analyzed.

Next, block jumps were performed. A new *laser-based timing system* allowed us to isolate and characterize critical events within block jumps. In one mode (middle-blocking), a stimulus cued individual athletes to jump, from a block-ready position, to make two-hand contact with two balls supported 8 feet 5 inches above and 11 inches across a volleyball net. The stimulus arrived between 0.5 and 5 seconds after the athlete was determined to be ready. In a second mode (option blocking), a randomly presented stimulus (presented at a known time) cued the athletes to block one of three balls, again located on the opposite side of the net, but spaced apart in middle, right or left positions. A laser beam passing parallel to the net, one inch behind each of the three balls, triggered the timing system when ball motion occurred. Figure 4 illustrates the test setup.

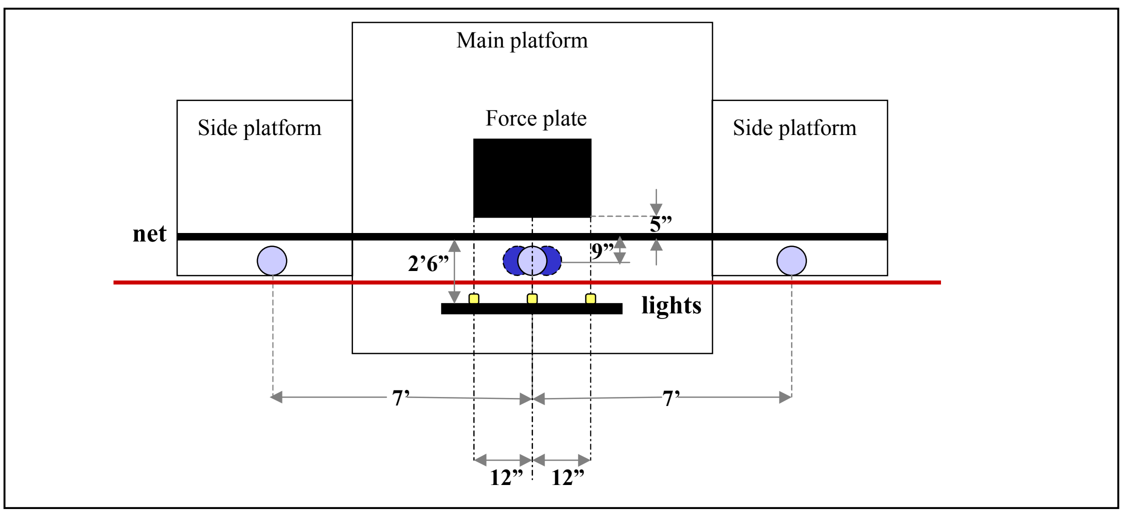

Figure 4 - Volleyball jump/timing analysis setup.

Jump height and propulsion times (for middle blocks) were measured as described earlier, along with *reaction time* and *overall movement time. Reaction time* was the time elapsed between illumination of the light stimulus and the first sign of change in the ground reaction force (Figure 5). *Movement time* was the time elapsed between illumination of the light stimulus and when the laser beam passing just behind the balls was broken (Figure 5). *Movement time* thus measured how quickly the athlete responded to the stimulus and actually executed the block.

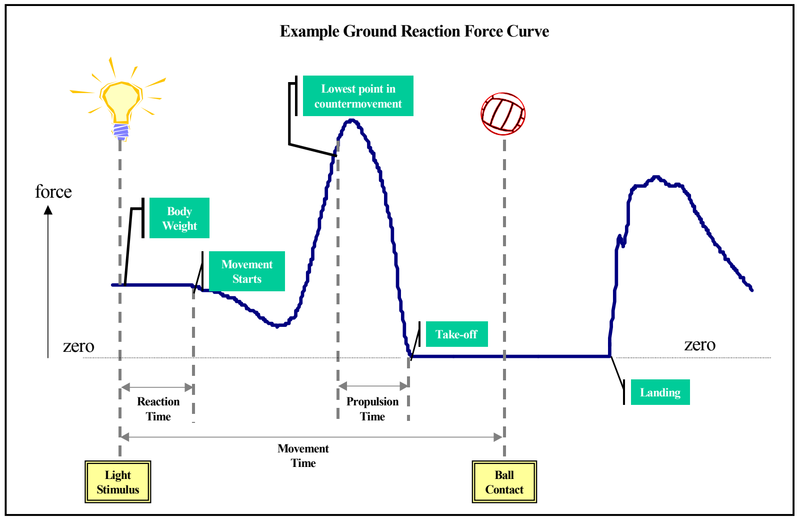

Figure 5 - Timing variables derived from the volleyball blocking vertical jump ground reaction force trace.

Maximal jump heights and propulsion times for each athlete were provided across the various jumps to characterize jump capability. Athletes were grouped according to their performances (high-fast, high-slow, low-fast, low-slow) for purposes of athlete-specific strength and conditioning program design. Timing data provided a quantitative description of each athlete's ability to react to varying block situations. In a subsequent version of the system, the light stimulus was replaced with a finger sensor attached to the setter's hand, allowing set deception and set "reading" to be part of the test.

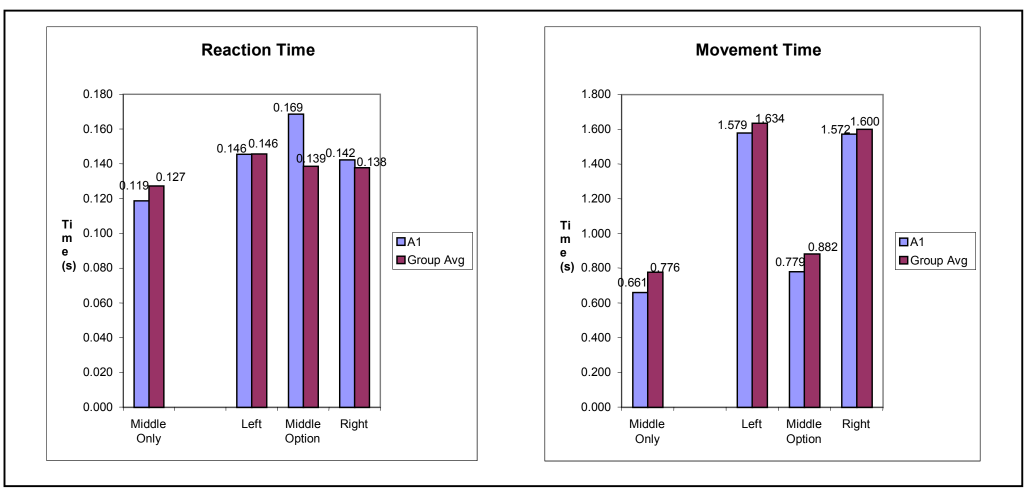

Figure 6 - Exemplar reaction and movement time data collected with the volleyball block and jump analysis system. Individual athlete data (blue bars) are shown relative to the group averages (red bars).

SUMMARY: The examples provided represent a variety of rapid, sport-specific data collection, analysis, and feedback systems in use today in the Olympic training environment. These and similar systems augment traditional, more labor-intensive quantitative analyses to provide Olympic coaches and athletes innovative and effective support as they strive for success at the highest level.