The athlete monitoring cycle: a practical guide to interpreting and applying training monitoring data

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I WANT TO MONITOR MY ATHLETE BUT WHERE DO I START?

Given the relationships among athlete workloads, injury[1] and performance,[2] athlete monitoring has become critical in the high-performance sporting environment. Sports medicine and science staff have a suite of monitoring tools available to track how much 'work' an athlete has performed, the response to that 'work' and whether the athlete is in a relative state of fitness or fatigue. The volume of literature, coupled with clever marketing around the 'best approaches' to optimising athlete performance, has resulted in practitioners having more choices than ever before. Furthermore, the range of different practices used in sport and the lack of agreement between parties emphasise the importance of having a clear rationale for athlete monitoring. The aim of this paper is to provide a practical guide to strategic planning, analysing, interpreting and applying athlete monitoring data in the sporting environment irrespective of data management software.

WHAT SHOULD I DO WITH ALL OF THESE DATA AND HOW DO I CHOOSE WHAT TO MEASURE?

When deciding on the athlete monitoring tools to use with your athletes, the first question one should ask is "What do I want to achieve through athlete monitoring?" Quite commonly, the answer is to maximise the positive effects (eg, fitness, readiness and performance) and minimise the negative effects (eg, excessive fatigue, injury and illness) of training. Once practitioners know the reasons for athlete monitoring, appropriate tools can be chosen in order to answer the athlete monitoring question.

For example, if practitioners wish to maximise 'fitness' and minimise 'fatigue', then appropriate monitoring tools to measure these outcomes are necessary. Measurement of fitness improvements for a Premier League football player (eg, a Yo-Yo test) will be very different from an American football player (eg, a maximum strength test). On the other hand, the measurement of external load and response to this load in baseball pitchers will likely require counting balls thrown (and speed) and the internal response to that external load (eg, 'arm health'). High-speed running is important for football, but less important for a baseball pitcher. In this respect, the ideal performance test and workload 'metric' should be context and sport-specific. Thus, understanding the physical demands of the sport and the physiological capacities required of the sport is critical in this decision-making process. Database management, data cleaning and statistical analysis skills are important for practitioners, but when first starting with a question, "What do I want to achieve through athlete monitoring?", analysing and interpreting the data become much easier.

HOW DO I ANALYSE AND INTERPRET THE DATA?

Sports medicine and science practitioners can now use global positioning technology,[3] inertial measurement sensors[4 5] and quantify a range of physiological responses (eg, heart rate variability, testosterone and cortisol concentrations, creatine kinase and the duration and quality of sleep). With such a range of monitoring tools available and no agreement on the most appropriate athlete monitoring 'system', it is difficult for practitioners to evaluate the available evidence and develop a process to effectively monitor athletes. A second challenge facing practitioners is how to (1) manage the 'large' amounts of data collected, (2) make meaningful interpretations of these data to inform subsequent training prescription and (3) translate these interpretations into actionable steps for all relevant stakeholders (eg, sport coaches, performance and medical staff).

In clinical practice, and the high performance sport setting, practitioners typically work with individual patients and athletes (even in team sports) and are therefore interested in individual responses and whether these changes are *practically meaningful*. In these environments, traditional null hypothesis testing (ie, using a $p<0.05$ statistical significance test) is limited as even a small change (which may have a potentially positive or negative effect) may be interpreted as having no effect (ie, $p>0.05$) due to factors such as small sample size. We would suggest the use of SDs, z scores, and the *smallest worthwhile change* statistic (also commonly referred to as the minimum clinically important difference)[6] to determine whether athletes have deviated (either positively or negatively) from 'normal', although practitioners should be aware of the potential limitations of these approaches.[7]

THE ATHLETE MONITORING CYCLE

Below we provide a step-by-step strategy for interpreting athlete monitoring data from the exposure of athletes to a single external training stimulus, through to the subsequent exposure of another training stimulus (figure 1). The inner cycle describes (1) the workload the athlete performed (ie, external load), (2) the athlete's response to the workload (ie, internal load), (3) whether the athlete is tolerating the workload (ie, perceptual well-being) and finally (4) whether the athlete is physically and/or mentally prepared for exposure to another training stimulus (ie, readiness to train/compete).

When combined with each previous step, the subsequent step of the cycle provides insight into how to interpret the data and prescribe an intervention (eg, additional training or extra recovery) to facilitate appropriate training adaptations. To assist decision-making for the practitioner, we have produced a matrix at each step of the cycle. These matrices are interpreted using *magnitude-based inferential statistics*, such as the smallest worthwhile change (for more detail see refs 6 and 7).

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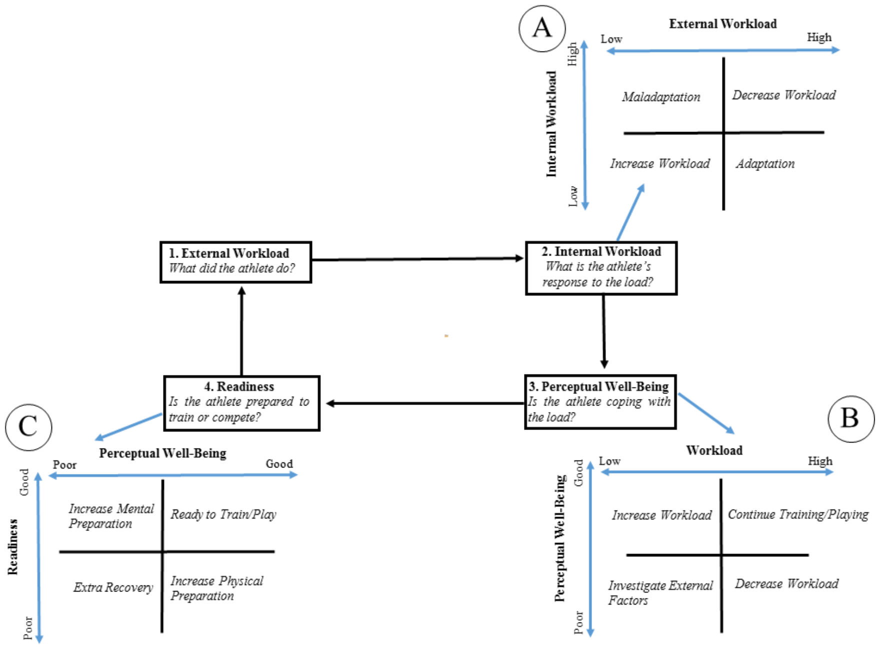

Figure 1 The athlete monitoring cycle.

For example, we first examine the relationship between external load and internal load (figure 1A). If an athlete has performed a greater external workload than planned and their internal workload is also higher than expected, it may be necessary to decrease workload. Maladaptive training responses may also be identified. Combining measures of workload with perceptual well-being scores[8] provides insight into whether the athlete is tolerating training (figure 1B). For example, factors other than high workloads can contribute to poor well-being; if athletes report that they are not coping with the training programme despite performing low workloads, investigation of additional life stressors and lifestyle factors may be warranted. High workloads are not the only reason why an athlete may be experiencing poor well-being.

Finally, many programmes include either a subjective or objective measure of 'readiness to train/compete'. These objective markers may include short (~3–6 s) maximal effort cycle ergometer tests,[9] counter-movement jumps[9] or submaximal heart rate recovery tests.[8] Combining perceptual well-being scores with these 'physical readiness' measures provides the final step in the training monitoring cycle (figure 1C). Depending on the combination of perceptual well-being and physical readiness, athletes may be ready to train/compete, require additional mental or physical preparation, or extra recovery before exposure to another training stimulus. Music, relaxation (eg, brief naps and meditation), nutrition (eg, caffeine) and soft tissue therapy (eg, physiotherapy, massage or foam rolling) may form some of the physiological and/or psychological strategies available to athletes. Athlete monitoring should not be viewed as a means of managing athletes away from training; if athletes are experiencing lower than normal 'readiness', then extra recovery is not the only option available to practitioners.

USE DATA TO SUPPORT COACHES, NOT REPLACE THEM

Because athlete monitoring has wide acceptance, practitioners risk becoming a pariah if they do not implement some form of athlete monitoring system. The proposed monitoring cycle discussed above provides a practical road map for informing performance decision-making. We would suggest that viewing external workload, internal workload, perceptual well-being and readiness to train/compete data in combination provides more meaningful individual training prescriptions than making interpretations based on data from any single athlete monitoring tool in isolation.

It is likely that the proposed monitoring cycle will have greater impact if accompanied by an education programme designed to encourage involvement from key stakeholders (eg, sport coaches) as well as complement the intuition (ie, 'gut feel') of these individuals. But the real challenge arises in creating tailored and palatable dissemination strategies for the relevant stakeholders involved in sport.

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