Identifying readiness to train: when to push and when to pull

By **Anthony Turner, Chris Bishop, Matt Springham,** and **Perry Stewart,**
London Sport Institute, Middlesex University

INTRODUCTION

Monitoring training load – and in particular an athlete's ability to cope with it – is now common practice; often the data is used to define an athlete's 'readiness' to train. The aim of this monitoring is to identify when athletes should be rested, when they can train as per normal, and when they can have their training load ramped up. Crudely put, this monitoring provides a 'push or pull' diagnosis to each athlete's training day. In this context, push defines an increase in training load, whereas pull refers to a reduction in training load. Although the idea of implementing this is generally well accepted, the statistical approach to identifying the point of push or pull seems unstandardised and – anecdotally – varies from club to club. Therefore, presenting methods to analyse the data in this regard will be the aim of this paper. The reader can then apply justifiable and sensitive methods of data analysis to their morning measures of fatigue, such that the subsequent training session can be appropriately altered.

Context of data

In this article we use hypothetical data in the form of jump height. For the purposes of this paper, we are not interested in the efficacy of this measure; there are many other measures used, including the reactive strength index (RSI), isometric squats, questionnaires and various indices available via force plates and heart rate – the validity of each is worthy of its own review. For a list of tests currently used and suggested further reading, please see Table 1 (next page). We will analyse jump height across seven time points: this could be seven consecutive mornings, every Monday morning for seven weeks, or any other permutation that resonates with the reader. Again, here we are simply interested in statistical methods to identify real changes.

The data set

Figure 1 (on page 11) identifies the athlete's response to training where we assume that data point one is 'normal' and represents an athlete ready to train. Data point two then increases, before jump performances reduce and eventually return to normal at data point seven. So, how meaningful are these changes: should we push, pull or ignore, classing them as regular day-to-day fluctuations in performance? The latter can often be the outcome, noting that not all changes in performance are governed by fatigue (or rather an accumulation of training stress) and in part this is what we want to filter out. For example, performance may be influenced by mood (and motivation), diet or environmental temperature; or perhaps the coach was watching or the athlete has developed contempt towards the test. As

Table 1. Tests used to monitor athlete readiness to train (references have been provided for further reading)

TEST	REFERENCE
Psychometric measures	
Questionnaires	15, 16
Heart rate indices	
Heart rate variability	16
Salivary immunoendocrine markers	
Salivary immunoglobulins	13, 14, 17
Salivary testosterone (T)	3, 4, 12
Salivary cortisol (C)	3, 4, 12
T:C ratio	3, 4, 12
Haematological markers of muscle damage, inflammation and oxidative stress	
Creatine kinase (CK)	6, 10, 17
Lactate dehydrogenase (LDH)	1, 10
Myoglobin	17
C-reactive protein (CRP)	1, 6, 10
Urea	5
Leukocyctes	1
Cytokines	1, 10
Neuromuscular fatigue	
Countermovement Jump	3, 4, 11, 16
Reactive Strength Index	2, 7

we set the criteria for this data, the need to standardise testing and use accurate, reproducible tests becomes evident. The validity of this monitoring is immediately invalidated the moment you do not pay due regard to these. Table 2 (on facing page) provides an essential checklist for the coach to go through prior to each test.

Naturally, then, you must first identify the reliability of this test by having your athlete complete several maximal jumps, each in a well-rested state, with a consistent environment. The more trials the better and they do not need to be done all on the same morning; in fact, it is better to carry them out across several days (normally 3–5), in order to capture day-to-day variations in performance and ideally to analyse at least 12 trials (this should be enough to fully capture the natural variations and error inherent to all testing). From here you can compute the coefficient of variation (CV) calculated as the standard deviation divided by the mean, and multiplied by 100.[18]

As well as generally identifying reliability – ie, the smaller the value the better (the value provided being a percentage) – the CV provides a relative indication of the score, indicating the percentage by which scores fluctuate. In our example, where the CV is 2.5%, it suggests that each trial, just by virtue of inherent error (or noise), will fluctuate by 2.5%. It is likely that as the athlete becomes familiar with the test and becomes more consistent in his/her behaviour in the hours leading up to the test, the CV will reduce and thus the test becomes even more sensitive to true changes – this of course should be the goal.

Indirectly, this also highlights issues with tests that have large CVs. For example, the RSI can be a great measure in some athletes but not others, as technical demands mean that only some will attain low CVs. It would not be uncommon (based on anecdotal observations) for some athletes to demonstrate a CV of ~ 10%, ultimately rendering the test as invalid for monitoring purposes. In this scenario, coaches should consider alternative testing (see Table 1) until athletes become technically proficient at it, demonstrating CVs ~ 3%. In the current example, where our athlete 'normally' jumps 45 cm, 2.5% represents 1.13 cm. Essentially jumps within the 'normal window' of 43.7 cm and 46.13 cm represent regular, expected trial-to-trial and day-to-day variations. Figure 2 (next page) has this window plotted, which can now identify data points outside

Table 2. Checklist to ensure a reproducible test environment, capable of producing accurate data

✓ Technique: athlete must demonstrate mastery if test is to be consistent and scores are to be accurate
✓ Timing – keep time of day consistent to avoid changes in the physiological environment consequent to diurnal variations
✓ Consistent environment: changes in body temperature of 1°C induce changes in power output by 4%
✓ Warm-up: consistent warm-up, also for reasons mentioned above
✓ Clothing: the mass of clothing may affect results and may also affect body temperature
✓ Motivation: keep this consistent; it may be more reproducible for the tester not to shout words of encouragement. Also consider who is watching and if the athlete is positively or negatively encouraged by them – consider trying to exclude an audience
✓ Diet and hydration: this will affect energy regardless of training-induced fatigue. The athlete should be consistent in his/her nutritional behaviour
✓ Equipment – is it calibrated and can it record at a high enough frequency not to limit data sensitivity in its own right?
✓ Tester – be strict with form and all the above; exclude any trials that deviate from near perfect.

of the normal. Statistically then, data point 4 represents an out of the ordinary jump that requires further exploratory analysis – this will be discussed later.

Other ways to monitor data include identifying the smallest worthwhile change, a statistical approach discussed by Hopkins.[8] Here the standard deviation of the athlete is multiplied by 0.2 to reveal the first value regarded as meaningful. Assuming a standard deviation of 1 cm, a 'small' change is equivalent to 0.2 cm – this has been illustrated in Figure 3. Additional weighting factors include 0.6 to describe 'moderate' changes (Figure 4), 1.2 to describe 'large' changes (Figure 5 on page 12) and 2 to describe 'very large' changes (Figure 6 on page 12).[9]

In this example, it is sensible to only identify large changes, as both small and moderate changes fall within the error of the test. One may argue that computing only very large changes masks jumps that are out of the ordinary. This value also creates a window that would be similar to a test that had a CV of just 4.5%! Again the need for sensitive measures of fatigue becomes apparent and you can see why having tests with a CV > 3% may be invalid.

Which statistic should we use?

To be as sensitive as possible, it is probably better to go with the CV, especially as you would have to compute this to justify the use of small, moderate or large changes anyway. Also, as the athlete becomes more technically proficient and consistent in his/her test performances, the CV value can be reduced, ultimately increasing sensitivity to real changes. This highlights the issues of using

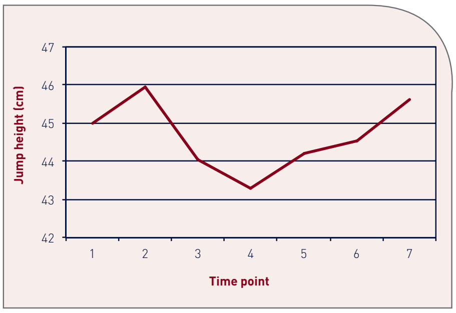


Figure 1. Raw jump height data across seven time points

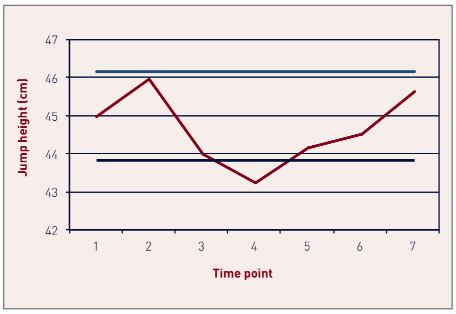


Figure 2. Normal window created by baseline score (45 cm, data appoint 1) ± CV of 2.5% (1.13 cm) ie, 43.87 cm (blue line) to 46.13 cm (green line). Data point 4 may be classed as out of the ordinary

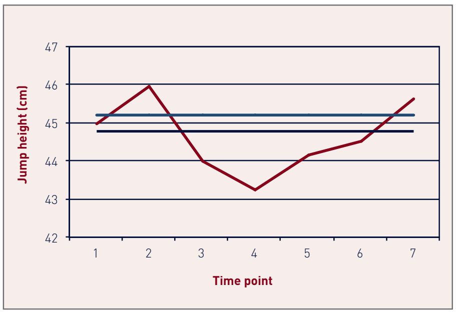


Figure 3. Normal window created by baseline score (45 cm, data appoint 1) ± smallest worthwhile change, calculated as 0.2 * SD. If SD = 1 cm, then upper (green line) and lower (blue line) window values represent 45.2 cm and 44.8 cm respectively

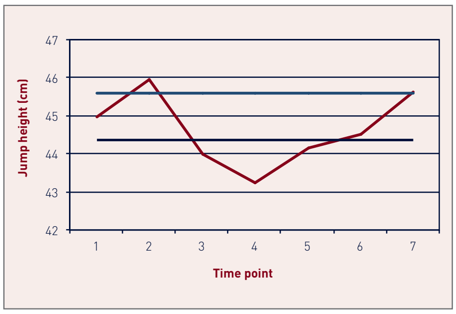
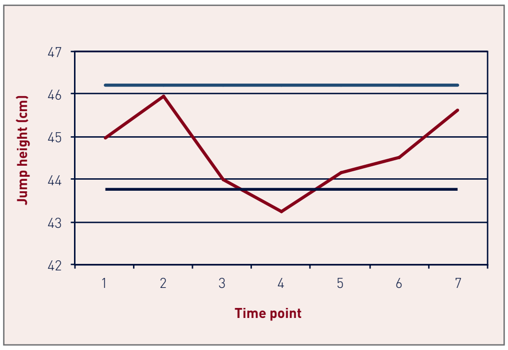
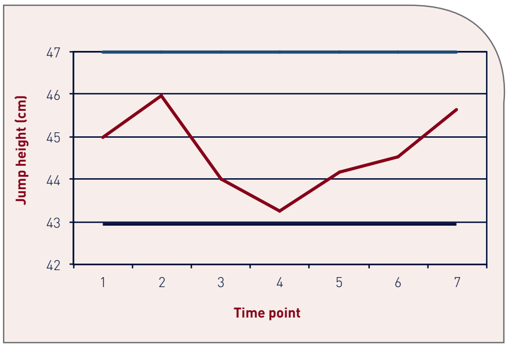


Figure 4. Normal window created by baseline score (45 cm, data appoint 1) ± a 'moderate' change, calculated as 0.6 * SD. If SD = 1 cm, then upper (green line) and lower (blue line) window values represent 45.6 cm and 44.4 cm respectively

Figure 5. (on left) Normal window created by baseline score (45 cm, data appoint 1) ± a 'large' change, calculated as 1.2 * SD. If SD = 1 cm, then upper (green line) and lower (blue line) window values represent 46.2 cm and 43.8 cm respectively

Figure 6. (on right) Normal window created by baseline score (45 cm, data appoint 1) ± a 'very large' change, calculated as 2 * SD. If SD = 1 cm, then upper (green line) and lower (blue line) window values represent 47 cm and 43 cm respectively. Of note, this window size is equivalent to that created by a CV of just 4.5%





'performance may be influenced by mood (and motivation), diet or environmental temperature'

group- or team-derived values for the CV and applying them across the squad. Because teams have some good and bad performers at any given test, the average score will always be under-sensitive for some – and continually identify abnormal stress when it is not present (ie, a false-positive) – and over-sensitive for others, and continually mask real accumulations in fatigue (ie, a false-negative). Subsequently, we advise using individual athletes' CVs whenever possible and continually checking this – so that the value changes in alignment with the athlete's ability to consistently execute the test.

A good question is: 'what happens if my athlete demonstrates a 2% change and my test CV is 3%? Can we really class that change as meaningless?' Firstly it is up to you: the data and worked examples herein provide the backdrop from which you can make informed decisions. If you choose to make a 2% improvement meaningful, then you also have to regard declines by 2% as meaningful. Given the error of the test (ie, 3% in this example), this change in score is quite likely on a frequent basis. This means you potentially run the danger of regularly flip-flopping between an athlete who is 'statistically' improving and deteriorating. You need also to consider the repercussions of this on the programme and performance team. In general, we advise against labelling data that falls within the error of a test as meaningful.

But remember, sometimes stress is good!

It should not be forgotten however, that the general goal of training is normally to induce some sort of physiological adaptation. Therefore, unless you challenge the body through overload, which is likely to manifest itself as fatigue, then the possibility of adaptation is greatly reduced. So to keep pulling a player whenever scores dip below normal might actually be counterproductive. Instead, these should be considered planned decreases, which are monitored to ensure that when the training stress is eventually tapered, a supercompensation in test performance is actually realised. Of course, when in the midst of the competitive season, faced with a high congestion of fixtures, the goal may actually be to maintain performance. In these circumstances, it may be prudent to push and pull according to test performance.

Be certain by double-checking the presence of fatigue

Finally, given the multifactorial nature of performance and stress, it may be prudent to take multiple measures of training stress and athlete readiness to train, such that an athlete must score below normal on two tests before their training intensity can be reduced; or increased in the case of above normal scores. In much the same way, other tests (see Table 1) can be analysed to check for peaks and troughs in performance and to assist in supporting your decision to inform the coach of how best to adapt an athlete's training session. Sometimes the data can simply act as a prompt, alerting you to the need for a discussion with the athlete regarding training, where they can reflect on progress.

A case study example: how to manipulate training based on abnormal scores

This case study describes the management of a senior professional football player during the end-stage of his rehabilitation from ACL revision surgery. The player, a forward, had played 45, 60 and 60 minutes in three previous development squad games that were each separated by one week. The player completed a standardised recovery session on match day plus one day (MD + 1) and had a day off on MD + 2 following each game. Analysis of GPS data from the most recent game demonstrated a significant increase in the volume of high intensity activity completed during match play in the form of high speed running, high metabolic load and sprint distances. A plan had been established for the player to complete his first 90-minute game a week later.

On MD–4 (ie, four days until his next match), the player completed a standardised monitoring protocol 60 minutes before training including a five-point recovery questionnaire, saliva swab for immuno-endocrine assessment (salivary IgA, alpha amylase, testosterone and cortisol), neuromuscular fatigue assessment (CMJ) and specific muscle function and range of motion tests (bent knee fallout, adductor squeeze and sit and reach). Monitoring data for perceived fatigue and muscle soreness (questionnaire) were above the normal CV range and salivary IgA and CMJ jump height were below the normal CV range (ie, we have ≥ 2 indicators of unaccustomed training stress). All other monitoring data was within normal range.

Team training volume and intensity was typically high on MD–4 for attacking players. The planned training structure was a warm-up with an athletic development component focusing on acceleration (~ 20 minutes), a high intensity passing practice (~ 8 minutes), an expansive, high intensity 8 v 8 directional possession (~ 20 minutes), a finishing practice (~ 15 minutes) and small-sided games (~ 15 minutes). Owing to the player's compromised neuromuscular function and specific injury history it was deemed necessary to manage his training involvement to minimise his risk of re-injury. It was also important to manage his training exposure to allow him to regenerate for his next game. The monitoring data was presented to both the player and coaches prior to training and it was agreed that he required a modified training session.

A new plan was established in which the player would warm up separately with a member of the sport science department and not complete the athletic development component. The player would then complete the passing practice as normal, but become a 'neutral' player during the possession practice. Given that the player is a forward it was deemed important for him to complete the finishing practice as normal but not to complete the high intensity small-sided games at the end of the session, thus reducing training volume by ~ 30%. This was later confirmed using GPS data. Following training the player completed the standardised recovery session and the monitoring protocol was repeated the following morning to observe if further adaptations to the training plan were required.

'it may be prudent to take multiple measures of training stress and athlete readiness to train'

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AUTHORS' BIOGRAPHIES

ANTHONY TURNER,

PHD, MSC, ASCC, CSCS*D

Anthony is the director of postgraduate programmes at the London Sport Institute, Middlesex University, where he is also the programme leader for the MSc in strength and conditioning. He is also a consultant to Queens Park Rangers Football Club and Saracens Rugby Club. Anthony was awarded the 2015 Strength and Conditioning Coach of the Year Award for Education and Research.

CHRIS BISHOP,

MSC, PGCHE, ASCC

Chris is a lecturer in strength and conditioning at the London Sport Institute, Middlesex University and consultant to a number of national level athletes in swimming. Chris is also on the review panel for the UKSCA's newly formed Applied Coaching Resources project.

MATT SPRINGHAM,

MSC, BSC (HONS), CSCI, ASCC

Matt is currently completing a PhD in football physiology at Middlesex University. He is a UKSCA-accredited S&C coach and a BASES-accredited sport and exercise scientist (physiology). He has worked in applied sport science and S&C support roles in professional and national football teams for the last decade.

PERRY STEWART,

MSC, ASCC, BASES

Perry is Head of Academy Sport Science at Queens Park Rangers Football Club and a sessional lecturer in strength and conditioning at the London Sport Institute, Middlesex University.