FIRSTBEAT

Understanding Athlete Training Load

Contents

Crack the Body's Physiological Code

How do you measure a training session? By the hours you put in? Maybe the distances racked up? Or asking an athlete for verbal feedback? Useful guides for sure, but how much does this information really tell you about how each athlete's body reacts to the training schedule it is being put through?

That's where training load data comes in.

Monitoring training load lets you appreciate the physiological impact of any training session on an individual player and team level. Adjusting intensity in real time, recognizing trends, and making sure training replicates game intensity are just some of the benefits.

The Firstbeat Sports method for tracking training loads and recovery is built on an advanced analysis of heart rate and heart rate variability data. Better insight means better decisions. Firstbeat Sports helps you optimize training, reduce injuries, and keep players on the fast track to reaching their full potential.

Getting results in sports is increasingly decided by ever-decreasing margins. Being able to see accurate, personalized and useable training load data is one way to ensure you stay ahead of the pack.

Glossary

EPOC
Excess Post-Exercise Oxygen Consumption, expressed in ml/kg. Used to quantify training load of a single session.

TRAINING EFFECT (TE)
An interpretation of EPOC describing the impacts of the training session on 0.0 to 5.0 scale.

AEROBIC TRAINING EFFECT
Describes the impact of the training session on cardiorespiratory fitness.

ANAEROBIC TRAINING EFFECT
Describes the impact of the training session on anaerobic performance using Firstbeat's algorithms to identify and interpret high-intensity activity.

TRIMP
Training Impulse, a measure to quantify training load.

ACUTE TRAINING LOAD
The sum of TRIMP scores over the last 7 days representing the current short-term load of an athlete.

CHRONIC TRAINING LOAD
The training load average over the last 28 days describing the typical training load of an athlete.

ACUTE VS CHRONIC TRAINING LOAD
An analysis of the balance between the athlete's acute (short-term) and chronic (long-term) load.

Understanding the
Key Metrics

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Firstbeat Sports is built on over 20 years of scientific research and work in professional sports. Our metrics provide the most comprehensive internal load monitoring analyses to help you measure the impact of, and response to, training and workouts.

TRIMP

Training Impulse (TRIMP) is used to describe training load as a single number. The original TRIMP calculation was developed by Dr. Eric Banister in 1991, and was based on an integration of time, intensity and relative weighting of the intensity of exercise. Since then, numerous authors have presented modified methods to calculate TRIMP.
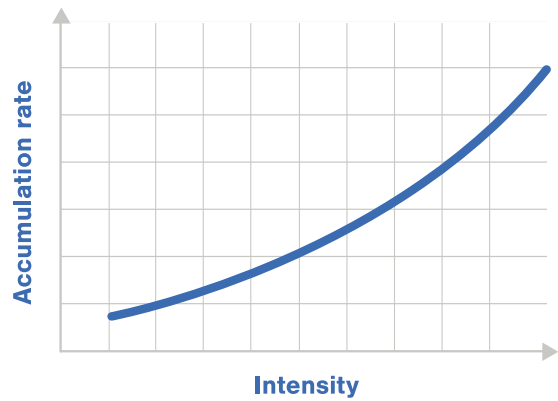
TRIMP accumulation rate models lactate accumulation rate increasing exponentially to intensity

The TRIMP calculation in Firstbeat Sports is based on Banister's original TRIMP calculation with some modifications. Instead of using the mean heart rate across a workout, Firstbeat uses beat-to-beat heart rate data to update TRIMP scores more frequently. This ensures more accurate training load assessment in interval type training. Firstbeat has also set a lower intensity limit for the TRIMP accumulation to ensure that TRIMP number is derived only from training.

Real-time TRIMP/min

Firstbeat Sports allows you to view real-time TRIMP/min data. This shows an athlete's TRIMP accumulation over the previous 60 seconds and lets you know if the session – or a particular drill – is having the desired physiological impact. This helps coaches manage training session content by combining different drills that achieve the desired overall training load.

$$TRIMP = T \times \left[\frac{(HR_{ex} - HR_{rest})}{(HR_{max} - HR_{rest})} \right] \times 0.64 e^{1.92 \left[\frac{(HR_{ex} - HR_{rest})}{(HR_{max} - HR_{rest})} \right]}$$

Where:
|	
T	duration of the workout
HRex	heart rate during workout
HRrest	resting heart rate
HRmax	maximal heart rate
e	~ 2,718

TRIMP accumulation has an exponential relationship with exercise intensity. Therefore, the duration of the exercise needs to be taken into account when scaling/classifying the TRIMP score. When interpreting TRIMP, it is also quite typical for the TRIMP/min value to be used. In relation to a 60-75-minute session, the typical breakdown for easy, moderate and hard training could be as follows:

<70 EASY TRAINING	70-140 MODERATE TRAINING	>140 HARD TRAINING

| 1 TRIMP / Min Easy	1.5 TRIMP/Min Moderate	2.2 TRIMP/min Hard

TRIMP/min scale

EPOC

EPOC stands for Excess Post-Exercise Oxygen Consumption, and it reflects how far the body's oxygen uptake is elevated from resting levels due to recovery needs after exercise. Firstbeat uses EPOC as a representation of the disturbance of a body's homeostasis, and analysis of EPOC can be used to measure the load of individual training sessions.
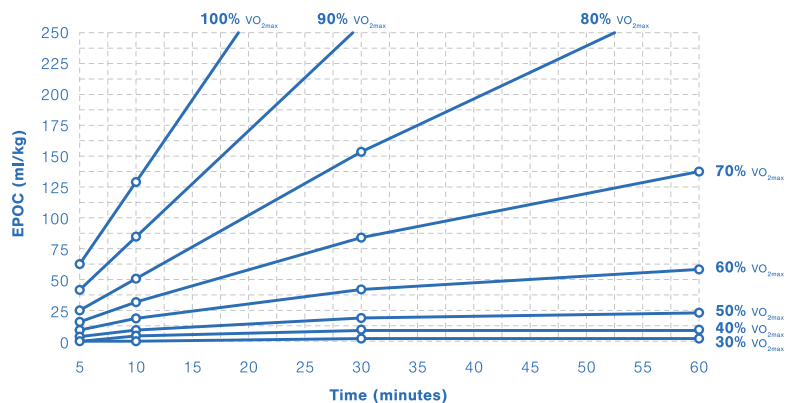
The original method for EPOC measurement involved capturing respiratory gases in laboratory conditions after exercise. While highly informative, the laboratory method was impossible to perform in real-world conditions. Recognizing the importance of EPOC for effective training programming and the limitations posed by laboratory testing, Firstbeat developed an algorithm capable of effectively predicting EPOC during the ongoing exercise using heart beat data.

EPOC is predicted dynamically based on current exercise intensity (%VO2max) and time spent at that intensity. The crucial point of EPOC modelling is to accurately measure exercise intensity, which, in the Firstbeat model, is performed by neural networks utilizing heart rate, heart rate variability-derived respiration rate, and on/off-kinetics information describing the different physiological responses in changing exercise intensities. The model can predict the amount of EPOC at any given moment and no post-exercise measurement is needed.
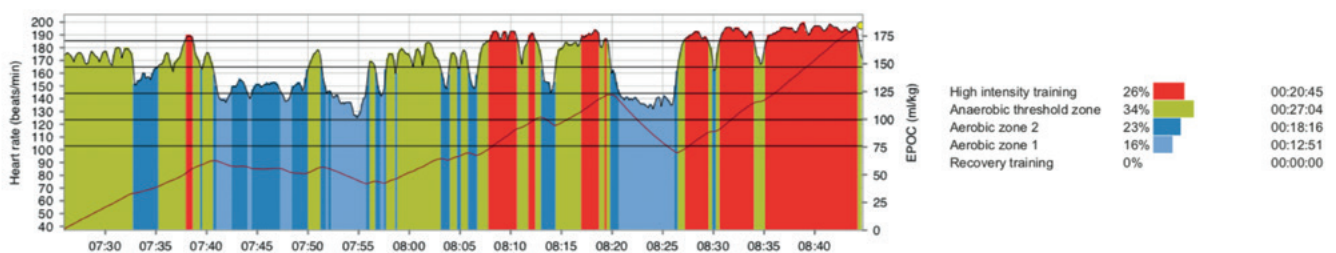
The EPOC accumulates dynamically during the exercise. It increases rapidly during the high intensity phase and decreases during easy periods.

When put into context using an athlete's Activity Class or a combination of aerobic fitness level and activity history, EPOC scores are used to calculate Training Effect.

Training Effect

Firstbeat's method of providing Training Effect feedback is based on a deep understanding and research of human physiology and research performed using elite athletes from various sports.
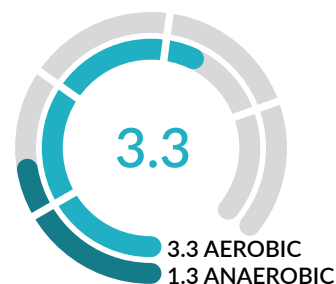
The resulting algorithms form a comprehensive system which can track which physiological performance characteristics, and to what extent, have been trained, i.e. aerobic and anaerobic Training Effects. Used in combination, they will help you see and understand the relationship between specific training activities and the development of future performance capacity, and give you the information you need to adjust training load towards training targets.
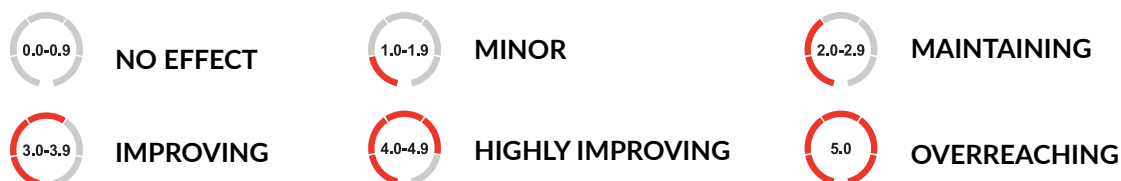

3.3

3.3 AEROBIC
1.3 ANAEROBIC

Training Effect is reported on a 0.0 to 5.0 range, which reveals whether a session highly improved, improved, maintained, or had a minor to non-existing effect on performance capacities. Very high scores indicate overreaching exercise stimulus which may require paying special attention to recovery.

Aerobic Training Effect

Aerobic Training Effect describes the impact of a training session on the development of VO2max and aerobic endurance capabilities. Its quantification is based on the highest level of EPOC achieved aerobically during the session reflecting the peak of homeostasis disturbance.

As active and fit individuals need harder training than less active and less fit individuals to improve their fitness the activity class of an individual must be known in order to effectively assess aerobic Training Effect.

The activity class value represents the activity level of the previous month and is key to individualizing Training Effect scores. Professional athletes will likely fall within the 7.5 to 10 activity class values.

Anaerobic Training Effect

Anaerobic Training Effect describes the impact of a training session on the development of repeated sprinting abilities and anaerobic performance capacity.

The calculation is based on identifying and analyzing high intensity periods (intervals) where the anaerobic energy system has been stressed, increasing the oxygen deficit. The method considers aspects relevant to anaerobic metabolism including; intensity and speed of intervals, duration of intervals, recovery status before intervals and fatigue accumulated during the session.

As the intensity of work performed during the anaerobic periods such as sprinting can be as high as 150% of VO2max, but intensity as percentage of HRmax is limited to 100%, heartbeat dynamics are utilized to assess Anaerobic Training Effects.

0.0-0.9	NO EFFECT	1.0-1.9	MINOR	2.0-2.9	MAINTAINING
3.0-3.9	IMPROVING	4.0-4.9	HIGHLY IMPROVING	5.0	OVERREACHING

Training Effect scale

Acute vs Chronic Training Load

Ensuring there is a balance between short and long-term training load helps to reduce injury risk and maintain and improve fitness and performance.
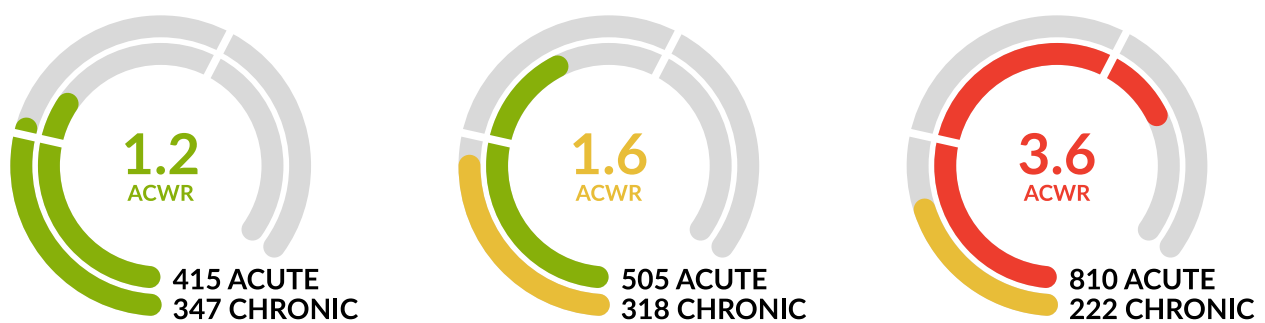
A sudden spike in an athlete's weekly training load can lead to a higher risk of injury. Conversely, an acute training load that is well below the 'norm' can hinder performance and reduce fitness as the body is no pushed enough to facilitate change. In this situation, the athlete is losing their tolerance to training which, again, can increase risk of injury. Monitoring the acute and chronic training load helps make sure they are in balance and flags up situations where load is changing too dramatically.

Firstbeat Sports' Acute vs Chronic Training Load metric does this by analyzing the acute vs chronic workload ratio (ACWR) and presenting the data in a color-coded gauge. The ratio, combined with training load values, indicate when a player is in a well-prepared state, or at an increased risk of getting injured.

The ranges for each individual are continuously scaled based on their measurement history. This ensures the results factor in an individual players physiology and are always relevant.

Acute vs Chronic Training Load Key

Green = Good ACWR
Yellow = Moderate ACWR
Red   = Poor ACWR

1.2
ACWR

415 ACUTE
347 CHRONIC

1.6
ACWR

505 ACUTE
318 CHRONIC

3.6
ACWR

810 ACUTE
222 CHRONIC

Three examples of the Acute vs Chronic Training Load as shown on the Firstbeat Sports dashboard. Player 3 has a high acute load, but low chronic load so is at an increased risk of injury, whilst Player 1 is in the training 'sweet spot' with an ACWR of 1.2.

Load optimization

The 'sweet spot' for load optimization is where the ACWR is around 1.0. This indicates that the athlete's recent training load is in line with their chronic load. This can be valuable when, for instance, preparing for a known busy period of fixtures or tournament play. By increasing the training load gradually over time a coach can ensure the chronic load over the 4-week period sets the athlete up to cope with the load during the known busy period.

Reducing injury risk

According to research by Dr. Tim Gabbett, the 'sweet spot' ratio when the risk of injury is reduced is 0.8-1.3.

Suddenly increasing training load has been associated with an increase in injuries. Piggot et al shows that when training load increased by no more than 5-10% on the previous week, athletes' risk of injury was below 10%. When training load increased by over 15% on the previous week, this increased to between 21-49%.

Monitoring the Acute vs Chronic Training Load of athletes can ensure increases in training load are introduced safely and effectively without putting athletes at greater risk of injury.

ACWR Zones

0.7-1.4   – Training 'sweet spot' where injury risk is the lowest
<0.7 or >1.5   – Zones where injury risk is increased

Calories Burned

Measuring energy expenditure (EE) is important when assessing its impact on an athlete's training load. Data showing an athlete's expended calories is vital in developing the ideal nutrition and recovery plan for that individual.

The precision of the Firstbeat Energy Expenditure estimation method is based on accurate intensity estimation. The neural network model utilizes information on heart rate, HRV-derived respiration rate, and on/off-kinetics of oxygen consumption. The algorithm is personalized to the user based on background parameters such as maximum heart rate, weight, gender and VO2max/Activity Class.

2350
kcal

462
kcal

Average burn
9
kcal/min

kcal/min
12
10
8
6

10_00   20_00   30_00   40_00   48:10
min

Firstbeat Sports also shows Energy Expenditure breakdown for carbohydrates and fats, providing guidance on fuel sources used in different intensities and workout durations.

The Firstbeat Sports system is built to automatically adjust, and fine tune, EE calculations based on updated background information (HR max, VO2max record).

To learn more about the method, including the calculation model, read our freely accessible white paper:
Firstbeat.com/en/energy-expenditure-estimation-firstbeat-white-paper/
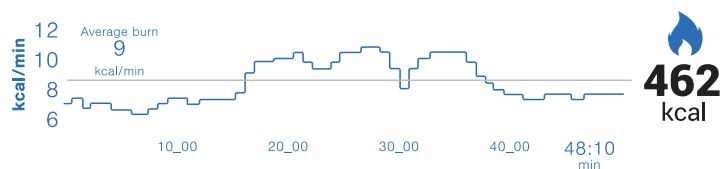
Getting Results with Training Load Data

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Firstbeat Sports puts accurate physiological data into your hands
- allowing you to make important training decisions on an
individual and team level. To do this effectively, it is important to
understand how the data provided can be put to practical use.

Track Progress and Plan Ahead

Training Load data provided by Firstbeat Sports makes it easy for you to track progress and inform long-term training plans. Shown on an easy-to-use dashboard, the key performance indicators allow you to recognize trends, ensure players are at their best physiologically for key fixtures, and safely guide players back from injury.

Typical uses:

- **TRAINING LOAD:** Analyze data retrospectively to see typical acute training load numbers throughout the season, letting you be prepared for the changing demands of the season.

<350 EASY	350–700 MODERATE	>700 HARD

Typical values for typical acute training (7-day) load.

- **INJURY RISK MANAGEMENT:** Recognize sudden changes in workload associated with increased injury risks using the Acute vs Chronic Training Load feature, or via data export.

- **TRAINING SESSIONS:** Classify typical drills and training sessions using TRIMP/min scaling. This helps plan the overall load of a workout by fine-tuning the duration and number of drills during the session.

1 TRIMP / Min Easy	1.5 TRIMP/Min Moderate	2.2 TRIMP/min Hard

Typical values for TRIMP/min.

Example of analyzing training load from the previous season. Here, training load increases from 800 in the preseason to around the 1000 level during the regular season before peaking at 1400 during the playoffs. The Acute:Chronic workload ratio graph provides important information showing the team was able to keep the load at the optimal level.

Monitor Athletes in Real Time

Real-time monitoring offers insights that let you adjust the intensity and training plan of the ongoing practice to make sure predetermined targets are met. Real-time feedback is also a great tool to inform players about their effort, motivate individuals, and turn findings into immediate actions.

With Firstbeat Sports, you can monitor intensity and watch a variety of training load metrics accumulate in real time. The analytic engine is supported by a Radio Frequency-based telemetry system which ensures accurate data transmission.

Typical uses:

- **INTENSITY:** Are players reaching their peak heart rates during high intensity drills?
- **RECOVERY HEART RATE:** See how quickly heart rate slows during breaks.
- **PRE-GAME WORKOUTS:** Remove players from session/individual drills when the cumulative training load reaches set targets.

- **IN SPEED/SKILL TRAINING:** Make sure the accumulative load is not too high. Adjust recovery breaks accordingly.
- **IN HARD PRACTICE:** Make sure everyone is getting the desired Training Effect.
- **CONTRAST:** Compare different groups in real time.
- **CONTEXT:** Data in an isolated session must be appreciated in the context of wider workload.

Putting it to use:

Henrik Kuchno, longtime trainer at German Bundesliga soccer team Hertha BSC, uses real-time monitoring as an effective way of tracking whether a session is fulfilling its requirements.

"The ability to see high-intensity training minutes is especially helpful. The time element of the metric makes it easy to understand and communicate to other coaches, the medical department, and to players."

**Henrik Kuchno,**
Trainer at Hertha BSC

Post-Session Analysis of Training Load Data

After a session is over, you have a chance to look more closely at the data, examine it, and contextualize it in ways that unlock additional meaning. Data collected during real-time monitoring is automatically synchronized to the Firstbeat Sports Cloud, where you can access it for review and analysis.


Once in the Firstbeat Sports Cloud, data can be easily shared with the individual athletes, coaching staff, trainers, physiotherapists and nutritionists - provided they have been given the proper permission to access the data.

You can also have training reports automatically sent via email at the end of each session. Stored on a single platform that combines training load and recovery data - a setup unique to Firstbeat - results from the most recent session can be compared to findings from one week, one month and beyond, going as far back as when you began measuring. With the Firstbeat Sports Cloud premium package, it is also possible to export selected variables to Microsoft Excel for deeper analysis.
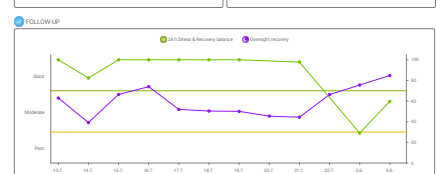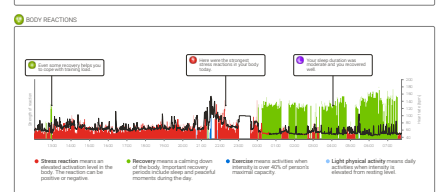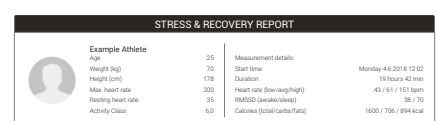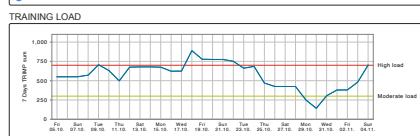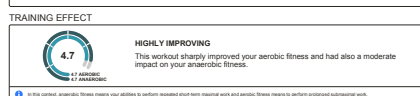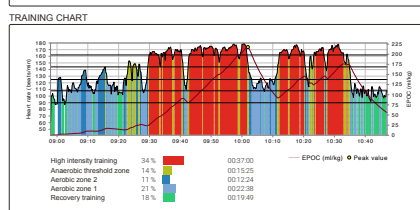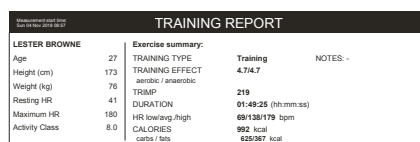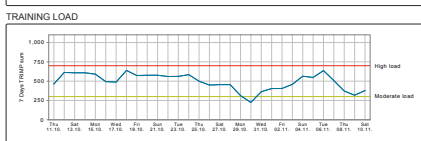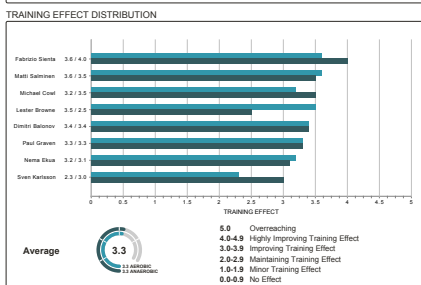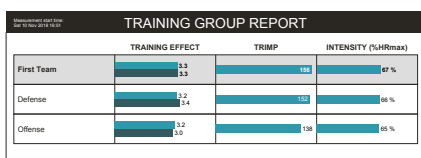
Typical uses:

- **SINGLE PLATFORM:** Easily present "full picture" findings to head coaches and decision-makers.
- **CUSTOMIZE:** Sort players in the dashboard based on selectable training load and recovery variables.
- **COMPARISONS:** Overlay up to five athletes' heart rate data on the same chart.

- **BROAD PERSPECTIVE:** Identify single-session anomalies, red flags and discover trends.
- **SELECTED VARIABLES:** Analyze data based on individual needs and agreed targets.
- **FEEDBACK REPORTS:** Review specific position groups or players via coach-friendly group and individual reporting.
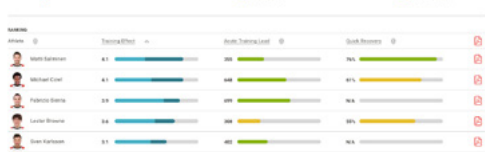
Athlete comparison by variable.
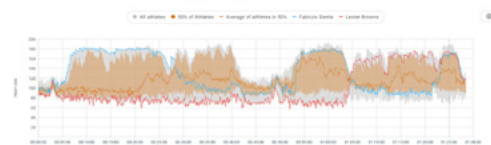
Comparison of two athletes' heart rate data.

Putting it to use:

An NHL team was struggling to replicate game intensity in practice whilst still maintaining the optimal load that ensured players were ready come game day. Previous game performance vs. training load data from sessions the day before games indicated that players were not ready at the beginning of games.

By cataloging game specific battle drill sessions, the strength and conditioning coach was able to introduce a plan to the head coach highlighting how many such drills they could run during practices the day before games while keeping training loads at optimal levels.

As a result, coaches adjusted the team's training program to ensure the team's average TRIMP was always below 100 the day before games. This immediately led to noticeable results as the team went on a 10-game winning streak.

Individualize Training Plans

Every athlete's physiological profile is different. Without taking individual training responses and recovery needs into account, an athlete will not reach their full potential. Managing this reality in a team environment is extremely challenging, making it an area where technology can be very helpful.

Firstbeat Sports offers an individualized view of training load data - allowing you to see each individual player's physiological status during a session, and map individual reactions to drills over time.

From the Firstbeat Sports dashboard, you can see Aerobic and Anaerobic Training Effects, TRIMP and Training Zone scores build and change in real time for every player wearing a heart rate belt. Combined with post-session analysis, you can determine the specific needs of each player (or position group) and modify training regimes accordingly. This gives you the freedom to guide individual training based on position, or even a desired style of play.

Typical uses:

- **INTERVENTION:** Identify players who should be taken out of a session to prevent overtraining, or who could be encouraged to push harder.
- **CHANGES:** Establish individual training norms and track a player's physiological reaction to similar drills over time.

- **RISK MANAGEMENT:** Adjust individual training intensity if training load data indicates a player is becoming increasingly at risk of injury.
- **MANAGE RETURN-TO-PLAY SCENARIOS:** Apply the right loads at the right times to get players back up to game speed quickly and safely.

Acute workload (7-day)

Average = **1000**

Range 650-1295

Chronic workload (28-day)

Average = **814**

Range 524-1031

Example of acute and chronic workload levels of a team (n=27).

Being able to see the full range within a team provides context to guide specific athletes towards the team average. To fully understand different scores amongst individuals, it is also crucial to recognize the difference between natural factors and things that can be altered:

Natural factors: Skills, style of play, age, heritage/genes, training history
Things that can be altered: Motivation, estimated HRmax, responses to different drills

Communicate Results to Athletes and Colleagues

Firstbeat Sports helps you present clear, easy-to-understand findings to players and fellow coaches.

The Firstbeat system is there to help make your job easier. One way this is achieved is by providing automatic reports to coaches, whilst still allowing you to send individually tailored reports manually if required.

We know each team communicates results differently and that's why we try to make our system as flexible to your needs as possible. For instance, the adjustable nature of the dashboard means you can tailor what is displayed depending on your needs and who you are communicating the findings to.

We do believe athlete's should be involved in the process as much as possible in order to enhance player buy-in and engagement. Firstbeat helps make this achievable by making their individual data available to the athlete themselves, and through our easy-to-use mobile app.

Typical uses:

- **REPORTS:** Send team training reports to coaches automatically at the end of a session. You can also send individual reports to coaches and athletes manually.
- **ATHLETE ACCESS:** Players can log in to see their own data. This access boosts player buy-in and engagement.

- **EDUCATIONAL:** Firstbeat can create specific educational materials (posters etc.) to suit team needs and help get colleagues and players invested.
- **ATHLETE-FRIENDLY:** Easy to interpret results (e.g. color-coded zones) make a good educational tool for athletes.
- **EXPOSURE:** Making real-time results easily visible encourages players to ask further questions.

Putting it to use:

Sports science staff at Australian Rules team Port Adelaide FC's use Firstbeat Sports data to produce quick glance post-training reports for each player.

The players' competitive nature surfaces as they assemble after training to review and compare their results. These reports focus on five key metrics: Average Heart Rate, HRmax, Time spent in Training Zone 4, Time spent in Training zone 5 (Maximal Training), and Training Effect score.

"We can show that the data we get is actually useful for the players... One outcome of our monitoring is it helps players learn to manage themselves. The players are able to anticipate many of these values themselves which indicated an improved awareness of how their body is working."

Stuart Graham
Head of Sports Science, Port Adelaide FC

The Next Step

You have gained insight into the key metrics behind monitoring training load, and the ways it can be optimized to get genuine results. So why us?

Physiological Data at your Fingertips

Firstbeat Sports puts real physiological data at your fingertips. Replacing guesswork with hard facts means better decision making and a better understanding of your athletes.

Core advantages of Firstbeat Sports include:

- Physiological analytics designed for coaches, based on 20+ years of scientific research
- Single platform providing information on both training and recovery
- Real-time training load and intensity tracking so you can make a difference when it matters
- Athlete-centric data management approach

Beyond training data, we also equip coaches with the tools to monitor athlete recovery and stress - giving you a truly 360-degree understanding of your players.

How do I learn more?

Visit firstbeat.com/sports-coaching/user-stories to read success stories from teams like Detroit Red Wings, Hertha BSC, UCLA football and Saracens Rugby.

Listen to the Firstbeat Sports Podcast to hear from leading coaches and sports scientists about the latest in performance monitoring: firstbeat.com/en/podcasts/.

MORE INFO: firstbeat.com/sports

"Firstbeat data means we can know where we are and want to be, even in the middle of a session. If it is meant to be a light, low intensity session I can see the data and see if we're creeping into the red intensity zone a little bit too much. Conversely, if we're trying to make sure it is tough, and the data shows it isn't tough enough then we can change what we do to get the response we want. Firstbeat has helped massively for the on-field stuff."

- Saracens Rugby

1000+
Elite Teams

25%
of Champions League Soccer Teams

26
National Teams

100+
NCAA Programs

>50%
of NHL teams

Advanced Performance Analytics

FIRSTBEAT

Firstbeat Technologies
Yliopistonkatu 28 A, FI-40100 Jyväskylä
Tel. +358 20 763 1663
sports@firstbeat.com