PIONEER OF WEARABLE SPORTS TECHNOLOGY

Polar Training Load Pro

November 12, 2019, March 2025

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1 Introduction

Traditionally, heart rate has been the most popular metric for objectively quantifying training load over the last several decades. However, new wearable technologies, including GPS, accelerometers, and power sensors have introduced various new possibilities. While measuring training load using heart rate remains the preferred method in some sports, athletes and coaches in other disciplines favor quantifying training load based on power metrics (e.g. in cycling) or by combining heart rate with distance, speed or acceleration tracking (e.g. in running, swimming, and team sports). Moreover, recent literature emphasizes the benefits of incorporating subjective feelings to define training load and recovery.[1,2]

To date, no gold standard exists for quantifying training load. A recent consensus statement of the International Olympic Committee (IOC) on load in sport and injury risk[2] recommended using the internal and external load metrics that are relevant and specific to the nature of each sport. The term 'external load' refers to any external stimulus applied to the athlete, measured independently of their internal characteristics (e.g. independent of fitness, age, gender, and body composition). In contrast, 'internal load' encompasses the physiological and psychological responses required to achieve the external load.

These responses are individual and depend on physiological characteristics (e.g. fitness level, training background, age, gender, body composition) and environmental factors (e.g. increased effort needed at altitude or high heat).

Following the IOC recommendation, Polar Training Load Pro integrates both internal and external training load metrics rather than relying on a single method. Selected internal loads measures include Cardio load (based on heart rate measurements) and Perceived load (based on ratings of perceived exertion). With respect to external factors, training load is quantified using Muscle Load, which is determined by total power output. Additionally, Polar Training Load Pro users can monitor other external load measures, such as training time, frequency, type, speed, and distance.

2 Why measure training load

Polar Training Load Pro provides users with the ability to:

- Quantify and monitor the strain placed on the cardiovascular and the musculoskeletal systems, as well as and how the training session was perceived.
- Compare training sessions with previous one (post-session).
- Compare the Polar-provided training load metrics with one another to track progress and detect early onset of fatigue (detailed further in Section 3.4).
- Analyze training patterns, such as identifying which training periods or weeks were more challenging and which were easier.

3 Description of Training Load Pro

3.1 Cardio load

Description

Cardio load—measured by heart rate—indicates the cardiac response to a training session.

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Advantages of use

- Users can assess and compare Cardio load across all sports from where heart rate recordings are available, using this data for training planning and analysis.
- Cardio load accounts for daily variations in the effort required to perform exercise. These variations depend on factors such as hydration and nutrition status, fitness level, fatigue, mood, and environmental conditions, which are not considered in Muscle load.

Calculation and interpretation

Cardio load is determined by a training impulse (TRIMP) calculation, a widely-used and scientifically accepted[2] method for quantifying training load. This calculation considers the duration and intensity of a session and can be applied to all sports where heart rate recordings are available.

Several formulas exist for calculating TRIMP. Based on a survey of scientists and practitioners, we found that the traditional Banister TRIMP formula[3] remains the preferred method. The TRIMPs are computed each second, and the total is then calculated (Figure 1). The weighting factor is based on the relationship between heart rate and blood lactate observed during incremental exercise.

$$W = \sum_{t0}^{tfinal} \frac{HR_{(t)} - HR_{(rest)}}{HR_{(max)} - HR_{(rest)}} \cdot 0.64 \cdot e^{1.92 \frac{HR_{(t)} - HR_{(rest)}}{HR_{(max)} - HR_{(rest)}}} \quad \text{eq.1}$$

$$W = \sum_{t0}^{tfinal} \frac{HR_{(t)} - HR_{(rest)}}{HR_{(max)} - HR_{(rest)}} \cdot 0.86 \cdot e^{1.67 \frac{HR_{(t)} - HR_{(rest)}}{HR_{(max)} - HR_{(rest)}}} \quad \text{eq.2}$$

Figure 1. Calculation of TRIMP with Banister method.
$HR_{(t)}$: Heart rate at a given time
$HR_{(rest)}$: Resting heart rate (from user settings)
$HR_{(max)}$: Maximal heart rate (from user settings)
eq1 for males and eq2 for females

The higher the Cardio load, the more strenuous the training session is for the cardiovascular system. Since TRIMP depends on user characteristics such as resting heart rate, maximal heart rate, and gender, it may vary slightly between users, even if they exercise with the same heart rate and duration.

For the same external load (e.g. Muscle load described later), fitter athletes show a lower TRIMP compared to those with lower fitness levels. This is because they perform the same exercise with a lower heart rate.

Limitations

There are two main limitations to using Banister TRIMP. Firstly, the well-known limitations of using heart rate for quantifying training load in sports with short bouts of very high intensity (anaerobic energy supply), such as strength training and certain team sports. Secondly, the reliance on generic weighting equations for modeling, which only differentiate between males and females. It is evident that gender is not the sole factor contributing to differences among athletes. Consequently, the TRIMP calculation may fail to account for all the individual differences that influence training load.

3.2 Muscle load

Description

Polar's Muscle Load metric is an external load measure that indicates the amount of mechanical energy (kJ) produced during exercise. It reflects your energy output, not the energy input required to generate that effort. Power measurements are a widely used and scientifically accepted method to quantify training load.[2]

Advantages of use

- Users can assess the work of the musculoskeletal system during training and utilize this data for training planning and training analysis.
- The work of the musculoskeletal system can be compared across training sessions, regardless of terrain (e.g. uphill or downhill). This comparison is not possible using speed or distance as external measures.
- Since Muscle Load is measured by power, it responds almost instantaneously to increases in the rate of work.

This makes it particularly well-suited for interval training, as it has a faster response time compared to heart rate, which may take several minutes to reach a steady state.

- The measurement range of Muscle Load is substantially broader. Muscle Load can measure both aerobic and anaerobic intensities, whereas the range of heart rate is limited to aerobic intensity.

Calculation and interpretation

Muscle Load is sport-specific because different muscles are engaged in each sport, making comparisons between sports impossible. Muscle Load is provided for sports where power data is available and is calculated using the following formula:

Muscle Load = average power during training session * duration of training session

It requires either direct measurement of power (e.g. through power pedals in cycling) or an estimation of power based on biomechanical formulas.

The higher the Muscle Load for an individual, the more strenuous the training session was for the musculoskeletal system. However, the same Muscle Load can be achieved with either a high or low perception of effort or heart rate, depending on the user's fitness level and numerous other factors, including hydration and nutrition status, mood, and environmental conditions.

Limitations

Muscle Load does not consider the effort required to exercise. When comparing Muscle Load measurements for a user, it is important to note that the effort needed to achieve the same power (whether absolute power on flat terrain or power-to-weight ration on an uphill slope) depends on factors such as fitness level, fatigue environmental conditions, (e.g. altitude or heat), and others.

3.3 Perceived load

Description

One of the most frequently used and simplest measures of training load is the session rate of perceived exertion (RPE).[2]—a measure of subjective exercise load. Polar's Perceived Load metric is derived from session RPE and duration.

RPE is defined as a measure of internal load and is a valid method for quantifying exercise training across a wide variety of exercise types.[4] It is particularly common in team sports and has also been shown to be useful for training load calculation in strength training, as demonstrated in several studies.[5,6]

Advantages of use

- Users can assess and compare Perceived Load across all sports and use it for training planning and analysis.

Calculation and interpretation

Perceived Load is calculated using the following formula:

Perceived Load = RPE * duration

The higher the Perceived Load, the more strenuous the training session was for the user. The perceived load is comparable both between and within individuals.

Users will input their RPE after the training session, using a scale from 1 to10 (Figure 2).[7]

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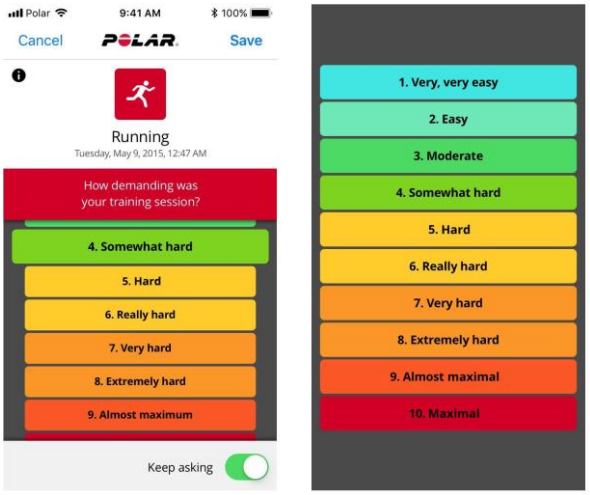

Figure 2. Session RPE scale

Limitations
Perceived Load is a subjective measure and can therefore be influenced by the user. Perceived exertion is also likely a product of cardiovascular and muscle effort and does not, therefore, separate the different physiological systems, which would be beneficial for optimizing training (e.g. in swimming or paddling when muscular load on legs is high).

3.4 Comparing different training loads

Description
As described previously, power measures the work done by muscles and is independent of effort (external load measures), while heart rate and RPE are measures of the effort needed to generate power (internal load measures). Comparing internal and external measures, as well as examining the relationship between RPE and heart rate, opens valuable new possibilities for monitoring training.

Advantages of use

- Users can track sport-specific performance progress after each training session (if power and heart rate data are available).

Calculation and interpretation
Example:
One runner wants to check their running performance development after ten training sessions. Let`s assume that they generated the data shown in Table 1:

Table 1. Data from 10 training sessions

Training session	Average heart rate [bpm]	Average power [W]	Ratio avg.HR/avg. power
1	178	385	0.462
2	150	330	0.455
3	132	291	0.454
4	138	305	0.452
5	144	326	0.442
6	168	385	0.436
7	180	415	0.434
8	160	378	0.423
9	130	310	0.419
10	155	380	0.408

The ratio of average heart rate to average power for each running session can be plotted as in Figure 3. The lower the ratio, the less effort (measured by the average heart rate of the training session in this example) was needed to achieve training performance (measured by the average power of the training session). This indicates improved running performance. On the other hand, an increase in the ratio of average heart rate/average power would indicate a decrease in submaximal running performance.

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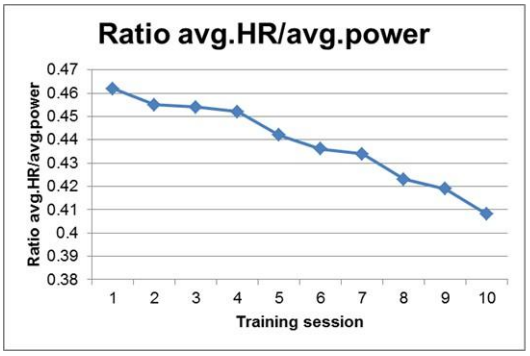

Figure 3. Improved running performance over ten training sessions, measured by the ratio of average heart rate to average power. The lower the ratio, the better the performance.

In addition, it can also be helpful to compare RPE with heart rate, as the "normal" relationship between these variables may be inverted before illness.[8]

Limitations

Variables such as hydration, temperature, mood, sleep quality, and nutrition contribute to heart rate and RPE, both positively and negatively. As such, changes in the ratio of average heart rate to average power are not necessarily caused by lower fitness unless they are measured under comparable conditions.

3.5 Training load and training load levels

Description

Polar's training load feature quantifies the strenuousness of a single training session and makes different sessions comparable. The feature calculates and presents three training load metrics separately:

- Cardio load (based on heart rate)
- Muscle load (based on power)
- Perceived load (based on rate of perceived exertion)

Polar Training Load Pro shows absolute numbers for all three loads (Figure 4). To make the each absolute number easier to understand, users can also see their Cardio, Muscle and Perceived Load relative to their own previous loads on a scale from 1 to 5. These relative training loads are called Cardio Load Level, Muscle Load Level, and Perceived Load Level.

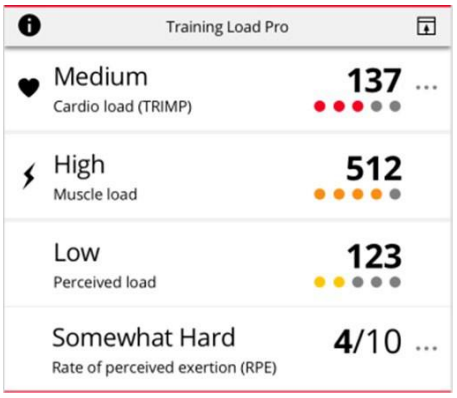

Figure 4. The Polar Training Load Pro view on the Polar Flow mobile app. Each load is shown in absolute numbers and on a 5-point scale interpretation with dots and text.

Advantages of use

- Users can use absolute numbers for training planning and training analysis.
- Training Load Levels help the user better understand the absolute training load number as load is shown in relation to their own training history.

Calculation and interpretation

The calculation of the different absolute loads is described in detail in the above chapters. In short, the higher the absolute number, the more strenuous the training session was.

The training load level is calculated by comparing the absolute Cardio Load, Muscle Load, and Perceived Load of a new training session to the average session training load from the previous 90 days. Table 2 outlines the different interpretations and how they are calculated.

Table 2. Training Load Levels

Very low	The new session load is less than 0.5 times the average of all training sessions conducted in the last 90 days
Low	The new session load equals 0.5-0.75 times teh average of all training sessions conducted in the last 90 days
Medium	The new session load equals 0.75-1.25 times the average of all training sessions conducted in last 90 days
High	The new session load equals 1.25-2 times the average of all training sessions conducted in last 90 days
Very high	The new session load is equal or higher than 2 times the average of all training sessions conducted in the last 90 days

Initially, the algorithm for Training Load Levels requires three training sessions. If fewer than three training sessions are completed within the sliding 90-day winding, the 90-day average values will not be updated, and the most recent valid average will be used.

Limitations

The limitations for absolute loads were described in previous chapters. With regard to load levels, the limitations are the boundaries between very low, low, medium, high and very high. These boundaries are based on the analysis of training loads from Polar customers, and are therefore not grounded in firm scientific evidence.

3.6 Strain and Tolerance

Description

So far, we've described how users see their Cardio Load, Muscle Load, and Perceived Load values after each training session, and how these values are calculated. Additionally, Polar Training Load Pro has the capability to calculate calculate Cardio Load as both short-term and long-term training load. In scientific literature, short-term training load is often referred to as acute training load, while and long-term is referred to as chronic training load. The Polar terminology uses "Strain" for short-term load and "Tolerance" for long-term load.

Advantages of use

- Users can track how Strain varied over the past months to identify when training weeks were harder or lighter.
- User can see how Tolerance varied over the past weeks or months to determine whether training has been progressive (a requirement for increasing fitness).

Calculation and interpretation

Strain is defined as the rolling average of the most recent seven days of daily average Cardio Load (referred in scientific literature as acute load), while Tolerance reflects the rolling average of the most recent 28 days of daily average Cardio Load (referred to in scientific literature as chronic load). Based on recommendations by Gabbet et al.,[9] Polar selected one week of training (7 days) as the default for Strain and 28 days as the default for Tolerance. However, Tolerance can vary between three to six weeks of training.

Strain is analogous to a state of "fatigue" (the more training done within the past week, the more fatigue/strain the body experience). Similarly, Tolerance is analogous to a state of "fitness" (the more training done in the past month, the fitter the user is expected to be, and the more prepared they are to endure and tolerate training).[10] Banister et al.[10] proposed that an athlete's performance in response to training can be estimated from the difference between a negative function (Strain) and a positive function (Tolerance).

Limitations

The interpretation of short-term loads as analogous to a state of *strain* and long-term training loads as analogous to a state of *tolerance* is only an estimate and depends on the individual's response to training. Factors outside of training and lifestyle can impact this response.

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Moreover, these interpretations do not apply during block training, where highly concentrated training workloads target carefully selected fitness components, unlike traditional training periodization, which typically aims to develop multiple abilities simultaneously.

3.7 Injury & illness risk

Description

When you've been training more than usual, your injury and illness risk increases. In this situation, the Polar Training Load Pro features shows an alert.

Advantages of use

- By seeing an alert when injury and illness risk increases, users can adjust their training accordingly to prevent injuries or falling ill.

Calculation and interpretation

Injury and illness risk is calculated from Strain divided by Tolerance, based on scientific literature.[2,9] An athlete is considered well-prepared when Tolerance has increased progressively and systematically to high levels (i.e., the athlete has developed fitness) and, the same time, Strain is low. Conversely, if Strain exceeds Tolerance (i.e., the training loads within the past week have been rapidly increased, resulting in fatigue, or training over the last four weeks has been insufficient to develop fitness), then the athlete is considered underprepared and likely at an increased risk of injury.

The "Sweet Spot" for training is defined as the zone where the acute-to-chronic load ratio is between 0.8 and 1.3 (Figure 5). This model has been validated in Australian football, cricket, and rugby[11], demonstrating that injury likelihood is low (<10%) when the acute-to -chronic load ratio (Strain divided by Tolerance) is within the range of 0.8–1.3. The likelihood of injury doubles when the ratio exceeds 1.5 (i.e., the load in the most recent week is 1.5 times greater than the average of the last four weeks).[11,12]

If the user has a higher training load than usual (when the strain-to-tolerance ratio between 1.3 and 1.5), the Polar Training Pro feature will show an alert of slightly increased injury and illness risk. A strain-to-tolerance ratio higher than 1.5 will be interpreted as increased injury and illness risk.

For previous Polar users, the minimum requirement for calculating injury and illness risk is three days with Cardio Load calculation within a 28-day window. Of those three days, at least one of them is outside the seven-day load window. For new users, the minimum requirement is three days with Cardio load calculation within a 28-day window. If a user's Cardio load is below the activity recommendations outlined in the WHO guidelines on physical activity and sedentary behavior,[13] injury and illness risk is not provided. However, a supportive message encouraging the user to listen to their body and remember rest days will be displayed of the ratio Strain-to-Tolerance exceeds 2 and the user is approaching higher loads.

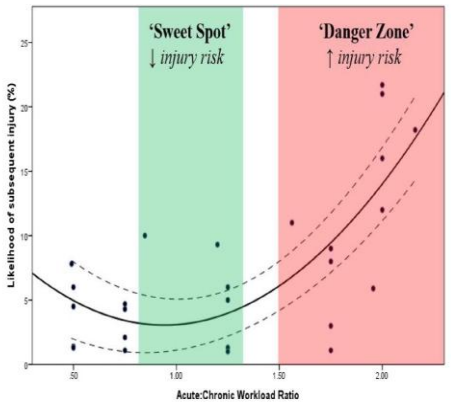

Figure 6 Guide to interpreting and applying acute:chronic workload ratio data. The green-shaded area ('sweet spot') represents acute:chronic workload ratios where injury risk is low. The red-shaded area ('danger zone') represents acute:chronic workload ratios where injury risk is high. To minimise injury risk, practitioners should aim to maintain the acute:chronic workload ratio within a range of approximately 0.8–1.3. Redrawn from Blanch and Gabbett.[11]

Figure 5. "Sweet Spot" for training according to Blanch and Gabbett (2016).

Limitations

It is believed that the same principles applt to athletes participating in individual endurance sports[14] and technical sports, even though researcg confirmation is lacking. The relationship between injury risk and the acute-to-chronic load ratio has not been investigated in users who frequently switch between sports. Engaging in a variety of sports is thought to reduce injury risk. Therefore, this feature may be less precise for users who participate in a diversity of sports.

3.8 Cardio load status

Description

Cardio load status shows how your current Strain relates to Tolerance (Cardio load status equals Strain divided by Tolerance). It allows users to

quickly determine whether their status is classified as detraining, maintaining, productive, overreaching, or recovering.

Advantages of use

- Users can track their estimated training adaptation and response to exercise: detraining, maintaining, productive, overreaching, or recovering.
- Users can view their training status before exercising to decide whether to train, adjust the intensity, or rest.
- Users can observe how their training status changes after exercise to understand the impact of the session on their load.
- Users can anticipate how their training status is estimated to change in the coming days, helping them plan the next key training session.
- Users can assess whether they have accumulated sufficient training load over the past weeks or months to ensure their training is productive and improving fitness.
- If users are overreaching, they can see when their training status is projected to return to productive or maintaining levels, allowing them to resume training without losing fitness by waiting too long.
- Users can review how their Cardio Load status has varied over past weeks and months to identify periods of harder or lighter training.
- Users will see a statues of “recovering” instead of “detraining” after being overreached. This encourages rest when needed, reducing the risk of prematurely increasing training load after overreaching,

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Calculation and interpretation

Cardio Load Status is calculated as “Strain” divided by “Tolerance”. While it uses a similar approach to the injury and illness risk, the limits are not exactly the same (Table 3). In brief, the “Sweet Spot” is divided into two categories:“Maintaining”: When Strain is slightly lower than Tolerance. “Productive”: “When Strain is slightly higher than Tolerance, reflecting progression. The algorithm requires a minimum of three training sessions within the past 28 days.If a user’s Cardio Load is below the WHO guidelines on physical activity and sedentary behaviour13, “Productive” will be shown instead of “Overreaching”. If users significantly reduce their Cardio Load after overreaching, “Recovery” will be displayed instead of “Detraining” for up to 14 days.

Table 3. Cardio load status logics

Strain divided by Tolerance	Textual interpretation	Supporting description
< 0.8	Recovering (if overreaching occurred on on day within the past 14 days)	You’re giving your body some time to recover. That's the way to go after an intensive training period.
< 0.8	Detraining	You’ve been training less than usual. If you keep this up, your fitness level will start going down.
0.8 – 1.0	Maintaining	You’ve been training less than usual, but just enough to maintain your fitness level. If you keep this up for long, detraining will occur.
1.0 – 1.3	Productive	You’ve been training progressively, which should be improving your fitness level. Keep it up!
> 1.3	Productive or Overreaching Including Injury and illness risk alert (the feedback depends on Strain, Tolerance, and the Strain-to-Tolerance ratio)	You’re doing great! Increasing your training gradually is the key. or You’ve been training progressively, which should be improving your fitness level. Listen to your body and don`t forget rest days.  or  You’ve been training much more than usual during the last few days. If you keep this up for long, your risk for sports related injuries will increase and your training may become counterproductive.  or  If you keep on overreaching, you`ll increase your risk for overtraining. With this much training, you`re prone to sports related injuries. You may also fall ill more easily.

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4 Validity

The calculations of Cardio Load,

Muscle Load, Perceived Load,

and injury and illness risk are based

on scientifically accepted methods.[2,9]

5 Limitations

Although Polar Training Load Pro employs a unique holistic approach, it does not encompass all possible aspects of the body's physiological and psychological systems.

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Table 4. Polar Terminology related to Training Load Pro and Recovery Pro

Polar Terminology	Definition
Cardio load	Cardio load (training impulse, TRIMP) shows the cardiac response to a training session. The Cardio load levels indicate how hard a training session was compared to your session average from the past 90 days.
Cardio load status	Cardio load status shows how the current Strain relates to Tolerance (The Cardio load status is Strain divided by Tolerance). Users can quickly see if their status is detraining, maintaining, productive, or overreaching.
cardio system	The circulatory system, also called cardiovascular system. Example: The Orthostatic test provides the following results: "Your cardio system is not fully recovered" and " Your cardio system is recovered.
cardio training	Cardio training involves large muscle movements sustained over a period of time while maintaining your heart rate at least 50% of its maximum. It provides an effective workout for the heart, lungs, and circulatory system.
detraining	Detraining Cardio load status: “You've been training less than usual intentionally or unintentionally. If you keep this up, your fitness level will start going down.”
injury and illness risk	If users have been training more than usual, they’ll have an increased risk of getting injured or sick. They’ll get an injury risk alert.
maintaining	Maintaining Cardio load status: “You've been training less than usual, but just enough to maintain your fitness level. If you keep this up for long, detraining will occur.”
Muscle load	Muscle load shows the amount of mechanical energy (kJ) that an athlete produces during a running or cycling session. It reflects energy output, not the energy input required to produce that effort. In general, greater fitness leads to improved efficiency between energy input and output. For running, body weight is also taken into account. Muscle Load levels indicate how hard a training session was compared to the average session over the past 90 days.
overreaching	Overreaching Cardio load status: “You've been training more than usual. If you keep this up for a long time, your risk of sports related injuries increases, and your training may become counterproductive.”
Perceived load	Perceived Load is calculated based on training duration and subjective assessment, such as the perceived demand of the training session. It is particularly useful for sports where measuring training load based solely on heart rate has limitations, such as strength training, short intervals, and sprints. Perceived Load levels indicate how demanding a training session was compared to the average session over the past 90 days.
productive	Productive Cardio load status: “If you've been training

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	progressively long enough, the chances are that you're getting fitter.”
RPE	The abbreviation 'RPE' stands for 'rate of perceived exertion.' This metric tracks how demanding training sessions feel. If the perceived exertion of similar sessions decreases over time, it may indicate improved performance. Conversely, unexpectedly high exertion levels can suggest factors interfering with recovery.
Recovering	“Recovering” status is displayed instead of “Detraining” if Cardio load status is equal or less than 0.8 and Cardio load status was Overreaching for at least one day in the past 14 days. The purpose is to encourage rest when needed, rather than motivating an increase in Cardio Load. Polar Recovery features allow to better assess recovery and determine readiness for the next exercise.
Strain	Strain describes how much strain has been experienced from recent training. It shows the average daily load over the past seven days. Cardio Load Status indicates how Strain relates to Tolerance (Cardio Load Status is Strain divided by Tolerance)
Tolerance	Tolerance describes readiness to endure cardio training. It shows the average daily load from the past 28 days. Cardio load status indicates how Strain relates to Tolerance. (Cardio load status is Strain divided by Tolerance)
Training Load Pro	Training Load Pro includes Cardio load, Muscle Load and Perceived load. It helps users understand the ways that their training sessions are straining their body.
your estimate	This estimate, RPE, tracks how hard training sessions felt and whether reality aligned with the planned effort. The abbreviation 'RPE' stands for 'rate of perceived exertion.' If estimates for similar sessions become lighter, performance is likely improving. Unexpectedly high estimates may indicate factors interfering with recovery.

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