# Polar Work-rest Guide

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Polar Research Center

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## 1 Introduction

The basic principles of high intensity training, such as interval or strength training, involve incorporating rest periods of a specified length between exercise sets to reach the desired state of recovery. The duration of these rest periods is traditionally chosen according to the desired training target and determined as a specified time. In workouts where the total load is critical for achieving the intended training effect, longer rest periods are necessary. To sustain high loads throughout the exercise, full or almost full recovery between the sets is essencial. On the other hand, when the goal is to maximize the metabolic stress during the exercise or the hormonal response due to the exercise are seeked, shorter resting periods may be beneficial. Training with short rest intervals promotes adaptations that enhance the body's ability to sustain high-intensity performance. [1, 2, 3, 4]

Rest periods aim to facilitate recovery in energy systems and neuromuscular mechanisms to achieve the desired training effect. It is important to acknowledge the subjective variations in reaching an appropriate state of recovery. Due to the lack of more accurate measurement methods, recovery instructions are typically based on time between sets. Although these instructions may vary among authors, they generally express similar temporal requirements. It is known that in training it is difficult to precisely define an optimal rest interval between sets because athletes have different goals and fitness levels [3]. Particularly, when the training goal is muscle endurance or hypertrophy, it can be argued that an optimal time for rest interval may not exist. Consequently, there is a need to develop alternative methods for determining rest period length beyond relying solely on a predetermined amount of time.

Time-based recovery periods don't consider workout-specific or individual variables. These variables include factors such as the intensity and duration of an exercise set, the size of the muscle group being trained, the effort, the perceived exertion of the set, fatigue accumulation during the workout, personal differences in recovery ability, and day-to-day variations within an individual. Taking these factors into account, one option is using user's heart rate to determine a personalized rest period for high intensity exercises.

## 2 Physiological background

The physiological parameters that contribute or reflect the acute recovery in muscle tissue are energy processes within working muscle. Oxygenation level reflects adenosine tri-phosphate (ATP) hydrolysis: when high amounts of ATP or phosphocreatine are hydrolyzed into their reduced forms adenosine diphosphate (ADP) and creatine, mitochondrias are consuming a significant amount of oxygen to replenish them through chemical reactions. Consequently, the level of blood oxygenation in the muscle decreases as more oxygen is transported from blood to muscle cells. As shown in Figure 1, the temporal manifestation of hypoxia closely resembles the recovery in heart rate after a work set. The dotted lines in the figure represent the performed exercise. In this example, the oxygenation level returns to the initial levels in approximately 100 seconds.

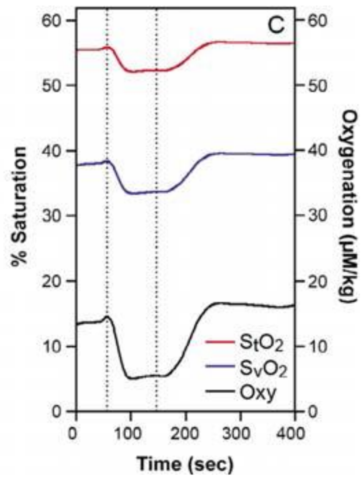


***Figure 1**. Oxygenation of the human arm muscles working in ischemic conditions (arm cuff) at 25% MVC level. [5]*

When the heart needs to pump more blood, it increases both the volume of each contraction and the rate of each contraction cycle. Several mechanisms prompt the heart to elevate heart rate, with the primary reason being the increased demand for oxygen. When muscle tissue is temporarily subjected to high work rates and reaches hypoxic conditions, like during high intensity exercise sest, a substantial amount of ADP or even adenosine monophosphate (AMP) needs to to be repleanished into ATP after the exercise set. This leads to a drop in the muscle's oxygenation level. The main consequence is that the blood leaving the muscle belly contains lower-than-normal levels of oxygen. This acts as a signal for the arteries and the heart to deliver more oxygen to the working muscles, resulting in the dilation of arteries and an increase in heart rate. Once the acute drop in muscle oxygenation level is restored, heart rate and blood flow to the muscles can decrease again. This phenomenon is clearly visible in the heart rate signal from strength training exercise (Figure 2.). It's important to note the drift of basal heart rate level along with the accumulated fatigue. Each exercise set causes a significant elevation in heart rate. The relative drop in hearte rate during interset recovery period stays the same regardless of elevated basal level in heart rate.

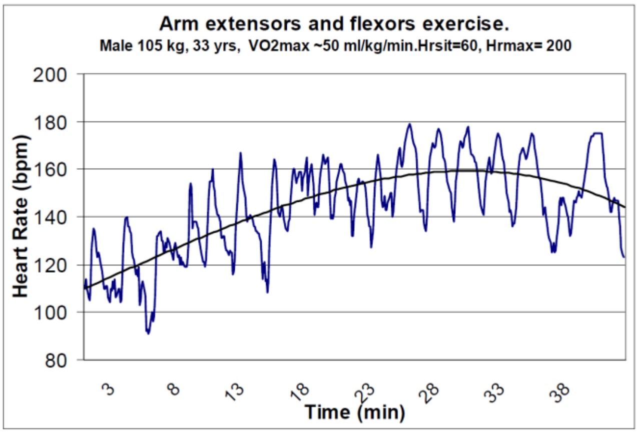


***Figure 2.*** *An example of 5-sec averaged HR-curve from 40 minute strength training exercise session.*

Heart rate serves as a reliable indicator of exercise sets and subsequent recovery due to its connection with the central nervous system. The high effort needed to end the set can cause the heart rate even to exceed the oxygenation and muscle metabolism required for such a workload. Figure 2 shows this in exaggerate form. The high level of effort elevates the heart rate to a point where significant oxygen consumption occurs, despite the fact that the trained muscles are relatively small and cannot utilize that amount of energy. Therefore, the heart rate observed during an exercise set is a function of muscle energy metabolism / hypoxia and training effort. Additioanlly, the drop in heart rate after an exercise set reflects re-oxygenation of the muscles.

## 3 Algorithm development

To create an interest recovery algorithm based on heart rate we chose to utilize a common prescription for "general muscular fitness", which recommends 8-12 repetitions with 1.5-2 minute recovery period between sets. By following this prescription, one can maximize the positive effects of strength training. This training approach offers a balance between high-repetition, short-recovery training for local muscular endurance, and low-repetition, long-recovery training for maximal strength development. The prescribed repetitions and recovery periods encompass a range that promotes a variety of adaptations typically seen in different types of strength training. Moderate (60-90 seconds) rest intervals enhance the body's anabolic environment and induce greater muscle hypoxia, thereby increasing the potential for muscular growth [2].

The algorithm was developed based on heart rate recordings from experienced fitness trainers during training sessions involving 8-12 repetitions and 1.5 minutes of inter-set recovery. The training sessions encompassed exercises targeting all muscle groups equally. Additionally, Test participants were interviewed to ensure that only successful training sessions were included in the subsequent analysis. As a result, we created an algorithm that goes beyond simply reaching a resting heart rate between sets. We recognised a phenomenon of "residual heart rate" or "basal heart rate" that occurs during training. Therefore, we cannot assume that the heart rate will always return to the low levels observed at the beginning of the exercise. Instead, we need to take into account the cumulative fatigue and ensure the recovery periods do not become excessively long towards the end of the training session.

# 4 Validity

The validity of the algorithm has been investigated by Piirainen et al, who conducted a study comparing hormonal, neuromuscular, and aerobic performance changes between a constant 2-minute interset recovery time and an interset recovery time based on individual heart rate (HR) responses during a 7-week (3 sessions per week, 3x10 repetition maximum [RM]) hypertrophic strength training period. [1]

The HR-dependent recovery time was determined using a Polar FT80 HR monitor, while the control groups adhered to a constant 2-minute period between sets. The FT80 heart rate monitor utilizes an HR-based recovery algorithm for guiding inter-set recovery time during strength training sessions. Polar Electro Oy has patented the algorithm with the European patent specification (EP2113290) and the United States Patent specification (US7914418). The new Polar Smart Coaching feature called *Work-rest guide* incorporates exactly the same algorithm as FT80, so the research findings presented here can be considered valid not only to FT80 monitor, but also to new *Work-rest guide* feature.

### Research findings

Piirainen et al. divided 24 male subjects in two equal groups. Ultimately, 21 participants completed the 7-week training period (FT80, n = 12; CONTROL, n = 9). Researchers measured concentric knee extension 1RM before, after four weeks, and at the end of the training period. Concentric knee extension and knee flexion 10RM, central activation ratio (CAR), and maximal oxygen uptake (VO2 max) were also measured before and after the training period. [1]

The group who utilized FT80 (p , 0.001) to guide rest periods saw a higher increase in 10RM (p , 0.05) than the CONTROL group (p , 0.001). Central activation ratio increased in both groups, with a more significant increase observed in the FT80 group (p , 0.05). VO2 max was unchanged in both groups. The higher TES responses, 10RM, and CAR development in the participants that used FT80 suggest that an HR-based recovery period system may be more efficient in this type of hypertrophic strength training (3x10RM). [1]

### Practical applications of the algorithm

Piirainen et al. concluded that a heart rate-based resting period may be more optimal compared to a constant resting period method in strength training aimed at maximizing the hormonal response instead of total load. The former method leads to shorter resting periods, and, consequently, to shorter training sessions, while still inducing similar or even increased training responses in the early phase of training. [1]

Considering the intensity of the traning, it is advisable to avoid using short rest periods without proper guidance in order to reduce nonfunctional overreaching and the risk of overtraining syndrome, especially during long-term training periods. [1]

# 5 Work-rest guide in practice

The Work-rest guide feature has been developed for easy use. It doesn't require the user to take any additional actions; they simply need to enable it before recording a training session with a compatible Polar watch. The algorithm automatically detects the highest heart rate reached during the execution of an exercise set, and performs subsequent calculations to determine a suitable recovery heart rate. Once the peak heart rate is recognized, a dotted line representing the targeted recovery heart rate is displayed on the training device along with a real-time heart rate graph. When the user's heart rate drops to the desired level, a reminder indicating successful recovery appears automatically. After that, the user can decide whether to follow the instructions or not. During next set, the peak heart rate is detected, and a subsequent recovery target is provided regardless of the previous recovery period fulfilment.


***Figure 3.*** *Work-rest guide training displays during workout.*

The user can enhance the functioning of the Work-rest guide feature by exercising with high focus and effort. Pushing oneself to true exhaustion during the work set will result in a higher heart rate during the set, making the exercise set more effective and heart rate peak more easily detectable for the algorithm. For a successful and healthy training experience, we recommend starting the training session with a warm-up period to gradually raise the heart rate before engaging in the the actual exercises. Having an elevated heart rate at the beginning of the session will contribute to an overall higher heart rate throughtout the entire session, which will increase the total energy expenditure and intensity of the training. Additionally, we advise the user to fully rest immediately after completing an exercise set. This will assist the algorithm in identifying a distinct peak in the heart rate signal. During this rest period, it is reccommended to avoid any strenuous activities, such weight-racking during strength exercises, until the dotted recovery heart rate target appears on the display.

The Work-rest guide feature is optimized for training sessions aimed at developing general muscle strength. However, if users are looking to achieve a different training response, they can deviate from the instructions given by the feature and use either shorter or longer breaks in their training, depending on their goals. In these cases, the feature can still be a good guide for improving your training rhythm.

## 6 Benefits

The utilization of heart rate-guided recovery offers several advantages in training. Instead of relying on a stopwatch to measure the time between sets, using heart rate as a means to determine the appropriate recovery state is both a novel concept and has been supported by research. This approach helps users maintain a high level of focus during exercise execution. Moreover, the integration of the algorithm into a modern sports watch with a revamped user interface has made the new method highly intuitive to use.

In addition to addressing usability concerns, the Work-rest guide feature offers entirely new possibilities to guide training. Traditional time-based rest periods don't consider several daily, workout, and personal variables. These variables include the intensity and duration of an exercise set, the size of trained muscle group, effort or perceived exertion of an exercise set, fatigue accumulation during workout, individual differences in recovery ability, and intrapersonal day-to-day variations.

Using the Work-rest guide feature enhances both the overall effectiveness and the average cardiovascular work rate of a training session. The feature provides personalized guidance for anyone to complete workouts without having to follow pre-defined training plans or generic fitness advice. In doing so, the feature emphasizes the importance of a suitable rest period duration between sets to maximize the body's response to training [4]. Incorporating relatively short rest periods is a suitable approach to design time-efficient resistance training sessions without significantly compromising the desired training effect [6, 7]. In addition, utilizing the Work-rest guide feature ensures that training constantly reaches a cardiovascular intensity averaging over 60% of HRmax, which serves as minimum threshold for cardiovascular training stimulus.

## 7 Patents

Patents: US7914418 and EP2113290

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