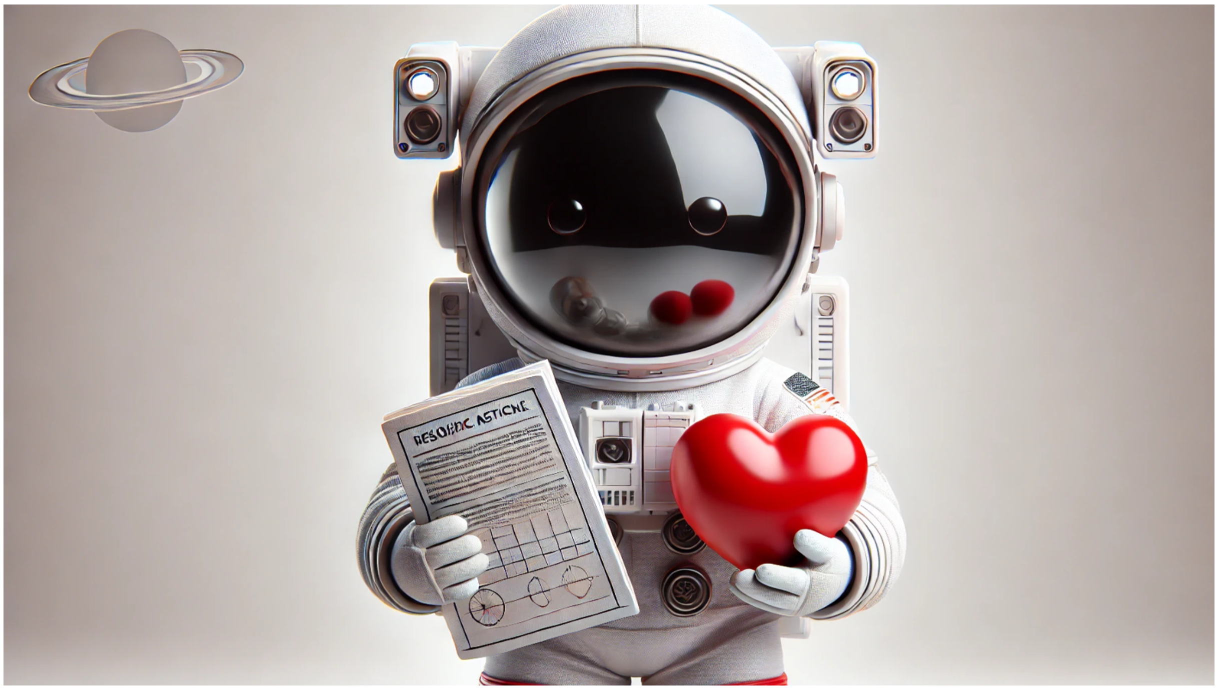
Sports Science 3.0 Series



The Tabatastrophe: How high-end exercise metabolism research turned into low-end fitness workouts

Martin Buchheit, [1 2 3 4 5 6] **Paul B. Laursen** [2 6 7 8]

[1]Type 3.2 Performance, Montvalezan, France
[2]HIIT Science, Revelstoke, Canada
[3]Aspetar, Doha, Qatar
[4]Optimo Performance Center, Estepona, Spain
[5]INSEP, Paris, France
[6]Athletica, Revelstoke, Canada
[7]Sports Performance and Athlete Development Environments (SPADE), University of Agder, Kristiansand, Norway
[8]Sports Performance Research Institute New Zealand (SPRINZ), AUT University, Auckland, New Zealand

Tabata | **HIIT** | **Anaerobic capacity** | **VO_2max** | **Exercise physiology** | **Metabolic demand** | **Fitness trends** | **YouTube workouts** | **Workout Reserve** | **Sports Science 3.0**

Headline

High-intensity interval training (HIIT) is everywhere—on YouTube, in group fitness classes, and even in pop culture. “Tabata” has become a household name, synonymous with short, brutal efforts set to pounding beats. The song “Welcome to Tabata” serves as anthem for countless workouts. The COVID-19 pandemic only fueled its rise, making it the go-to home workout. But today’s Tabata is a far cry from its scientific origins. Fortunately, Sports Science 3.0 is poised to change that.

The origins of Tabata training

The Tabata protocol originates from a 1997 study by Japanese researcher Izumi Tabata and colleagues, which remains one of the most rigorous investigations into the metabolism of HIIT (Tabata et al., 1997). The study’s methodology was particularly advanced (Figure 1), utilizing the maximal accumulated oxygen deficit (MAOD) method to estimate anaerobic (lactic) contribution (Medbø 1996). This research became a benchmark for Sports Science 1.0 and has been cited over 500 times.

Participants performed high-intensity cycling intervals: 20 seconds at 170% of the power associated with VO_2max, followed by 10 seconds of rest, repeated for six to seven rounds. This precise intensity ensured that both aerobic and anaerobic energy systems were maximally engaged. The combination of controlled exercise conditions, direct VO_2 measurements, and MAOD analysis made this study a staple in HIIT metabolism research. However, as the fitness industry adopted the concept, some of the key details were lost.

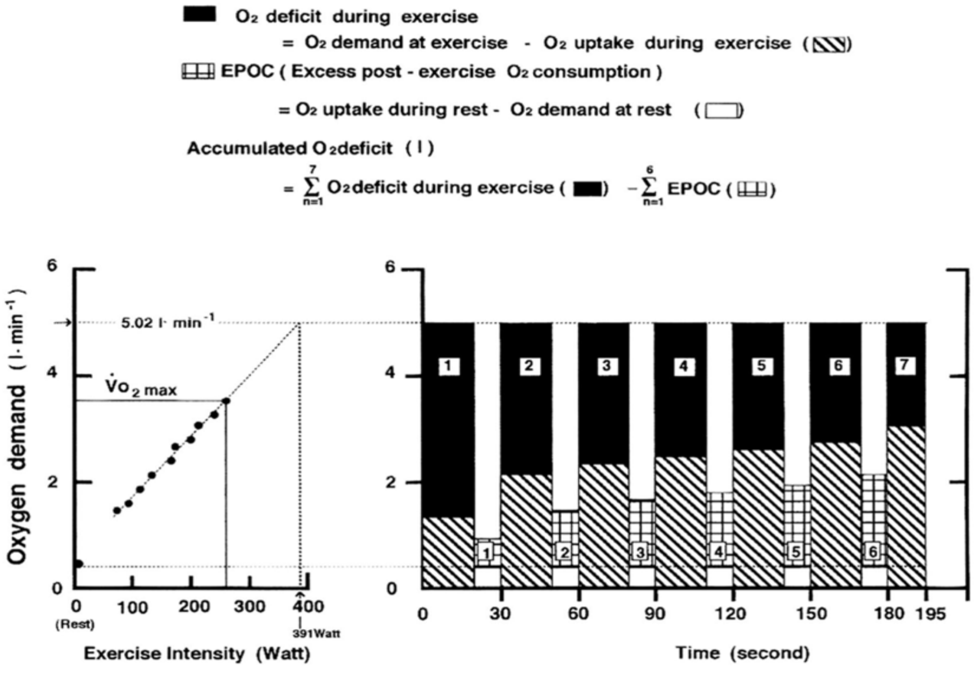


Fig. 1. **Principle of calculating the maximal accumulated oxygen deficit (MAOD) for the high-intensity intermittent exercise (Tabata 1997).**

From science to spectacle: How Tabata became a YouTube-friendly burn session

The rationale for using the Tabata protocol as a training method is sound—research has shown it to be one of the most efficient stimuli for taxing both the aerobic and anaerobic systems maximally (Figure 2, Tabata 1997).

The original study demonstrated its effectiveness under precisely controlled conditions, making it an appealing option for high-intensity training. But what happened over subsequent decades is where things went off course. Today's "Tabata" workouts often involve random bodyweight movements—burpees, jumping jacks, push-ups—performed at maximal effort. However in the original study (Figures 1 & 2), the intensity was not just about going "all out"; it was precisely calibrated based on physiological markers (i.e., 170% of the power associated with VO_2max).

Thus, the key flaw in modern Tabata-style workouts is the failure to use the appropriate exercise mode. Metabolic demand is directly tied to the amount of active muscle mass engaged (Poole & Richardson, 1997). The original protocol used cycling to ensure maximal engagement of large muscle groups. However, many of today's versions rely on exercises that do not generate the same metabolic stress, likely resulting in lower aerobic stimulus and a disproportionate anaerobic load.

As a consequence, it is unclear whether these workouts even replicate the physiological effects of the original method. Many people are unknowingly following a diluted, suboptimal version—misled by poor translation of research and a limited understanding of exercise physiology. But in an era where workouts are designed for views and likes, what matters most is that they "look" intense on YouTube and make athletes "feel the burn" (i.e., following a Sport Science 2.0 approach, Buchheit & Laursen 2024) (Figure 3).

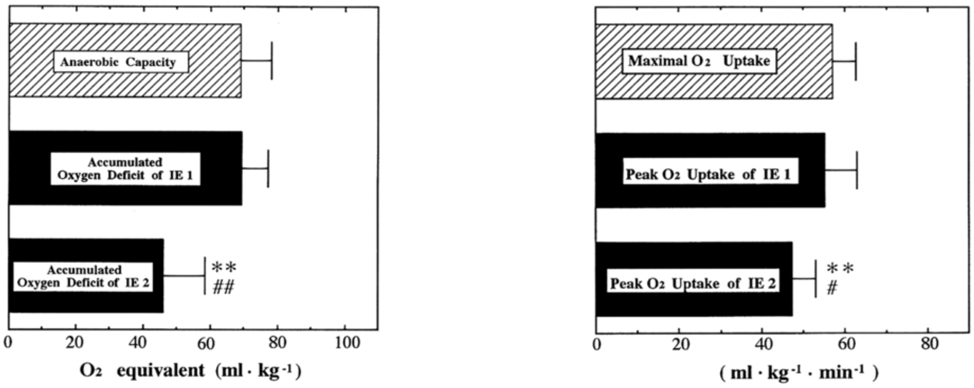


Fig. 1 Accumulated oxygen deficit during the intermittent exercise (IE)1 protocol (Tabata training) and the IE2 protocol and the anaerobic capacity, i.e., the maximal accumulated oxygen deficit (MAOD) [12]. $^{**}p < 0.01$ vs. the anaerobic capacity (MAOD). $^{\#\#}p < 0.01$ vs. the accumulated oxygen deficit in the IE1 protocol

Fig. 2 Peak oxygen uptake during the last 10 s of the IE1 (Tabata training exercise) and IE2 protocols, and the maximal oxygen uptake [12]. $^{**}p < 0.01$ vs. the maximal oxygen uptake. $^{\#}p < 0.05$ vs. the peak oxygen uptake during the last 10 s of the IE1 protocol

Fig. 2. Accumulated oxygen deficit (AOD) and VO_2 demand during the original Tabata intermittent exercise (IE1) 1 protocol. The IE1 protocol, consisting of 7–8 bouts of 20-second cycling at 170% VO_2max with 10-second rest intervals, elicits both maximal anaerobic and aerobic energy contributions. The AOD reaches values equivalent to anaerobic capacity, while oxygen uptake during the final bouts approaches VO_2max, confirming the simultaneous recruitment of both energy systems (Tabata et al., 1997). In contrast, the IE2 protocol (4–5 bouts of 30-second cycling at ∼200% VO_2max with 2-minute rest intervals) results in lower aerobic and anaerobic demands than IE1.

Tabata training: proven benefits, but what do they mean?

Several studies have shown that Tabata-style training improves fitness, particularly in untrained or recreationally active individuals. The original study by Tabata et al. (1996) demonstrated significant increases in both VO_2max and anaerobic capacity after six weeks of high-intensity intermittent cycling. Variations of the Tabata protocol have been found to enhance aerobic power to a degree comparable to traditional HIIT, while often being more effective at increasing anaerobic capacity (Tabata 2017; Viana, 2018). When performed correctly—especially using cycling, as in the original protocol (Tabata 1996; 1997) — these adaptations are well-documented and appear to be driven primarily by peripheral mechanisms, such as increased enzymatic activity in skeletal muscles and improved buffering capacity.

While Tabata training has gained popularity as a tool for weight loss, the scientific evidence does not strongly support this claim. Studies indicate that the total energy expenditure of these workouts is relatively low due to their short duration, and while excess post-exercise oxygen consumption (EPOC) and thermogenic responses may be elevated, they are not sufficient to significantly impact long-term weight loss. Additionally, the metabolic effects observed in Tabata training align with those of other HIIT protocols, meaning its claimed advantages over other methods for fat loss remain unsubstantiated.

Is Tabata training the right fit for everyone?

Like any training method, Tabata workouts should be selected based on an individual's goals, whether for athletic performance or health. Improving VO_2max is a widely relevant objective, as it directly enhances performance in endurance sports like running, rowing, and skiing, and indirectly benefits team sports by improving inter-effort recovery (Laursen & Buchheit, 2019). Beyond sports, VO_2max is also the single most important physiological marker for health and longevity (Attia, Outlive, 2023), reinforcing its role as a key training target.

But who actually needs to improve anaerobic capacity? This is highly sport-dependent. Short-duration, high-intensity efforts—such as those in sprinting, combat sports, or certain team-sport positions—may benefit from anaerobic capacity gains (Laursen & Buchheit, 2019). However, for many sports and obviously the general population, the advantages of specifically targeting anaerobic capacity are less clear. Given the high neuromuscular and metabolic cost of Tabata training, its necessity outside of sport is questionable due to the considerable stress imposed that may be malproductive (Maffetone & Laursen, 2015). Even if performed correctly (which, as discussed, is rarely the case in mainstream fitness), is it truly the optimal training solution? For many, structured HIIT protocols that prioritize sustainable aerobic improvements may be more effective, practical and sustainable (Laursen & Buchheit, 2019).

Lastly, the reported improvements often reflect what is referred to as the "toothpaste theory": when someone is untrained, almost any exercise produces measurable results. For long-term progress, it is critical to target specific physiological adaptations, such as sustained improvements in VO_2max or muscular strength (Laursen & Buchheit, 2019). Poorly designed HIIT sessions that rely on arbitrary "all-out" efforts fail to achieve this, often causing excessive stress without optimizing the training stimulus. To ensure meaningful and sustainable gains, HIIT must be recalibrated to align with physiological principles and individualized targets.

physical fitness and performance

Metabolic profile of high intensity intermittent exercises

IZUMI TABATA, KOUICHI IRISAWA, MOTOKI KOUZAKI, KOUJI NISHIMURA, FUTOSHI OGITA, and MOTOHIKO MIYACHI

Department of Physiology and Biomechanics, National Institute of Fitness and Sports, Kanoya City, Kagoshima Prefecture, 891-23 JAPAN; and The Japanese National Speed Skating Team, National Skating Union of Japan, Kishi Memorial Hall, Shibuya City, Tokyo 150, JAPAN

ABSTRACT

TABATA, I., K. IRISAWA, M. KOUZAKI, K. NISHIMURA, F. OGITA, and M. MIYACHI. Metabolic profile of high intensity intermittent exercises. *Med. Sci. Sports Exerc.*, Vol. 29, No. 3, pp. 390–395, 1997. To evaluate the magnitude of the stress on the aerobic and the anaerobic energy release systems during high intensity bicycle training, two commonly used protocols (IE1 and IE2) were examined during bicycling. IE1 consisted of one set of 6–7 bouts of 20-s exercise at an intensity of approximately 170% of the subject's maximal oxygen uptake ($\dot{V}O_{2max}$) with a 10-s rest between each bout. IE2 involved one set of 4–5 bouts of 30-s exercise at an intensity of approximately 200% of the subject's $\dot{V}O_{2max}$ and a 2-min rest between each bout. The accumulated oxygen deficit of IE1 (69 ± 8 ml·kg^{-1}, mean ± SD) was significantly higher than that of IE2 (46 ± 12 ml·kg^{-1}, $N = 9$, $p < 0.01$). The accumulated oxygen deficit of IE1 was not significantly different from the maximal accumulated oxygen deficit (the anaerobic capacity) of the subjects (69 ± 10 ml·kg^{-1}), whereas the corresponding value for IE2 was less than the subjects' maximal accumulated oxygen deficit ($P < 0.01$). The peak oxygen uptake during the last 10 s of the IE1 (55 ± 6 ml·kg^{-1}·min^{-1}) was not significantly less than the $\dot{V}O_{2max}$ of the subjects (57 ± 6 ml·kg^{-1}·min^{-1}). The peak oxygen uptake during the last 10 s of IE2 (47 ± 8 ml·kg^{-1}·min^{-1}) was lower than the $\dot{V}O_{2max}$ ($P < 0.01$). In conclusion, this study showed that intermittent exercise defined by the IE1 protocol may tax both the anaerobic and aerobic energy releasing systems almost maximally.

ACCUMULATED OXYGEN DEFICIT, ANAEROBIC CAPACITY, MAXIMAL OXYGEN UPTAKE, BICYCLING

During high intensity exercise, ATP is resynthesized by both aerobic and anaerobic processes (17,18). The ability to resynthesize ATP may limit performance in many kinds of sports. Thus, the focus for training of athletes participating in sports involving high intensity exercise should be on improving the athletes' ability to release energy both aerobically and anaerobically. It is conceivable that the more demanding the training is the greater the fitness benefit will be. In this study we were interested in how commonly used specific exercises tax the anaerobic and aerobic energy release systems.

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The aerobic energy release has traditionally been determined by measuring the oxygen uptake during exercise (1,8,10,12,13). By measuring the oxygen uptake and comparing that value with the subjects' maximal oxygen uptake ($\dot{V}O_{2max}$), the stress on the aerobic energy release can be evaluated during training. The anaerobic energy release, depending on phosphocreatine breakdown and lactate production, is probably limited by lactate accumulation in the working muscles (18).

Until recently, methods for quantifying the anaerobic energy release have been inadequate, and therefore little information is available on the anaerobic energy release during exercise. We have proposed that the accumulated oxygen deficit, first introduced by Krogh and Lindhard (11), is an accurate measure of the anaerobic energy release during continuous exercise such as treadmill running (16,19) and bicycling (7,17). This principle may also allow quantification of the anaerobic energy release during high intensity exercises. Therefore, the metabolic profiles of high intensity exercise may also be evaluated by determining the accumulated oxygen deficit during high intensity exercises and comparing that entity with the subjects' anaerobic capacity (16,20).

Previously reported profiles of high intensity exercises were limited to exhausting continuous exercises (16,20). We have studied metabolic profiles of high-intensity intermittent exercises that have been used frequently as training exercise by top athletes involved in high intensity exercise lasting 1 min or less. Two different intermittent exercise protocols that are regularly used by coaches of top level Japanese speed skaters have been compared.

MATERIALS AND METHODS

Subjects. Nine young male students majoring in physical education volunteered for the study (Table 1). They were members of varsity tennis, baseball, basketball, football (soccer), or swimming teams. After receiving an explanation of the purposes, potential benefits, and

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Fig. 3. From science to spectacle.

The need for proper HIIT calibration: Optimizing Tabata prescription

A well-designed HIIT session is far more complex than simply pushing to exhaustion for 20 seconds. Effective HIIT requires precise intensity control, which can be achieved using external markers such as maximal aerobic speed (MAS) or maximal aerobic power (MAP), both of which represent the intensity at which VO_2max occurs and provide a structured way to prescribe workload (Laursen & Buchheit, 2019). One advantage of the original Tabata protocol was its use of a fixed percentage of MAP (170%) rather than an uncontrolled "all-out" effort, ensuring a more structured and physiologically anchored intensity than many modern HIIT adaptations.

However, for supramaximal efforts (above VO_2max), intensity should ideally be further refined using percentages of the anaerobic speed or power reserve (ASR or APR), which accounts for an individual's maximal sprinting speed (MSS) and maximal peak power (MPP) (Sandford 2021). Precise details of the protocols used to assess these parameters are described elsewhere (Laursen & Buchheit, 2019), but in practice, MAS/MAP can be determined using either an incremental test to exhaustion, a 5-minute all-out effort on a bike or track, or a running 2 km time trial, while MSS/MPP can be assessed through a maximal sprint effort lasting 3–6 seconds. This approach ensures that high-intensity efforts are physiologically appropriate rather than arbitrary bursts of maximum effort. Conveniently, artificial intelligence (AI) training platforms such as Athletica allow for the capture of this data and subsequent zone calibration using invisible monitoring–simply monitoring individuals using wearables or prescribing specific all-out efforts of various durations (Figure 4).

Table 1 presents typical values for VO_2max, MAP, peak sprint power, and APR across different training backgrounds. It is important to note that an individual's profile may not fit neatly into a single category. For example, an endurance-trained athlete with limited sprint training may have an MAP typical of elite endurance specialists but a peak sprint power closer to that of well-trained speed/power athletes. Similarly, a team sport athlete with a strong aerobic base may align with endurance-trained individuals in MAP but have a higher APR due to enhanced sprint capacities. This overlap highlights the need for individualized assessments when designing training programs.

An improved approach to Tabata intensity prescription would be to base it on a %APR rather than MAP. Setting intensity at approximately 70% of APR could help ensure that efforts remain physiologically appropriate and sustainable while still eliciting the desired metabolic stress, similar to that of the initial intentions of the authors. This refinement addresses a key limitation observed in the original study, where not all participants could complete the full protocol. Specifically, six of the nine subjects were able to finish the sixth bout at 170% VO_2max, while the remaining three became exhausted during the seventh bout. This suggests that for some individuals, particularly those with a lower APR, the power at

170% of MAP may have been excessively demanding (closer to their MPP than their counterparts with a greater reserve), limiting their ability to complete the entire designed session.

Table 2 highlights how the same Tabata session imposes varying metabolic and neuromuscular demands depending on the athlete's profile. For endurance-trained athletes with a high MAP but lower APR, the workout represents a greater anaerobic/neuromuscular challenge, potentially leading to premature fatigue. Conversely, speed/power-trained athletes with a high APR may experience a lower anaerobic/neuromuscular load, as the relative intensity of the workout remains closer to their MAP. By incorporating APR into intensity prescription (i.e., Figure 4), the Tabata protocol can be better tailored to individual physiological profiles, improving both adherence and effectiveness across a broader range of athletes and populations.

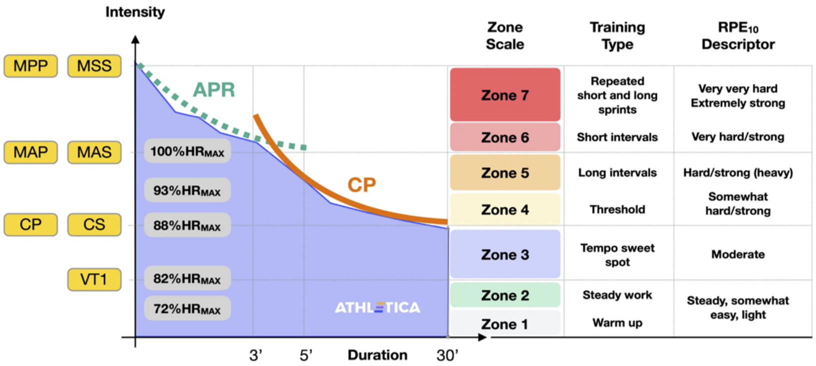

Fig. 4. **Arbitrary external load markers used by Athletica to calibrate training zones and prescriptions: Maximal peak power (MPP), maximal sprinting speed (MSS), maximal aerobic power (MAP), maximal aerobic speed (MAS), anaerobic power reserve (APR), critical power (CP), critical speed (CS), first ventilatory threshold (VT1), maximal heart rate (HRmax), and rating of perceived exertion (RPE10).**

Table 1. **Physiological characteristics of athletes across different training backgrounds. VO_2max represents maximal aerobic power, while MAP (maximal aerobic power output) corresponds to the power associated with VO_2max. Max Peak Power (MPP) reflects short-duration maximal power output during an all-out cycling sprint. Anaerobic Power Reserve (APR) is calculated as Max Peak Power – MAP. Values are expressed in relative terms ($W \cdot kg^{-1}$) and for a 75kg reference athlete in absolute watts (W).**

Training Status	VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	MAP ($W \cdot kg^{-1}$)	MAP (W, 75kg athlete)	Max Peak Power ($W \cdot kg^{-1}$)	Max Peak Power (W, 75kg athlete)	Anaerobic Power Reserve (APR) ($W \cdot kg^{-1}$)	APR (W, 75kg athlete)
Sedentary/Untrained	∼30–40	∼3.0–3.8	∼225–285	∼6–8	∼450–600	∼3.0–4.2	∼225–315
Recreationally Trained	40–50	∼3.8–4.5	∼285–340	8–11	600–825	∼4.2–6.5	∼315–485
Well-Trained (Endurance Athletes, Team Sports)	50–65	∼4.5–5.8	∼340–435	10–14	750–1050	∼5.5–8.5	∼415–615
Elite Endurance Athletes (Cyclists, Runners, Rowers, Skiers)	65–85	∼5.8–7.0	∼435–525	12–16	900–1200	∼6.2–9.0	∼465–675
Elite Speed/Power Athletes (Track Cyclists, Sprinters, Speed Skaters)	45–65	∼4.5–6.0	∼340–450	16–22+	1200–1650+	∼10.0–16.0+	∼750–1200+

Table 2. **Example profiles of athletes with different MAP and MPP capacities illustrate how Tabata power output corresponds to different percentages of the anaerobic speed/power reserve (ASR/APR).**

Athlete profile	Endurance	Low Capacity	Speed/Power	Hybrid
MPP (W)	800	800	1200	1100
MAP (W)	380	290	290	380
APR (W)	420	510	910	720
Tabata Power - 170% MAP (W)	646	493	493	646
Tabata power / APR (W)	266	203	203	266
Tabata power / APR (%)	63%	40%	22%	37%

Know your training history: how Workout Reserve optimizes HIIT

An essential advancement in training prescription is the integration of historical maximal mean power data into workout design (Quod et al., 2010). The ability to execute any given session is shaped by an athlete's prior training history and accumulated fatigue.

Athletica addresses this with its proprietary Workout Reserve algorithm (Figure 5), which predicts session depletion based on external load variables such as power or pace. Workout Reserve begins at 100% and depletes as work is performed, reaching 0% when an athlete has expended their predicted reserve. If Workout Reserve goes negative, it indicates the athlete has surpassed their best effort for a given duration within the past six weeks—effectively setting a new personal best. This real-time tracking provides a more precise measure of performance sustainability and fatigue, enabling adjustments to training intensity and structure.

By integrating Workout Reserve, HIIT prescriptions can move beyond fixed, one-size-fits-all approaches (Zignoli, 2023). Traditional Tabata intervals, for example, are typically prescribed without considering an athlete's real-time readiness. With Workout Reserve, work-to-rest ratios, intensity targets, and total session volume can be dynamically adjusted based on an athlete's historical and real-time fatigue markers, ensuring both effectiveness and sustainability (Figure 5).

Short HIIT 20"/10" interval ride

Short interval 20-10 VO2 set. This session targets high power outputs and VO2max development.

WU 6′ (include some short bursts)

★ 2 × 8 × 30″

(3′ recovery between sets)

20″

10″ just turning over legs

CD 8′

Session outline:

Fig. 5. **Workout Reserve predicted across a *Tabata* session. Traditional *Tabata* intervals prescribe a fixed 20s work / 10s rest ratio, often without accounting for individual fatigue dynamics. By integrating Workout Reserve, that takes a user's power profile into account (i.e., Figure 4), Athletica can predict session depletion in real time, enabling more precise adjustments to interval intensity, work-to-rest ratios, and total session volume. This approach allows for a more sustainable execution of high-intensity intervals, optimizing both training adaptation and fatigue management (Zignoli, 2023).**

Conclusion

Tabata training has been widely adopted in the fitness industry, but its mainstream interpretation often deviates from the original research. While it remains an effective method for improving both aerobic and anaerobic capacity, modern versions frequently overlook key physiological principles, leading to suboptimal adaptations. The misuse of exercise mode, lack of proper intensity calibration, neglect of historical training data, and an overemphasis on "feeling the burn" rather than structured training have contributed to confusion around its effectiveness.

Ultimately, Tabata is just one tool in the HIIT toolbox and should be classified as a Type 4 HIIT session according to HIIT Science terminology (Laursen & Buchheit, 2019). As discussed, different HIIT types—each targeting specific metabolic demands—may be more appropriate depending on the athlete, sport, or training goal. To fully maximize the benefits of high-intensity training, workouts must be carefully designed based on physiological targets rather than trends or aesthetics.

With the emergence of Sports Science 3.0, training prescriptions can now be enhanced by integrating real-time and historical data to guide performance decisions. A key advancement in this space is Workout Reserve, which quantifies an athlete's ability to sustain external load (e.g., power or pace) based on historical training data. By tracking session depletion and identifying when an athlete exceeds prior efforts, Workout Reserve allows for real-time adjustments to work-to-rest ratios, intensity targets, and session volume. This data-driven approach moves beyond outdated, one-size-fits-all prescriptions, aligning HIIT training with an athlete's physiological reality rather than generic formulas. Future research should continue exploring how Workout Reserve can refine HIIT programming across different training populations, ensuring smarter and more effective adaptations.

Another important area for future research and application is adapting Tabata to other exercise modes beyond cycling—particularly those involving large muscle mass and allowing for quantifiable external power output (e.g., rowing, SkiErg, Assault Bike). While cycling remains a strong option, alternative modalities can enhance motivation, reduce overload, and provide viable solutions for athletes managing lower limb injuries or sport-specific fatigue. Additionally, incorporating cross-training applications may help athletes maintain fitness without overloading primary movement patterns. By leveraging Sports Science 3.0 principles—integrating wearable technology, AI-driven insights, and personalized workload adjustments—HIIT training can evolve beyond static prescriptions, making it more precise, adaptable, and athlete-centered.

Key takeaways

- Tabata training is highly efficient for improving both VO_2max and anaerobic capacity - when performed correctly.
- The original protocol used cycling and precisely calibrated intensity, ensuring maximal metabolic stress.
- A key advancement would be calibrating intensity based on %ASR and historical Workout Reserve, rather than just MAP, to ensure a more individualized metabolic load.
- Modern Tabata workouts often miss the mark, using random exercises that fail to replicate the intended physiological adaptations.
- The need for anaerobic capacity improvements is sport-specific, and their necessity for the general population is questionable.
- Tabata is just one of many HIIT formats and is classified as a Type 4 HIIT session (HIIT Science), with large aerobic and anaerobic energy systems demands, associated with a large neuromuscular load. Depending on the athlete, sport, or training goal, other HIIT types with different metabolic demands may be more appropriate.
- Expanding Tabata beyond cycling to other high-power, large-muscle-mass exercises (e.g., rowing, SkiErg, Assault Bike) can enhance motivation, reduce overload, and support cross-training, making the method more versatile while maintaining precise intensity calibration.
- Weight loss claims are largely unsupported, as Tabata's short duration limits total energy expenditure.
- The "toothpaste theory" applies—untrained individuals improve with almost any exercise, but long-term progress requires targeted adaptation.
- HIIT should be structured based on science, using appropriate intensity, exercise mode, and individual goals to ensure meaningful results.

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