A guide to Zone 2 training: its profound impact on health, detailed training instructions, addressing male and female differences, and more

PA **peterattiamd.com**/guide-to-zone-2-training

Peter Attia August 21, 2024

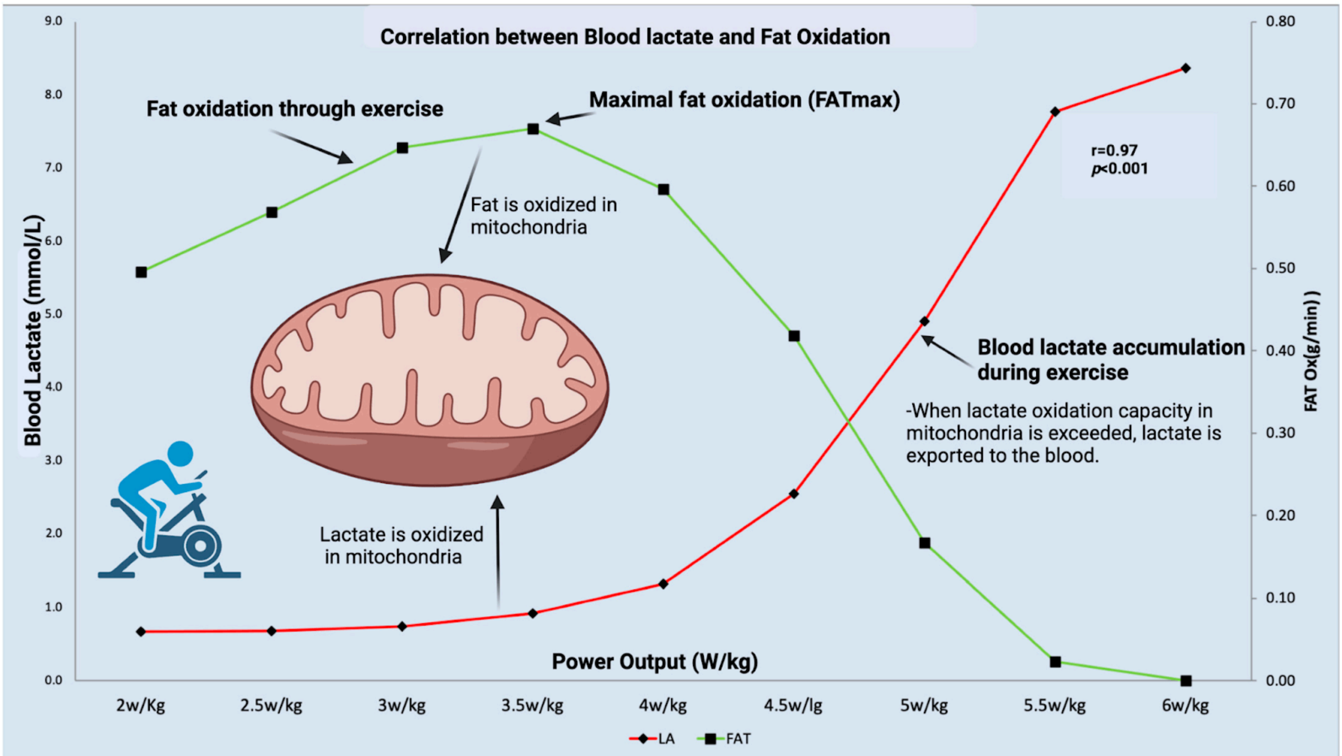

Figure: Example representation of the relationship between power output during exercise, blood lactate, and fat oxidation. From San-Millan 2023.[2]

Among the topics we're asked about most frequently, Zone 2 training is always near the top of the list. The interest is certainly justified; Zone 2 training is one of the four essential "pillars of exercise" for maintaining health and physical capabilities as we age, as it is arguably the single most important tool we have at our disposal for improving and sustaining the health of our mitochondria, which are central players in cellular aging and metabolic health. With this in mind, we've decided to create a one-stop resource to answer common questions and serve as a guide for all things Zone 2: what it is, why it's important, how to incorporate it into an exercise regimen, and more.

Pillars of exercise

The importance of exercise for health and longevity is a common theme on *The Drive* and throughout our newsletters. But of course, the term "exercise" encompasses many different activities targeting various aspects of physical fitness, and the optimal exercise regimen will depend on specific end-goals of the individual. For instance, although elite marathon runners and powerlifters both exercise frequently, their training programs will bear very little resemblance to each other, as one must prioritize aerobic performance while the other must prioritize strength.

When the end-goal is maintaining health and the ability to perform the physical tasks of daily life into our old age, training programs should target four key elements, which I refer to as the "four pillars of exercise": stability, strength, aerobic efficiency, and peak aerobic output. We recently explored the last (but certainly not least) of these pillars – also known as VO_2 max – in another premium article. But as we emphasized in that piece, building a strong VO_2 max depends in part on the third pillar, aerobic efficiency, which we develop through Zone 2 training. I'm not suggesting these are equally important for sport-specific fitness and performance, but if your "sport" is life, and you want to crush it as you age, especially in your Marginal Decade, you'll need to achieve some mastery of these domains.

What is Zone 2?

Searching on the internet for "Zone 2" is likely to yield a plethora of definitions and thresholds. However, when we refer to Zone 2, we're talking about something very specific: Zone 2 is the highest level of exertion you can achieve without a net accumulation of lactate.[1] Rather than relying on heart rate, this definition relates to what is happening metabolically on the *cellular* level in terms of fuel utilization and hints at why this type of training is so critical for mitochondrial health.

Our cells, including muscle fibers, produce usable energy in the form of ATP primarily through the breakdown of carbohydrates and fats. The most efficient way for the cell to accomplish this is through the oxidation of molecules derived from fats in a process known as oxidative phosphorylation, which can only take place in the mitochondria and requires utilization of oxygen (and thus is alternatively termed aerobic respiration). This is the main source of energy for Type I ("slow-twitch") muscle fibers, which contain a higher density of mitochondria than "fast-twitch" Type IIa and Type IIx fibers. When energy demands are relatively low, such as during low-intensity exercise, fats thus serve as the muscle's primary fuel source, and Type I fibers are the primary fibers that are being recruited for generating movement.

However, as energy demands increase with more intense exercise, muscle fibers must supplement this mitochondrial ATP production with faster, less efficient ATP-generating processes outside of the mitochondria, which produce lactate as a byproduct. Because fat can only be oxidized through mitochondrial aerobic respiration (whereas carbohydrates, in addition to serving as a substrate for mitochondria, can also be utilized in the anaerobic, cytosolic process of glycolysis), increasing utilization of non-mitochondrial processes corresponds to a shift toward use of carbohydrates as a primary fuel. (As exercise intensity continues to climb, cellular energy generation eventually transitions more fully to these non-mitochondrial processes.) Lactate itself can be oxidized in the mitochondria, but as lactate production increases, it eventually exceeds the mitochondria's capacity to clear it, resulting in a net lactate accumulation. At this point, which corresponds to approximately 2 mM of lactate, excess lactate is exported into circulation, and blood lactate begins to rise sharply **(see Figure)**.

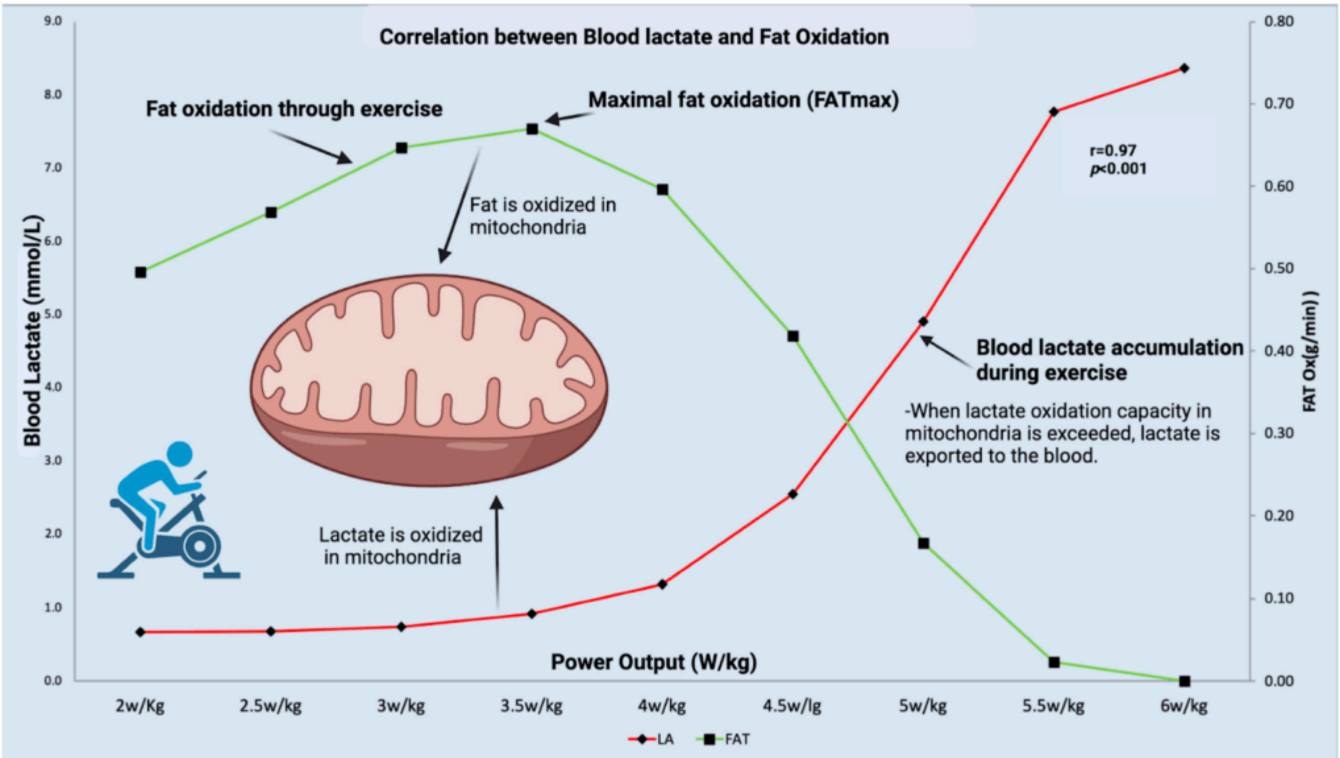

Figure: Example representation of the relationship between power output during exercise, blood lactate, and fat oxidation. From San-Millan 2023.[2]

The level of exercise intensity (measured in power output in watts per kilogram of body weight if using a bike, but can be measured in incline and speed if running) at which one reaches this transition point of net lactate accumulation is known as one's "Zone 2 threshold." This threshold varies according to the individual's mitochondrial health, as it primarily reflects the capacity of mitochondria to clear lactate as it is produced. For the most elite professional endurance athletes (such as shown in the figure above), it might be around 4 to 4.5 watts/kg, whereas for very metabolically sick individuals, it might be below 1 watt/kg. Also shown in the figure above, this threshold also coincides approximately with the point at which fat oxidation is maximized, and thus, a high Zone 2 is indicative of a high capacity for fat oxidation, which in turn also reflects mitochondrial health.

Why is Zone 2 training so important?

Zone 2 training eventually leads to an increase in Zone 2 threshold – which is to say, an increase in fat oxidation capacity and overall mitochondrial function. But why are these cellular effects so important?

Mitochondrial health (or a lack thereof) plays a central role in aging and disease. Mitochondrial dysfunction, including altered respiration and decreased energy production, is one of the hallmarks of cellular aging and has downstream effects that are likely to trigger or exacerbate other hallmarks as well.[3] Mitochondrial health is also a concern with regard to its role in numerous diseases, including cardiovascular disease,[4] neurodegenerative disease,[5] and metabolic syndrome.[6,7] Indeed, improving mitochondrial function through Zone 2 training improves insulin sensitivity and may reverse prediabetes.[2]

Considering only these effects on aging and disease, we already have plenty of reasons to view the improvement and maintenance of mitochondrial function as a worthwhile endeavor – and Zone 2 training appears to be the most effective means of doing so. But for anyone who might need further convincing, the benefits of Zone 2 and mitochondrial health also extend to enhancing *physical* function by laying the foundation for better overall aerobic capacity. Zone 2 reflects the extent to which cells are capable of oxidizing fat for fuel. This constitutes what's known as an individual's "aerobic base," which is vital for the body's ability to sustain low intensity efforts for an extended time.

As we explained in our previous article on VO_2 max, aerobic base and peak aerobic performance (i.e., VO_2 max) together define overall aerobic capacity. I find the analogy of a triangle to be valuable in illustrating this point: if we imagine aerobic capacity as the *total area* of a triangle, both a wide base and a high peak are necessary in order to maximize the triangle area. While Zone 2 training is important for increasing the triangle base, VO_2 max training is important for elevating the triangle peak. As my cycling coach used to always say, "If you want a high peak, you need a wide foundation."

How to tell if you're in Zone 2

Considering how we've chosen to define Zone 2, the most accurate means of determining whether or not a person is in this zone is to use a whole blood lactate meter, which can provide insight into variables that impact Zone 2 threshold by using a small drop of blood from a finger or ear stick (at least among trained individuals who monitor lactate regularly and track results over time). However, these devices and test strips can be quite expensive, and for the vast majority of those who only wish to know when they are in Zone 2, a lactate meter simply isn't necessary. Moreover, for someone who is very *deconditioned*, this method provides no useful information whatsoever, as these individuals will have high lactate at baseline and will see a substantial spike the moment they begin even very light exercise. In other words, lactate levels don't serve as a good proxy for exercise intensity until *after* a person has reached a certain level of fitness.

For most individuals, the best way to track Zone 2 is instead to triangulate between rate of perceived exertion (RPE) and estimations based on heart rate.

Rate of perceived exertion

The simplest way to determine whether or not you are in Zone 2 is through RPE, which refers to the subjective sense of how hard the body feels like it's working during exercise. A useful benchmark for using RPE to determine Zone 2 is the ability to speak and hold a conversation. If you would have no trouble conversing with someone throughout the workout, you are below Zone 2, whereas if you are completely unable to speak, you are above Zone 2. Thus, Zone 2 can be regarded as the point at which speech is uncomfortable but not impossible, as I've demonstrated in a past video. If my phone rings while I'm doing a Zone 2 ride on my trainer, I don't want to answer it. If I do, the person on the other end knows that I am exercising, but if I must carry out a conversion with them, I can. It's just not enjoyable.

Heart rate guidance

If you know your maximum heart rate (max HR) based on having undergone a VO_2 max test or cardiopulmonary exercise test (CPET), Zone 2 can be *estimated* as a fraction of max HR. For deconditioned individuals, 70-75% of max HR is generally a place to start, whereas trained individuals can aim to start higher, closer to 78-80% of max HR.

For someone who doesn't know their max HR (probably most people), we advise using Phil Maffetone's 180 Formula for determining MAF ("maximum aerobic function") heart rate – in other words, the heart rate at which mitochondrial oxidative phosphorylation is maximized. The MAF 180 Formula involves subtracting one's age from the number 180 to provide an approximation of target heart rate, which can be adjusted based on variables related to fitness and training readiness.[8] For instance, for someone who is 50 years old, a target heart rate for reaching Zone 2 is around 180 – 50 = 130. Starting with this approximation, we might subtract 5-10 if the individual in question is deconditioned, is recovering from illness or injury, or has asthma or some excess fat. On the other hand, we might *add* 5-10 to the initial approximation if the individual in question is a trained athlete without any additional health concerns. This suggests a 50-year-old might have a range as wide as 120 to 140 bpm, if only relying on this test (hence the need to triangulate with RPE, regardless of which method you deploy).

Fitness trackers

It's critical to reiterate that the methods described above are intended to provide an estimate of Zone 2 according to the *specific Zone 2 definition that we use in our practice* – i.e., exercise that maximizes mitochondrial aerobic respiration without a net increase in lactate production. We have chosen to adopt this definition because it is the definition most closely tied to underlying mitochondrial and metabolic health – the factors we care about most when it comes to lifespan and healthspan – but it is not the *only* definition of Zone 2 in existence. As a result, we cannot rely too heavily on fitness trackers in estimating Zone 2, as these often define Zone 2 differently from what we've described here.

Many fitness trackers, including Garmin and Polar brands, monitor heart rate and define five exercise zones according to percentages of max HR. With these devices, Zone 2 is typically considered to be around 60-70% of max HR, but for most people, this is *below* the level of exertion required to hit mitochondrial targets of lactate processing. Thus, for our purposes, outputs from these systems indicating "Zone 2" can be ignored.

Power meters, by contrast, tend to define *seven* exercise zones, increasing in intensity from one to seven. In these systems, Zone 2 is typically defined as 55-75% of functional threshold power (FTP, defined as the maximum power a cyclist can hold for 60 min). However, as with heart rate monitors, this also is an *underestimate* of the power required for Zone 2 by our definition.

One fitness tracker which does offer a decent estimate of Zone 2 heart rate in a given day is Morpheus, which I have discussed in detail in a podcast episode with its developer, Joel Jamieson. The Morpheus system takes inputs each morning and returns an output with three

HR “zones” for low, moderate, and high intensity. The cut-off between what it calls “Zone 1” and “Zone 2” is the best estimate I’ve found for what your Zone 2 heart rate should be on that day, but this estimate varies quite a bit day to day.

Although many fitness trackers will report an overnight heart rate variability (HRV), changes in HRV during sleep may be less helpful in assessing recovery than the integrated effects of the entire night’s sleep. For this reason, Morpheus specifically measures *morning* heart rate and HRV to assess what is appropriate for you on that day, since you are in the most recovered state first thing in the morning. This is done using a chest strap, which uses the electrical signals of the heart and also produces higher fidelity HR and HRV measurements than wrist-based fitness trackers. In addition to these quantitative measurements, the Morpheus app asks questions about how long you slept, the quality of your sleep, how sore you are, and subjectively how good you feel, a metric that will influence your desire to train. When done consistently, these measurements are taken under roughly the same conditions, which is important to get an accurate baseline and range of normal variability in measurements. Adjustments to the output HR zones come from these daily inputs as well as your history (i.e., trends from the past week). For example, a drop in morning HRV that is more than one standard deviation away from your average likely means you have been experiencing more stress and are less recovered. This would shift your Morpheus HR zones and cutoffs lower than what your HR zones would be when you are at your baseline.

Frequency and volume of Zone 2 training

In assessing how to incorporate Zone 2 into an overall exercise plan, one of the first questions to address is how much Zone 2 training is needed in order to increase one’s Zone 2 threshold (and thus, increase one’s mitochondrial health and capacity for fat oxidation). Unfortunately, we don’t have a clear, universal answer to this question, but to some extent, it certainly depends on the baseline fitness of the individual.

While trained individuals may be able to maintain their baseline mitochondrial fitness level with two days per week of Zone 2 exercise, nobody but the most deconditioned individuals will make any *gains* in aerobic fitness at this frequency, and even those who are deconditioned will subsequently plateau and require a higher training volume to see further improvements. Three sessions per week is generally sufficient to see positive changes in Zone 2 threshold, and we consider four or five sessions per week as ideal.

With regard to session duration, it’s clear that longer workouts are more effective in challenging the mitochondria and generating positive results than shorter workouts. However, the *minimum* time required to yield improvements varies according to fitness level. For those who are just beginning, 20- or 30-minutes in Zone 2 can be sufficient, but as aerobic fitness continues to improve, longer durations become necessary to further enhance mitochondrial function. Iñigo San-Millán, an exercise physiologist and elite cycling coach, has estimated in an interview on *The Drive* that 45 minutes is the minimum length of time necessary to see benefits in trained individuals, while 1-1.5 hours is a more optimal goal.

It is critical, however, that once an individual has ramped up to Zone 2, they must remain there throughout the workout. Temporary dips down to Zone 1 should be avoided simply because they ease the strain on the mitochondria and thus diminish any positive effects on mitochondrial health, but less intuitively, *increases* in exercise intensity to Zone 3 or higher must also be avoided. In this case, the reason relates to the metabolic effects of lactate, which, by definition, begins to accumulate any time a person exceeds their Zone 2 threshold. In addition to serving as a fuel source, lactate acts as a signaling molecule locally within the muscle, where it inhibits import of fatty acid derivatives by the mitochondria and thus prevents mitochondrial fat oxidation.[9] Further, adipose (fat) tissue can detect increased lactate levels in the blood and responds by suppressing lipolysis (release of free fatty acids for use as fuel by other tissues).[10] Together, these signaling effects of lactate accumulation cause a decline in fat oxidation and mitochondrial respiration – which is why exercise that is *more* intense than Zone 2 has *less* impact on improving mitochondrial health and building an aerobic base. Therefore, whether slipping down to Zone 1 or kicking up to Zone 3+, the more time you spend outside of Zone 2 in a "Zone 2 workout," the more you compromise any potential benefits for mitochondrial function.

How to train in Zone 2

Achieving a steady state in which you maintain the same level of intensity and avoid floating up to Zone 3 or down to Zone 1 throughout the workout is a challenge, but perhaps the easiest and most consistent way to accomplish this is to use exercise machines such as stationary bikes or stair steppers. Treadmills are also effective; while trained runners are able to sustain Zone 2 with running or jogging, for most people, Zone 2 is best achieved on a treadmill by walking briskly on a moderate incline (I typically recommend ~10-15°). I coach patients to start with a level surface at a pace of 3-3.5 mph and a stride that is clearly walking not trotting, and from there, the incline can be introduced. Rowing machines are another possibility for Zone 2 training, but only for those with enough strength and rowing experience to remain efficient and maintain good form over a full workout. Most people lack the rowing technique to stay in Zone 2. For most, bikes, steppers, and treadmills are the best places to start for consistency.

Unfortunately, the importance of achieving a steady state means that many outdoor conditions are not optimal for Zone 2 workouts, as changes in terrain (e.g., hills), wind conditions, traffic, wildlife, or other factors can result in substantial upward and downward swings in exercise intensity throughout the workout. Best bets for steady-state outdoor workouts include swimming in a lap pool or jogging/cycling on a track or other flat, traffic-free terrain. By contrast, hiking, rucking, urban jogging or cycling, or ocean swimming are much more subject to variability, and while it's certainly possible to *enter* Zone 2 for periods of time with these exercise modalities, it is very difficult to ensure that you're *remaining* in Zone 2 for the majority of the workout. Fitness trackers can be misleading in this regard, as they might report that an individual has spent X% of a workout in Zone 2, but this time might be disjointed – i.e., spread out with a couple of minutes here and a couple of minutes there – which does not yield the same results as a dedicated, continuous Zone 2 workout.

Not all muscle groups are equal when it comes to Zone 2. As discussed in my recent interview with Dr. George Brooks, muscles of the leg have a higher concentration of mitochondria – and consequently, have a higher capacity for fat oxidation – than muscles of the arms, which are comparatively very glycolytic. Thus, for a given exercise intensity or power output, working the arms will generate more lactate than working the legs, resulting in a lower Zone 2 threshold. Zone 2 performance with exercises such as swimming or rowing therefore can't be meaningfully compared to Zone 2 performance with exercises such as cycling or walking on a treadmill. Most of the data that we have available for correlating heart rate, RPE, and Zone 2 threshold come from cycling tests, so those who wish to train Zone 2 using other exercise modalities such as rowing machines or ski ergometers will need to adjust downward to some degree from the RPE and heart rate benchmarks we've described for estimating Zone 2. However, it's important to note that regardless of the muscle groups involved in the exercise, the increase in the muscles' fat oxidation capacity derived from Zone 2 training benefits the body as a whole – for instance by improving glucose tolerance through increased insulin sensitivity.

Another factor to consider in engaging in Zone 2 exercise is the ambient temperature and humidity. Generally speaking, a relatively cool environment (50s to 60s in degrees Fahrenheit) with moderate humidity (i.e., below ~55% relative humidity, based on measures of internal temperature and heat production[11]) is best for sustained Zone 2 exercise. At higher ambient temperature and humidity, Zone 2 performance declines, as heart rate and RPE increase more quickly with power output than they would in cooler temperatures.[12,13] Utilization of glycogen and anaerobic metabolic pathways are increased in heat, and indeed, blood lactate has been shown to be increased during moderate-intensity exercise in hot conditions (~105°F) relative to cold conditions (~48°F).[14] This indicates that Zone 2 is likely to be achieved at a lower power output (and will be associated with lower rates of fat oxidation and mitochondrial respiration) in high temperatures than in low temperatures.

Order of exercise: considerations for mixed training sessions

As we discussed early in this piece, Zone 2 is just one of the pillars of exercise needed for maintaining physical function with age, so the three or four Zone 2 workouts per week recommended above must be incorporated into a larger exercise plan that also includes strength training, VO_2 max training, and stability training. Although separating different types of exercise across different gym sessions is likely optimal for maximizing the benefits of each, this strategy involves more time and more trips to the gym than many people can realistically afford. But for those who must combine different exercise modalities in the same workout, the order of exercises matters, particularly with respect to Zone 2.

In a mixed training session, Zone 2 exercise should always *precede* strength or VO_2 max training (Zone 5), and once again, the reason comes down to lactate. Intense strength and VO_2 max training produce more lactate than can be cleared by mitochondria, resulting in a net buildup of lactate which takes time to return to baseline. Thus, even after dropping exercise intensity (and lactate production) back to the lower level associated with Zone 2, the lactate from the earlier, more intense exercise is still present and can interfere with fat oxidation as described above.

Conversely, Zone 2 training prior to VO_2 max or strength training can negatively impact performance in the latter sessions, except in highly trained individuals, so being strategic about recovery times and other variables can help to avoid performance deficits and enhance benefits of all training modalities. For those who are not well trained, VO_2 max training should still be done after Zone 2, but we recommend a modest recovery period between the two to optimize benefits of each. With regard to strength training, virtually everyone will experience negative effects on lifts if performed immediately after Zone 2 training. The best way to avoid this is, of course, to introduce a *large* gap between training sessions (such as doing Zone 2 training in the morning and lifting weights in the afternoon), but again, we recognize that this is not always possible, so the *second* best option is to alternate between upper and lower body across the two training modalities. In other words, if you are working your lower body with a stationary bike for Zone 2 training, a subsequent strength workout should focus only on the upper body.

Influence of food and medications

The definition of Zone 2 that we use in our practice concerns how the muscle is utilizing fat, carbohydrates, and lactate as fuel, which in turn relates to the availability of these fuels as well as the availability of oxygen as supplied by blood pumping through the body. Thus, it is unsurprising that food intake (which affects circulating fuels) and the use of certain medications (which can influence heart rate, blood pressure, and other parameters impacting the supply of fuel and oxygen to muscles) might alter some aspects of Zone 2 training.

Zone 2 approximates a state of maximal fat oxidation by mitochondria, which relies on the availability of free fatty acids in the blood. Fatty acids are relatively abundant in circulation in a fasted state, as low insulin levels during fasting contribute to the stimulation of lipolysis in adipose tissue. By contrast, after a carbohydrate-rich meal, lipolysis is suppressed due to the release of insulin stimulated by a spike in blood glucose. Therefore, consuming a large amount of carbohydrates prior to Zone 2 training likely limits the maximal fat oxidation in muscle mitochondria, which would correspond to a lower Zone 2 threshold. The same is not true for a meal with minimal carbohydrates that is high in *fat*, as consuming dietary fat would result in an ample supply of circulating free fatty acids derived from the food itself. However, my preference is generally to train Zone 2 after a few hours of fasting, if for no other reason than it allows for more consistent comparisons (and I always do my Zone 2 training in the morning, anyway, so fasting poses no inconvenience).

Hydration status is another important variable, as dehydration decreases blood pressure and reduces Zone 2 performance. While it’s best to avoid sugary sports drinks prior to and during Zone 2 training for the reasons described above, adequate intake of water and electrolytes will help to maximize Zone 2 performance. Further, medications such as diuretics can increase the risk of dehydration, so these, too, may negatively impact Zone 2 output unless care is taken to replace lost fluids.

Indeed, the effect of medications affecting heart rate and blood pressure on Zone 2 threshold or the rewards from training is the subject of many questions in this area. Beta-adrenergic blockers (a.k.a. "beta-blockers," such as propranolol) are commonly prescribed for anxiety, high blood pressure, and arrhythmias and cause a reduction in heart rate. Due to this effect, heart rate becomes *less reliable* as a means of evaluating whether or not you are in Zone 2, which means RPE and/or lactate must be used as the principle methods instead. Heart rate on these drugs may remain under 75% of max HR even when lactate has begun to accumulate, but despite the relatively low heart rate, RPE at this point will be quite high and can clue you in to the fact that you have exceeded your Zone 2 threshold.

Meanwhile, beta-adrenergic *agonists* (e.g., albuterol), which are often prescribed for treatment of asthma and other lung diseases, have the opposing side effect of *increasing* heart rate, but the implications for Zone 2 training are the same as for beta-blockers – i.e., they render heart rate unreliable as an indicator of Zone 2. In this case, heart rate may reach 75-80% of max HR at a relatively low power output and RPE, but this does not mean that you have achieved a level of intensity at which the challenge to mitochondria is maximized. Thus, although beta-blockers and beta-agonists won't hinder your ability to derive benefits from Zone 2 training or alter Zone 2 threshold, they undermine heart rate as a metric for determining whether or not you're in Zone 2, which can make it easy to fool yourself as to whether or not you've reached or exceeded the ideal steady state.

Should men and women approach Zone 2 differently?

Apart from the nuts and bolts of how to train Zone 2, one of the most frequently asked questions relates to the Zone 2 requirements of women versus men. Claims that women – and more specifically, postmenopausal women – should *not* do Zone 2 exercise have recently gained substantial attention on social media, and the reasoning behind this view relates to sexual dimorphisms in the distribution of muscle fiber type, mitochondrial oxidative capacity, and changes in lactate transporters in response to exercise. But do these arguments hold any water?

Muscle Fiber Distribution

Women have more "slow-twitch" Type I muscle fibers than men, which, as noted above, rely mainly on mitochondrial respiration for energy production. These fibers contain far more mitochondria than "fast-twitch" Type II fibers, which instead rely more heavily on glycolysis. A meta-analysis of 110 studies analyzing fiber type and size from muscle biopsies (mostly in the lateral quadriceps in men and women ages 18-59) showed a moderate to large effect size of sex on muscle fiber cross-sectional area for all fiber types, with larger muscle fiber sizes in men.[15] The study also showed a *small* effect of sex on the *distribution* of muscle fiber type. Women had on average about 2.6% more Type I fibers than men (53.2% compared to 50.6%). Likewise, men had about 2% more Type II fibers when combining all of the Type II subtypes. Because Zone 2 training primarily targets Type I fibers, these observations have been used as evidence that women require less time in Zone 2 than men, with the rationale that women ought to instead focus on training modalities that prevent atrophy of their more limited Type II fibers.

However, the analysis described above classifies each muscle fiber as a “pure” type (e.g., Type I, Type IIa), but humans also have *hybrid* fibers (e.g., Type I/IIa, Type IIa/IIx), which in any given muscle may represent 20-40% of all fibers and are known to transition their “type” based on training stimuli.[16] Endurance training results in more Type I fibers and fewer Type II fibers, whereas training strength or power (e.g., sprinting) increases the number of Type II fibers and reduces the number of Type I fibers. The shifts in fiber distribution observed in training studies ranged from 4-17% depending on the intervention, *a far more dramatic shift in fiber distribution than the observed differences between men and women*.

Women historically tend to do more endurance exercise and less strength/power/explosive exercise, so in the absence of any discernment between hybrid muscle fibers from “pure” muscle fiber types, we do not know whether the apparent discrepancies between men and women in fiber type distribution reflect an inherent, biological difference between sexes or if they are instead a result of different training tendencies. For example, the percentage of hybrid Type I/Type IIA fibers in humans is estimated to be between 5-15% of muscle fibers (depending on the person and the muscle), which means that *training*-related shifts toward Type I in women and Type II in men could more than account for observed differences in fiber types – no *biological* difference necessary.

Mitochondrial Capacity

Another argument for why women don’t need Zone 2 training relates to the observation that healthy women have greater metabolic flexibility than men[17] because women utilize more glucose in the prandial and postprandial periods and oxidize more fat during exercise.[18] Even if inherent differences exist between young men and women in fat oxidation at baseline, Zone 2 exercise has been shown to improve fat oxidation *regardless of your starting point*, especially if you haven’t been doing any cardio. A study of untrained young men and women prescribed one hour of cycling at 60% of VO_2 max (this is also a great approximation for Zone 2, but typically not very applicable outside of a research setting) five times per week for seven weeks, after which *both* sexes showed increases in mitochondrial size.[19] Over the study period, the men improved their fat oxidation from 19% to 24%, whereas women improved from 34% to 41%, a metabolic improvement attributed to both the increased mitochondrial biomass *and* increased mitochondria-adjacent intramyocellular lipid droplets, an indication of greater use of lipids as fuel. In all, these results demonstrate that although women may *start* at a higher level of fat oxidation, they are still very capable of seeing meaningful improvements with training. And when it comes to metabolism, there is no such thing as being “too healthy.”

Another argument relates to differences in mitochondrial quality, which one study showed to be higher in women than in men when groups were matched by VO_2 max.[20] Compared to male mitochondria, mitochondria from female muscle biopsies demonstrated greater mitochondrial respiration. However, mitochondrial respiration in this study was normalized to *total* mitochondrial protein concentration, and the apparent difference between sexes is largely balanced out by the fact that the men simply had more mitochondrial protein. In other words, men had a larger denominator, but when looking at overall mitochondrial respiration alone (i.e., without normalization to total mitochondrial protein), men and women were nearly equivalent. This suggests that the same aerobic capacity is achieved in different ways, one with more *efficient* mitochondria (women), and the other with more mitochondrial *mass* (men).

Further, participants in this study were young (20s and early 30s) with an average VO_2 max of ~50 ml/kg/min for VO_2 max-matched analyses – the top quartile of VO_2 max values for this age range. Thus, conclusions about the differences in mitochondrial quality may not generalize to those with poorer cardiovascular fitness (i.e., almost everyone!). Additionally, in a separate analysis between women with an average VO_2 max of ~50 ml/kg/min and highly trained men with a VO_2 max of 67 ml/kg/min (the top ~2%), the women had a comparable normalized mitochondrial respiration to the highly trained men, but without normalization (i.e., taking into account the men's greater total mitochondrial mass), the highly trained men unsurprisingly had the highest levels of mitochondrial respiration. Even if we conclude that lesser trained women have equally efficient mitochondria as the highly trained men, the women would still benefit from increased mitochondrial biomass developed from Zone 2 training.

Cross-sectional studies have shown a higher prevalence of impaired fasting glucose and diabetes in men compared to women. In intravenous glucose tolerance tests, women have been shown to have a faster rate of glucose disposal compared to men.[17] However, most interventional studies are in healthy populations, and most involve premenopausal women. The fact that men are more prone to insulin resistance doesn't mean that women can't also develop insulin resistance and diabetes, and further, the insulin resistance that accompanies the estrogen depletion starting in perimenopause would suggest that this benefit is not maintained later in life.[21] Improving mitochondrial oxidative capacity is the reason to train Zone 2.

Cardio that isn't Zone 2

The notion that women don't need to do Zone 2 is based on historic patterns of exercise in women, who are more likely to do cardio or exercise classes. But when exercising in a group fitness class or "just going for a run," it is more than likely that this effort was in a higher zone, especially if you feel gassed afterwards. It's not that these forms of exercise are inherently bad, especially if you get other benefits like socialization or being outdoors, but if you have limited time or capacity based on other stressors, these types of workouts may unnecessarily add physical stress without optimizing muscular or metabolic adaptations.

Individuals who are deconditioned or are just starting out with exercise should particularly prioritize Zone 2 over higher intensity cardio. As we discussed in our article on VO_2 max, training at a relatively low intensity (such as Zone 2) is key for developing proper form and tissue tolerance in order to reduce risk of injury at higher exercise intensities.

The goal of Zone 2 isn't to change body composition

The other misconception about cardiovascular exercise is that it is the "best" way to lose fat mass, but this is not the aim of Zone 2. In fact, in the aforementioned study that increased mitochondrial size with seven weeks of Zone 2 cycling, training was found to have a nonsignificant effect on percent body fat, fat-free mass, and overall bodyweight.

The notion that postmenopausal women in particular shouldn't do Zone 2 reflects a mindset that the only goal of exercise for older women is to maintain a relatively high ratio of lean mass to fat mass. Since estrogen is anabolic, a drop in estrogen that occurs with menopause promotes fat deposition while simultaneously making it harder to add lean mass. Thus, maintaining a healthy body composition after menopause is certainly worthy of special attention. Zone 2 does not increase muscle mass, so those arguing against Zone 2 in postmenopausal women say this type of training ought to be skipped in favor of resistance training, but it doesn't have to be either/or. People can walk and chew gum simultaneously and they can lift and do zone 2 in the same week, I'm pretty sure. Zone 2 should be regarded as one piece of a more comprehensive exercise program, and those who are already doing a lot of cardio but are concerned about muscle mass should consider periodization – a strategy of temporarily reducing the volume of cardio to add in more resistance training to increase muscle mass and strength, which is important in both men and women.

Don't neglect mitochondrial health

When training for the "sport" of life, none of us can afford to be single-event specialists. Maintaining health and the ability to perform the actions of everyday life into old age requires *all four* "pillars of exercise" – which, in many ways, also rely upon each other – and the benefits of these pillars extend far beyond optimizing athletic performance. Zone 2 training and aerobic efficiency exemplify these far-reaching effects through their implications for mitochondrial health, a factor that intersects with the pathogenesis of myriad disease states and features of aging.

Deriving benefits of Zone 2 training on mitochondrial health requires sustained effort at a fixed level, with care not to exceed the point at which muscle is primarily burning fat for fuel and experiences no net accumulation of lactate. With training, the power output at this "sweet spot" gradually increases, indicating higher fat oxidative capacity – and hence, healthier mitochondria. This is a goal that everyone should strive to achieve, for *no one* – young or old, conditioned or deconditioned, male or female – can ever be "too healthy" in the game of metabolism and longevity.

References

1. San Millán I. Zone 2 training: Build your aerobic capacity. TrainingPeaks. Accessed July 31, 2024. https://www.trainingpeaks.com/blog/zone-2-training-for-endurance-athletes/

2. San-Millán I. The Key Role of Mitochondrial Function in Health and Disease. *Antioxidants (Basel)*. 2023;12(4). doi:10.3390/antiox12040782

3. López-Otín C, Blasco MA, Partridge L, Serrano M, Kroemer G. The hallmarks of aging. *Cell*. 2013;153(6):1194-1217. doi:10.1016/j.cell.2013.05.039

4. Yang J, Guo Q, Feng X, Liu Y, Zhou Y. Mitochondrial Dysfunction in Cardiovascular Diseases: Potential Targets for Treatment. *Front Cell Dev Biol*. 2022;10:841523. doi:10.3389/fcell.2022.841523

5. Johri A, Beal MF. Mitochondrial dysfunction in neurodegenerative diseases. *J Pharmacol Exp Ther*. 2012;342(3):619-630. doi:10.1124/jpet.112.192138

6. Ren J, Pulakat L, Whaley-Connell A, Sowers JR. Mitochondrial biogenesis in the metabolic syndrome and cardiovascular disease. *J Mol Med* . 2010;88(10):993-1001. doi:10.1007/s00109-010-0663-9

7. Kim JA, Wei Y, Sowers JR. Role of mitochondrial dysfunction in insulin resistance. *Circ Res*. 2008;102(4):401-414. doi:10.1161/CIRCRESAHA.107.165472

8. Maffetone P, Laursen PB. Maximum Aerobic Function: Clinical Relevance, Physiological Underpinnings, and Practical Application. *Front Physiol*. 2020;11:296. doi:10.3389/fphys.2020.00296

9. San-Millan I, Sparagna GC, Chapman HL, et al. Chronic Lactate Exposure Decreases Mitochondrial Function by Inhibition of Fatty Acid Uptake and Cardiolipin Alterations in Neonatal Rat Cardiomyocytes. *Front Nutr*. 2022;9:809485. doi:10.3389/fnut.2022.809485

10. Liu C, Wu J, Zhu J, et al. Lactate inhibits lipolysis in fat cells through activation of an orphan G-protein-coupled receptor, GPR81. *J Biol Chem*. 2009;284(5):2811-2822. doi:10.1074/jbc.M806409200

11. Moyen NE, Ellis CLV, Ciccone AB, et al. Increasing relative humidity impacts low-intensity exercise in the heat. *Aviat Space Environ Med*. 2014;85(2):112-119. doi:10.3357/asem.3787.2014

12. Gupta JS, Swamy YV, Dimri GP, Pichan G. Physiological responses during work in hot humid environments. *Indian J Physiol Pharmacol*. 1981;25(4):339-347. https://www.ncbi.nlm.nih.gov/pubmed/7341461

13. Borg DN, Stewart IB, Costello JT, Drovandi CC, Minett GM. The impact of environmental temperature deception on perceived exertion during fixed-intensity exercise in the heat in trained-cyclists. *Physiol Behav*. 2018;194:333-340. doi:10.1016/j.physbeh.2018.06.026

14. Fink WJ, Costill DL, Van Handel PJ. Leg muscle metabolism during exercise in the heat and cold. *Eur J Appl Physiol Occup Physiol*. 1975;34(3):183-190. doi:10.1007/BF00999931

15. Nuzzo JL. Sex differences in skeletal muscle fiber types: A meta-analysis. *Clin Anat*. 2024;37(1):81-91. doi:10.1002/ca.24091

16. Plotkin DL, Roberts MD, Haun CT, Schoenfeld BJ. Muscle Fiber Type Transitions with Exercise Training: Shifting Perspectives. *Sports (Basel)*. 2021;9(9). doi:10.3390/sports9090127

17. Lundsgaard AM, Kiens B. Gender differences in skeletal muscle substrate metabolism – molecular mechanisms and insulin sensitivity. *Front Endocrinol* . 2014;5:195. doi:10.3389/fendo.2014.00195

18. Cano A, Ventura L, Martinez G, et al. Analysis of sex-based differences in energy substrate utilization during moderate-intensity aerobic exercise. *Eur J Appl Physiol*. 2022;122(1):29-70. doi:10.1007/s00421-021-04802-5

19. Tarnopolsky MA, Rennie CD, Robertshaw HA, Fedak-Tarnopolsky SN, Devries MC, Hamadeh MJ. Influence of endurance exercise training and sex on intramyocellular lipid and mitochondrial ultrastructure, substrate use, and mitochondrial enzyme activity. *Am J Physiol Regul Integr Comp Physiol*. 2007;292(3):R1271-R1278. doi:10.1152/ajpregu.00472.2006

20. Cardinale DA, Larsen FJ, Schiffer TA, et al. Superior Intrinsic Mitochondrial Respiration in Women Than in Men. *Front Physiol*. 2018;9:1133. doi:10.3389/fphys.2018.0113321. Mauvais-Jarvis F. Gender differences in glucose homeostasis and diabetes. *Physiol Behav*. 2018;187:20-23. doi:10.1016/j.physbeh.2017.08.016