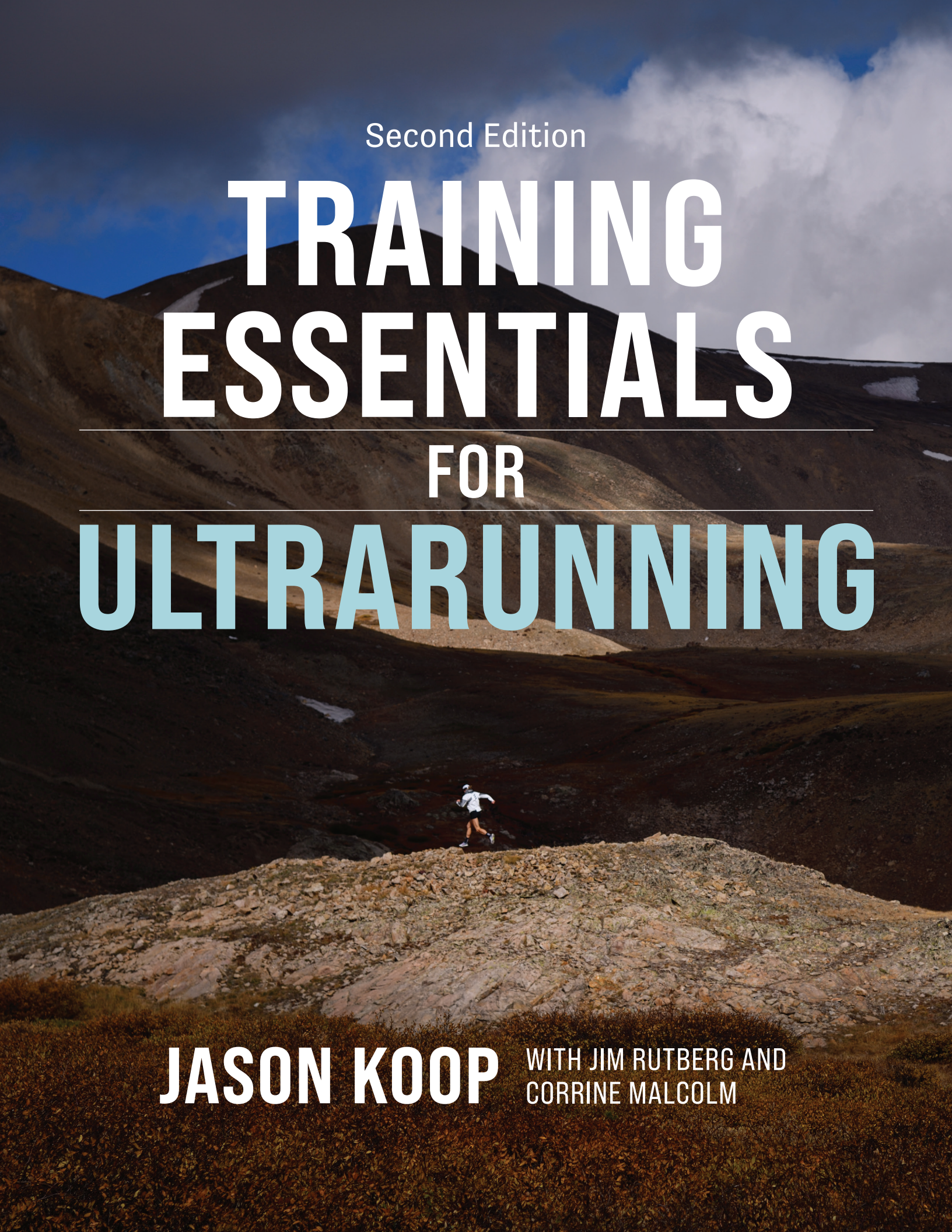

Second Edition
TRAINING ESSENTIALS FOR ULTRARUNNING
JASON KOOP
WITH JIM RUTBERG AND CORRINE MALCOLM

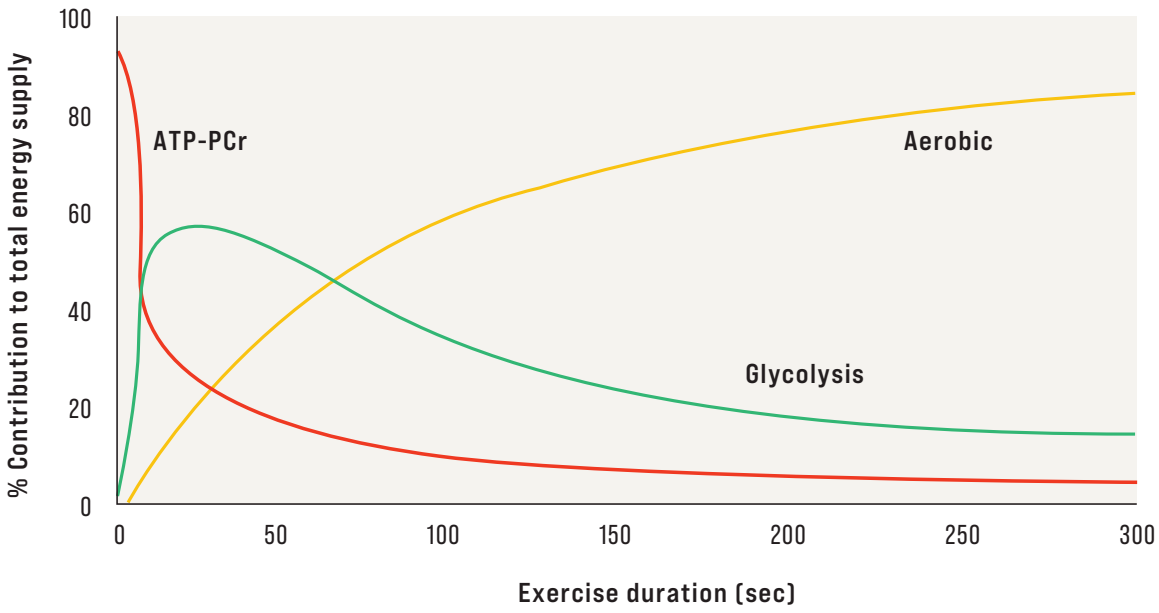


FIGURE 2.1 The contributions of the three energy systems (ATP-PCr, glycolysis, and aerobic) to energy production over time (seconds) during an all-out effort. Adapted from Gastin 2001.

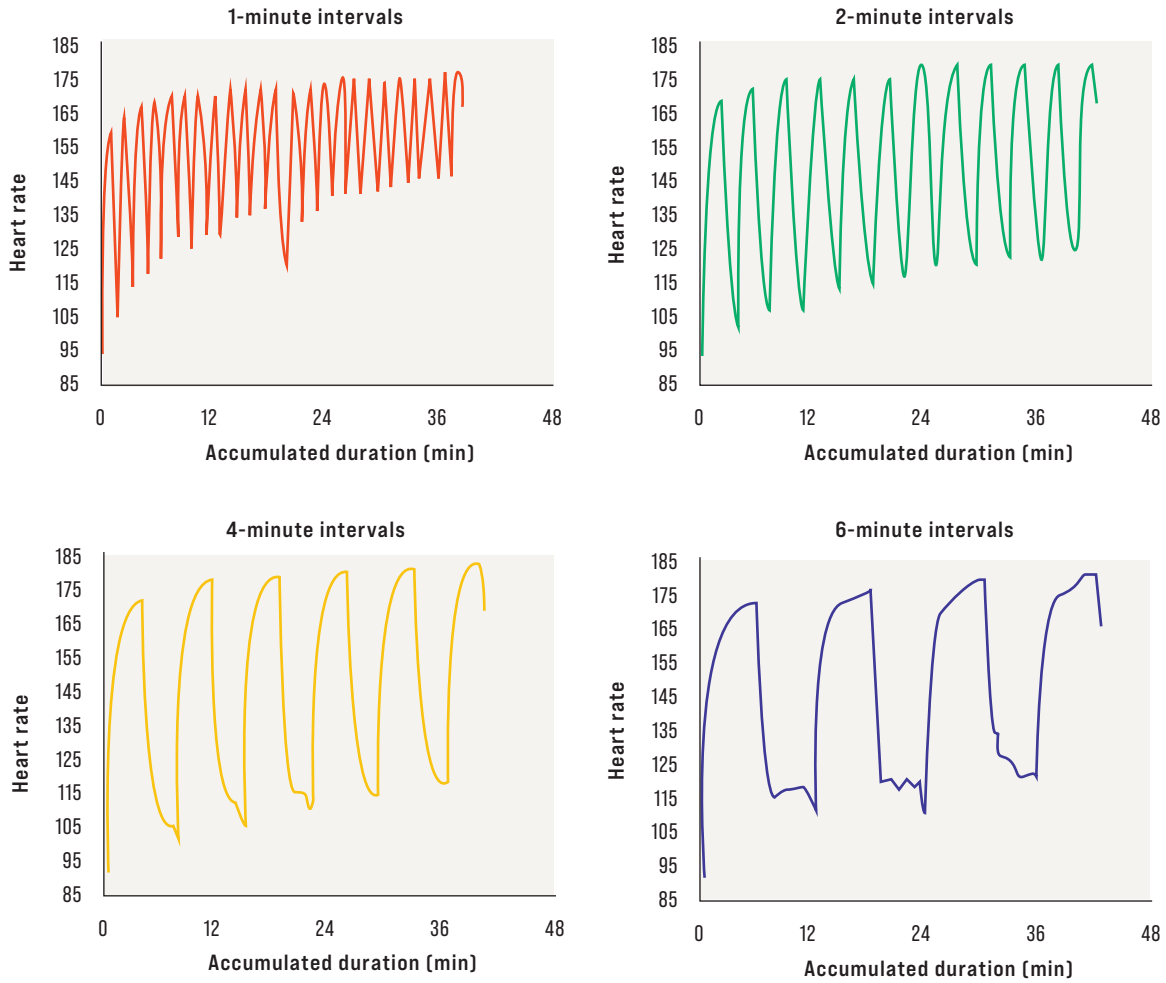


FIGURE 2.2 Mean heart rate responses during (A) 1-minute, (B) 2-minute, (C) 4-minute, and (D) 6-minute intervals. Adapted from Seiler and Sjusren 2004.

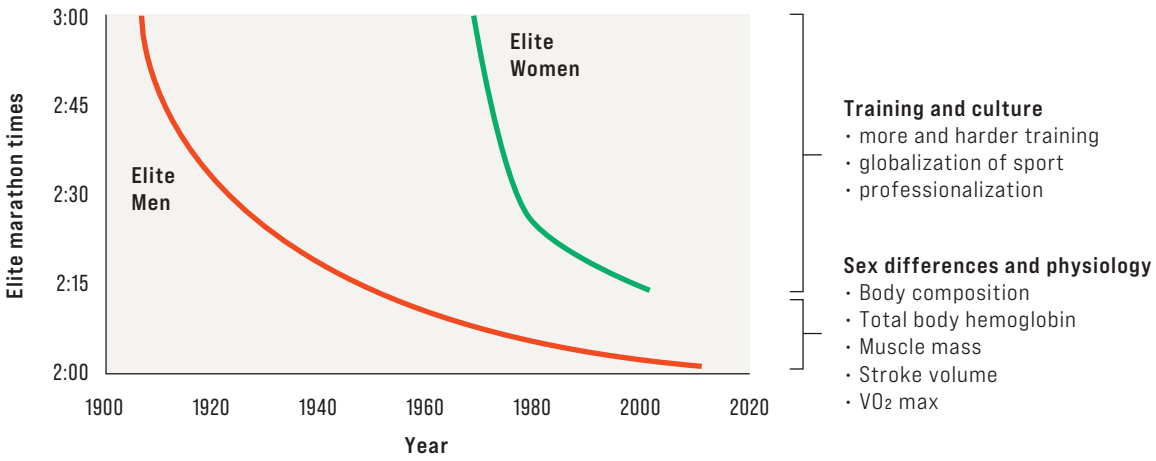


FIGURE 2.3 Many of the initial differences between male and female performance can be attributed to social factors like training and cultural support. The remaining differences that contribute to differences in performance are body composition, total body hemoglobin, muscle mass, stroke volume, and VO_2 max. Source: Joyner 2017.

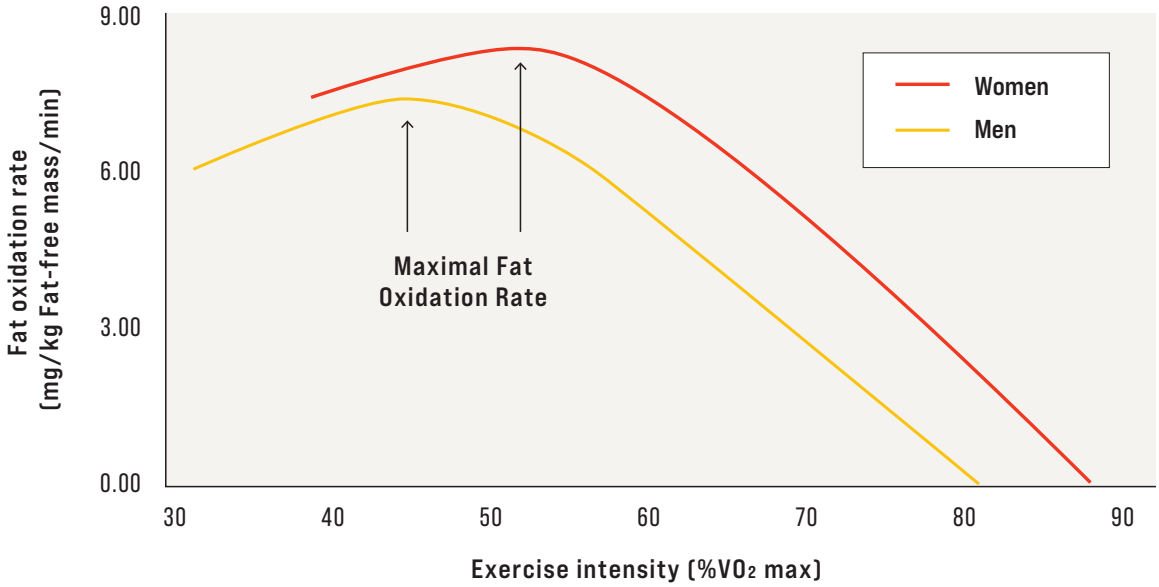


FIGURE 2.4 Women exhibit higher rates of fax oxidation relative to their body mass. Adapted from Venables, Achten, and Jeukendrup 2005.

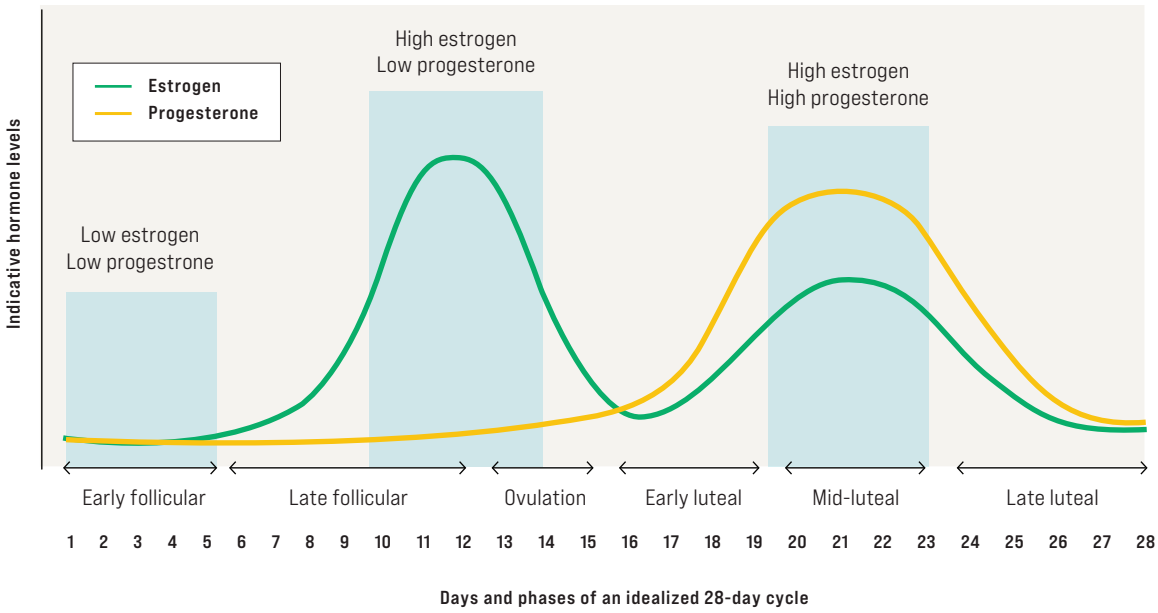


FIGURE 2.5 Representation of the hormonal fluctuation across an idealized twenty-eight-day menstrual cycle.

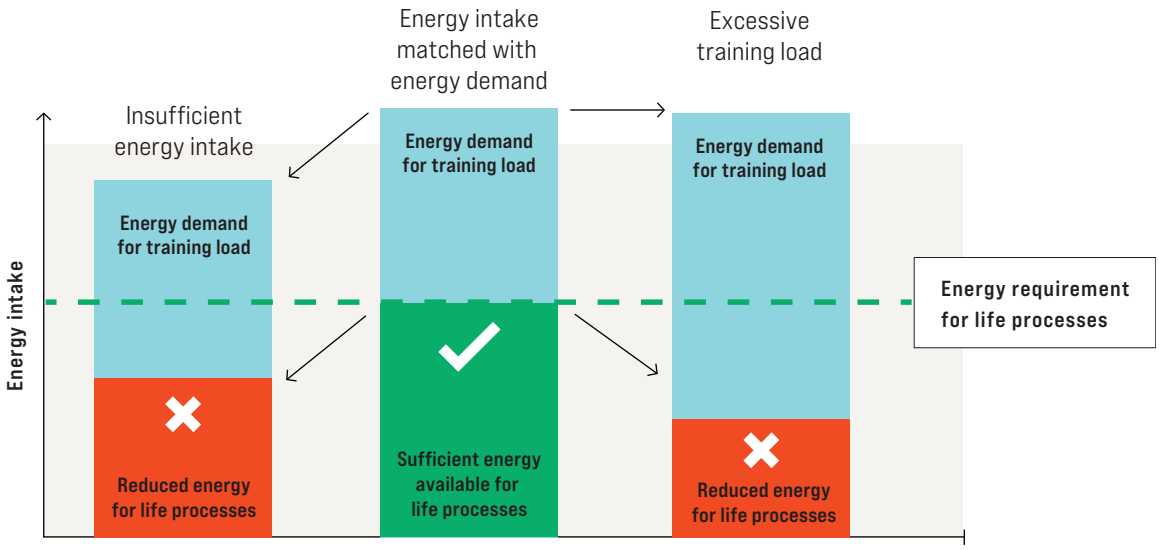
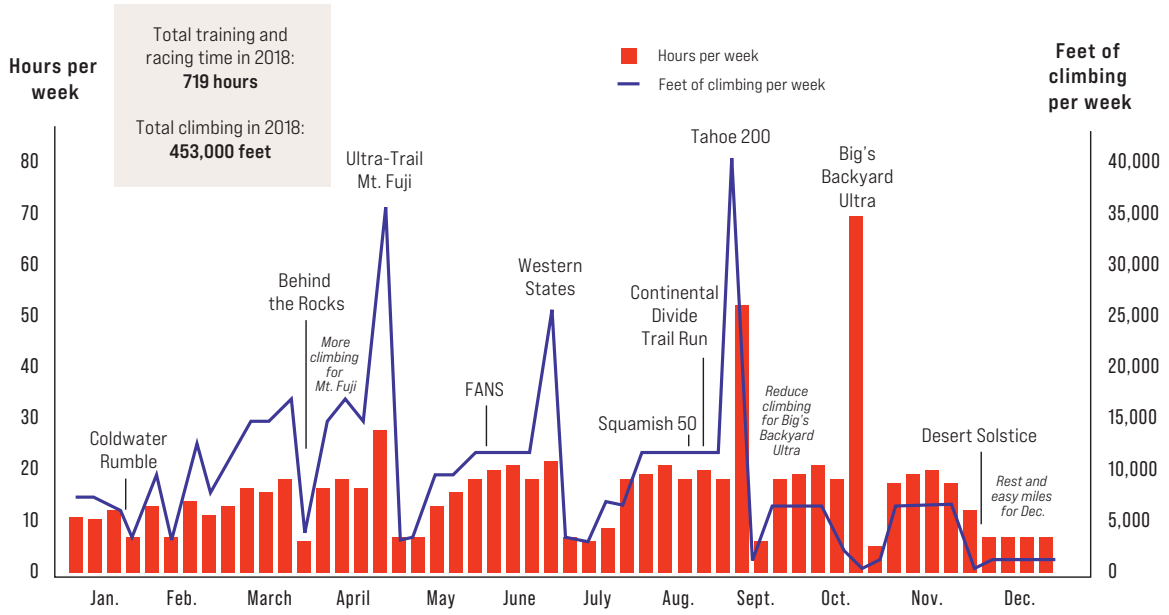
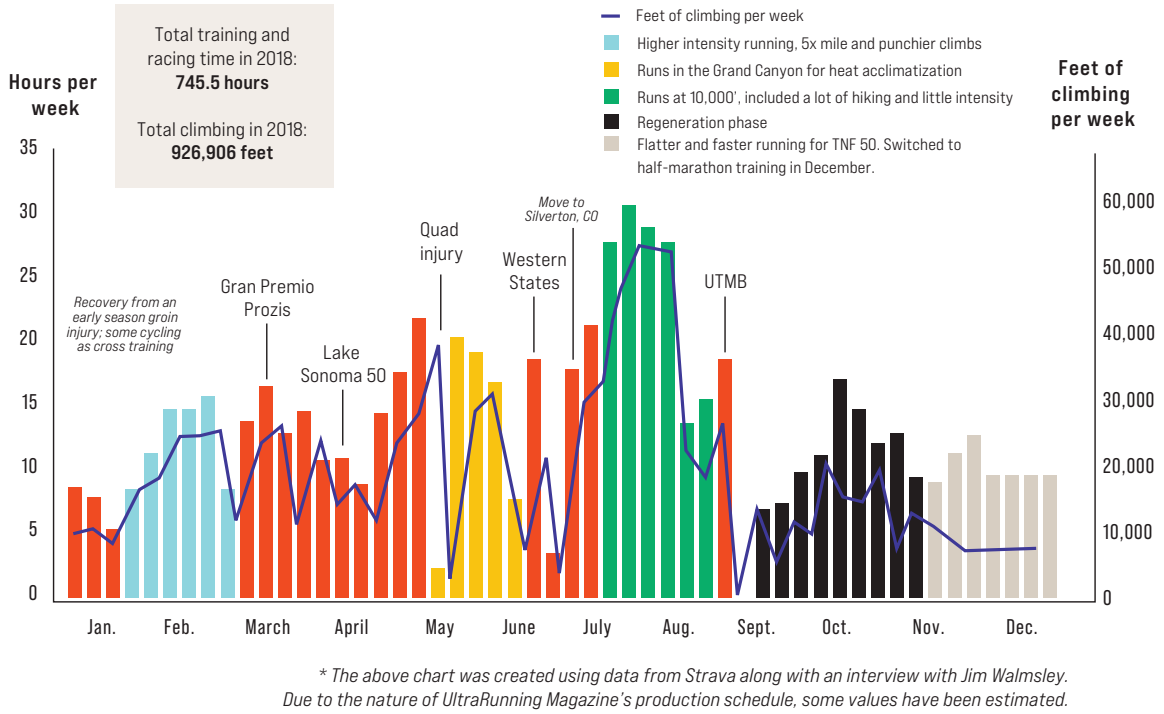


FIGURE 2.6 Matching energy intake to demand. Adapted from Keay 2018.



** Although she does not keep a formal training log, the above chart has been stylized based on an interview with Courtney.*

FIGURE 3.1 Courtney Dauwalter's 2018 training. Source: Koop 2019.



** The above chart was created using data from Strava along with an interview with Jim Walmsley. Due to the nature of UltraRunning Magazine's production schedule, some values have been estimated.*

FIGURE 3.2 Jim Walmsley's 2018 training. Source: Koop 2019.

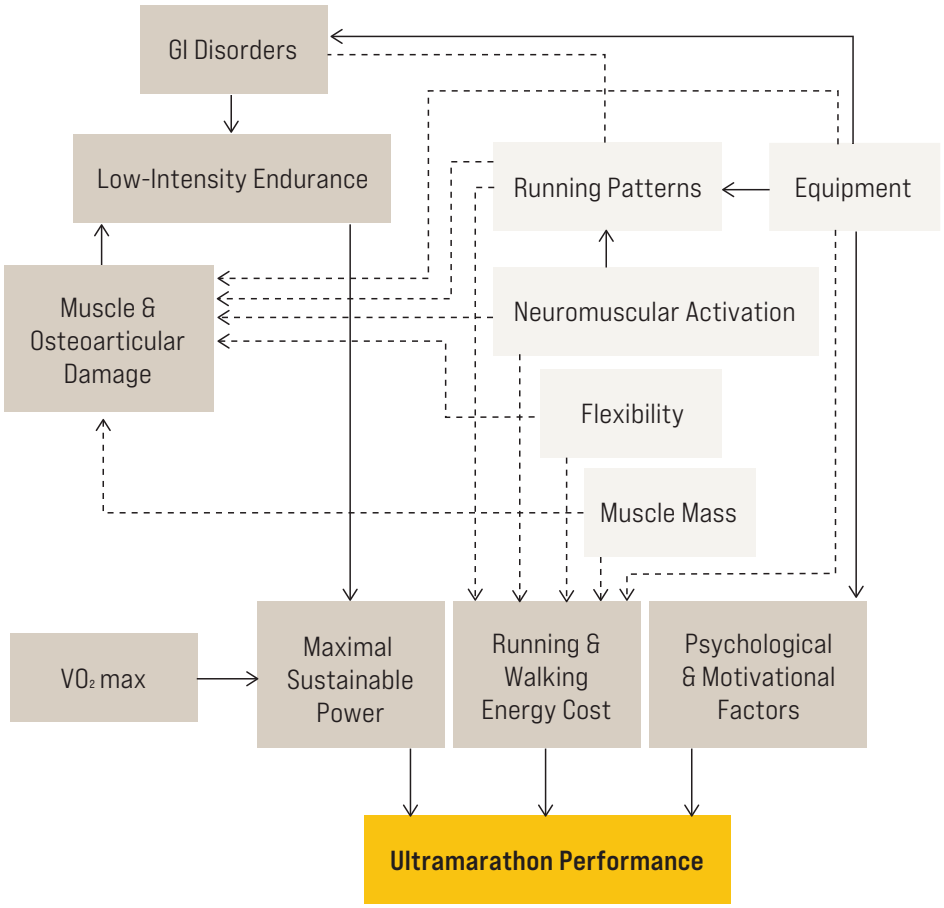


FIGURE 3.3 Proposed determinates of ultramarathon performance. Adapted from Millet 2012.

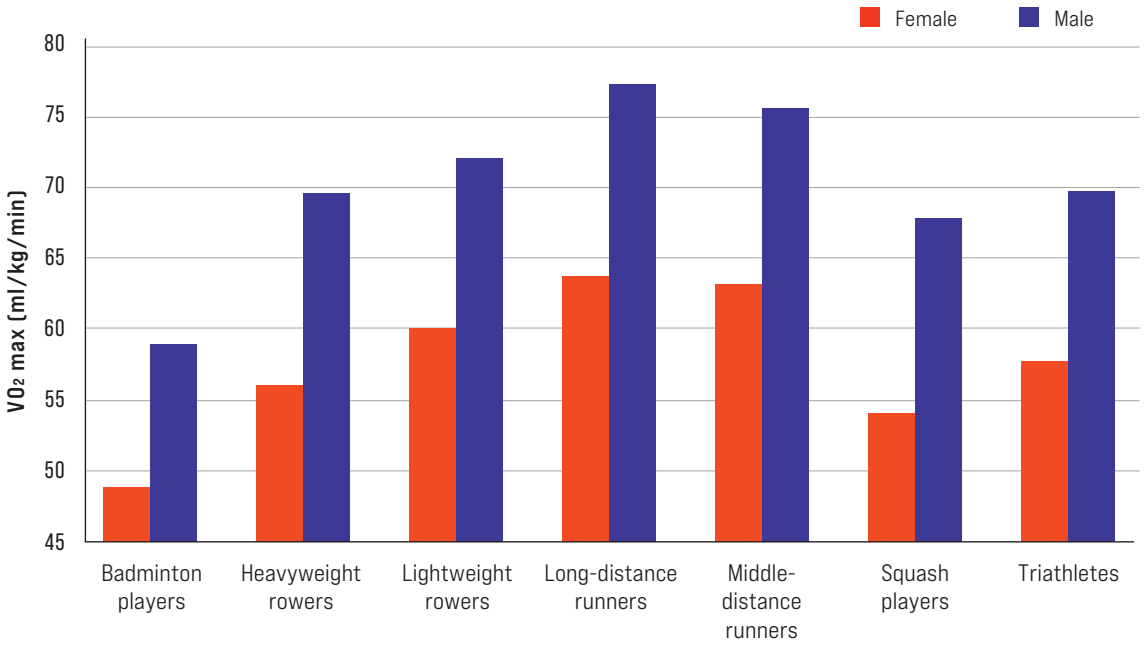


FIGURE 3.4 Typical VO_2 max values for elite athletes in various sports. Adapted from Nevill et al. 2003.

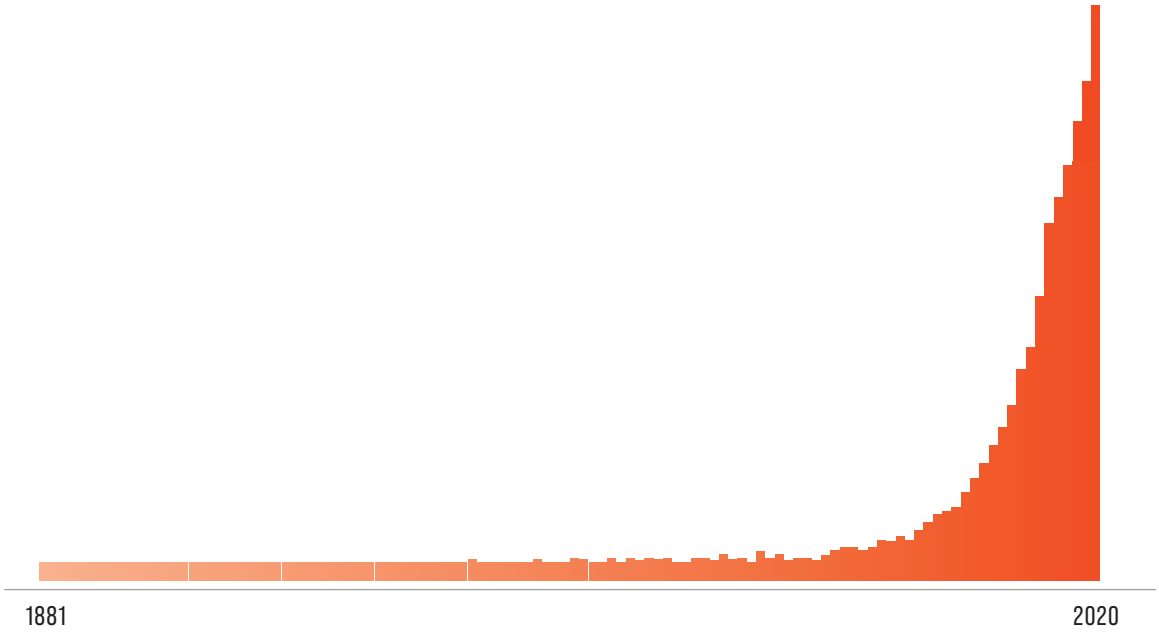


FIGURE 4.1 A PubMed search for the word "ultramarathon," "ultra marathon," or "ultra endurance." Accessed March 2021.

PROBLEM	FINISHERS (%)	NONFINISHERS (%)
Blisters or “hot spots” on feet	40.1	17.3
Nausea and/or vomiting	36.8	39.6
Muscle pain	36.5	20.1
Exhaustion	23.1	13.7
Inadequately heat acclimatized	21.0	28.1
Inadequately trained	13.5	15.1
Muscle cramping	11.4	15.8
Injury during the race	9.0	10.1
Ongoing injury	7.5	15.8
Illness before the race	6.0	5.0
Started out too fast	5.1	6.5
Vision problems	2.1	3.6
Difficulty making cutoff times	1.8	27.3
Other, not categorized	11.7	26.6

TABLE 4.1 Comparisons of problems that impacted race performance.

PROBLEM	%
Nausea and/or vomiting	23.0
Unable to make cutoff times	18.7
Other, not categorized	12.2
Ongoing injury	7.9
Injury during the race	7.2
Inadequately heat acclimatized	7.2
Blisters or “hot spots” on feet	5.8
Muscle cramping	5
Muscle pain	4.3
Exhaustion	3.6
Illness before the race	2.9
Vision problems	0.7
Started out too fast	0.7
Inadequately trained	0.7

TABLE 4.2 Main reasons given by nonfinishers for dropping out. Source: Hoffman and Fogard 2011.

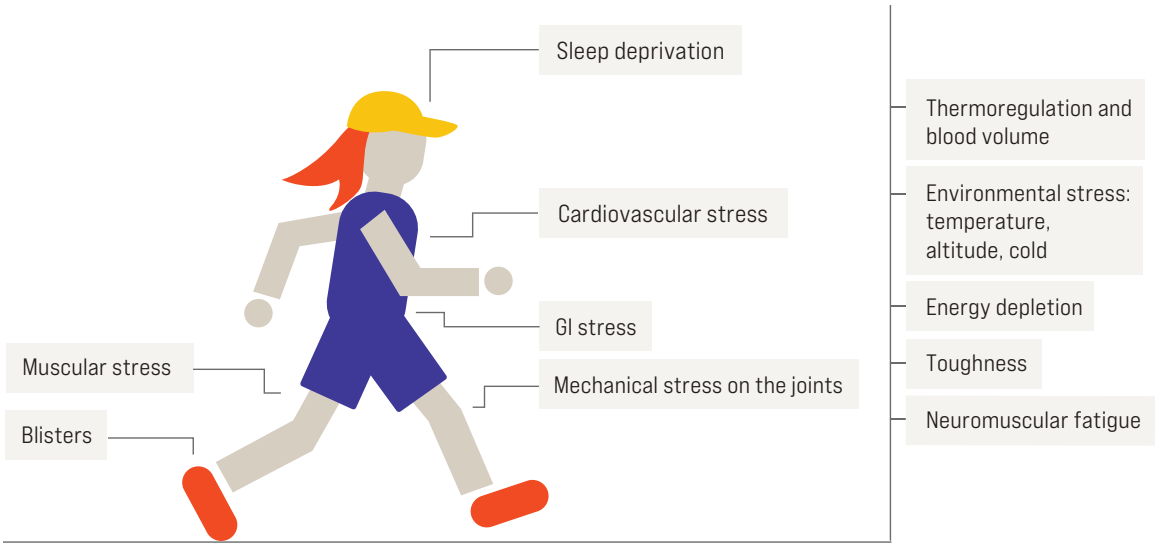


FIGURE 4.2 Ultramarathon race stressors.

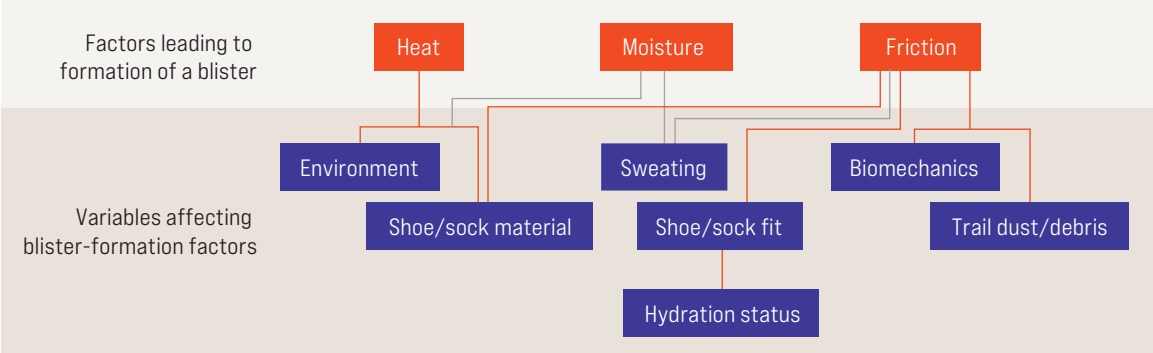


FIGURE 4.3 Heat + moisture + friction = blister.

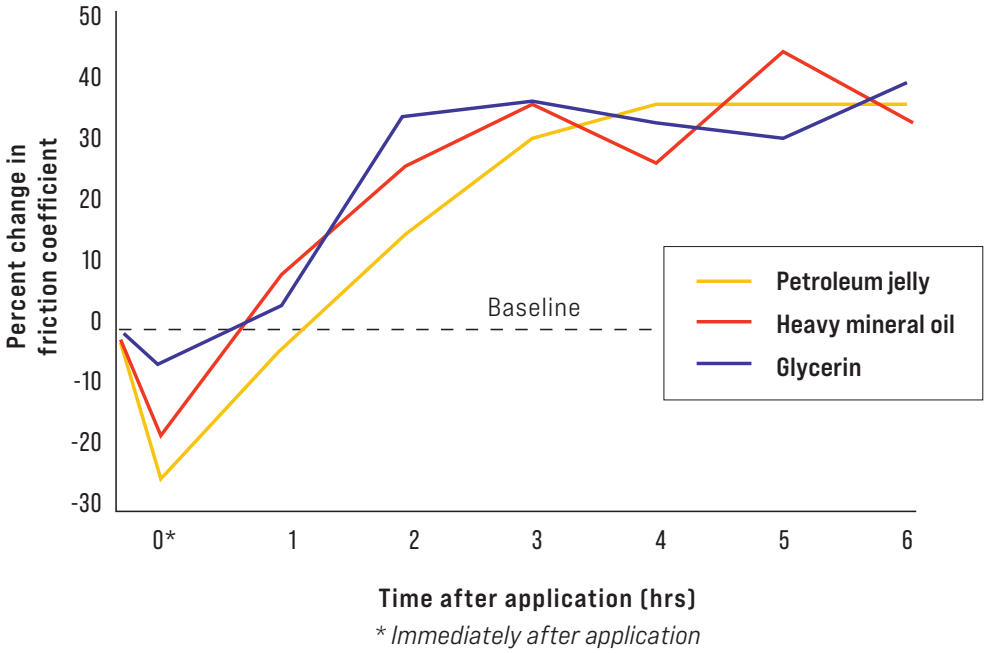


FIGURE 4.4 Graph showing an initial decrease, then increase, in friction of common lubricants when used on the skin. Source: Nacht et al. 1981.

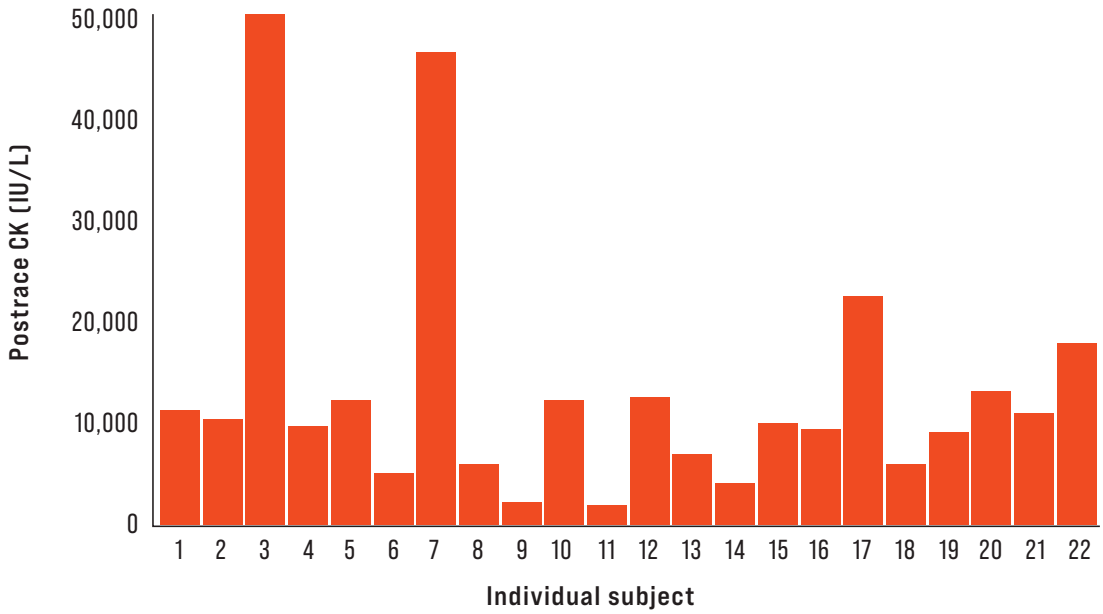


FIGURE 4.5 Postrace creatine kinase (CK) levels in Ultra-Trail du Mont-Blanc finishers. Adapted from Millet et al. 2011.

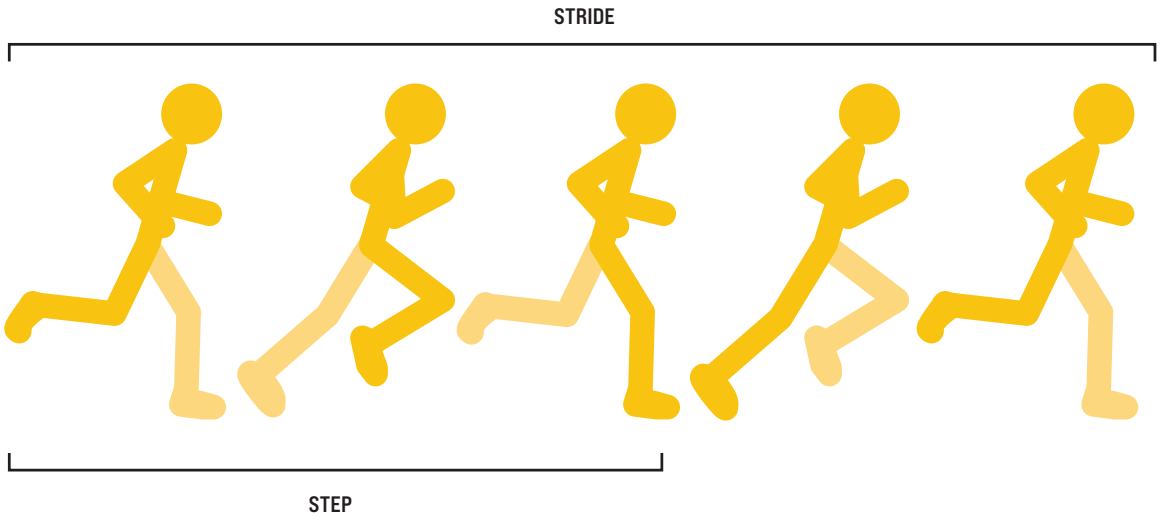


FIGURE 4.6

FIGURE 5.1 (A) Normal and (B) parallel ground reaction forces vs time traces for a typical subject (73 kg) running at 3 m/s (~9 min/mi) on different slopes. Adapted from Gottschall and Kram 2005b.

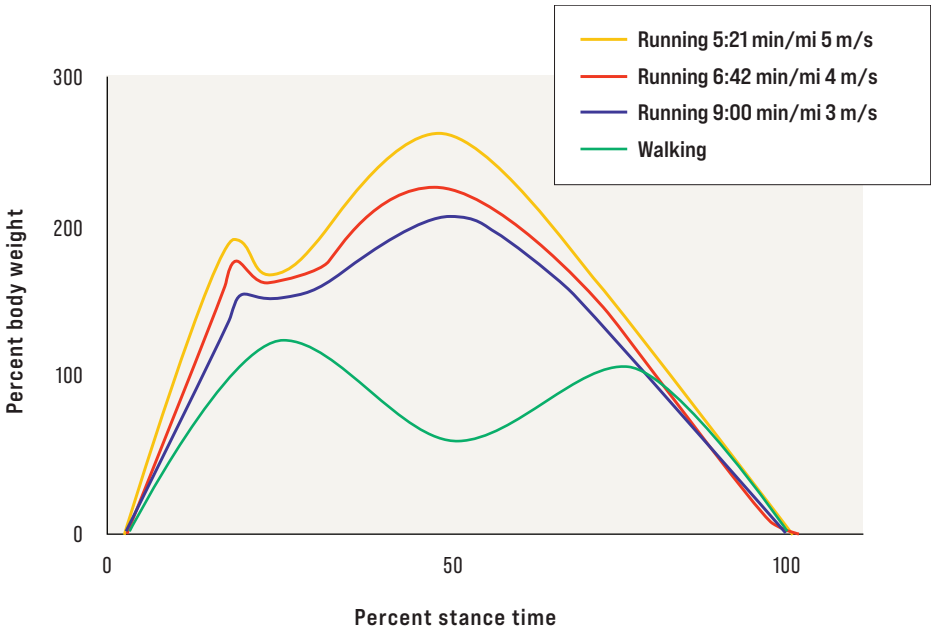


FIGURE 5.2 Vertical (normal) ground reaction force (GRF) for running at different speeds and walking. The running GRF increases with speed, and the walking GRF is noticeably less.

Adapted from Browning and Kram 2007; Gottschal and Kram 2005b; Grabowski and Kram 2008; Keller et al. 1996; Nilsson and Thorstensson 1989.

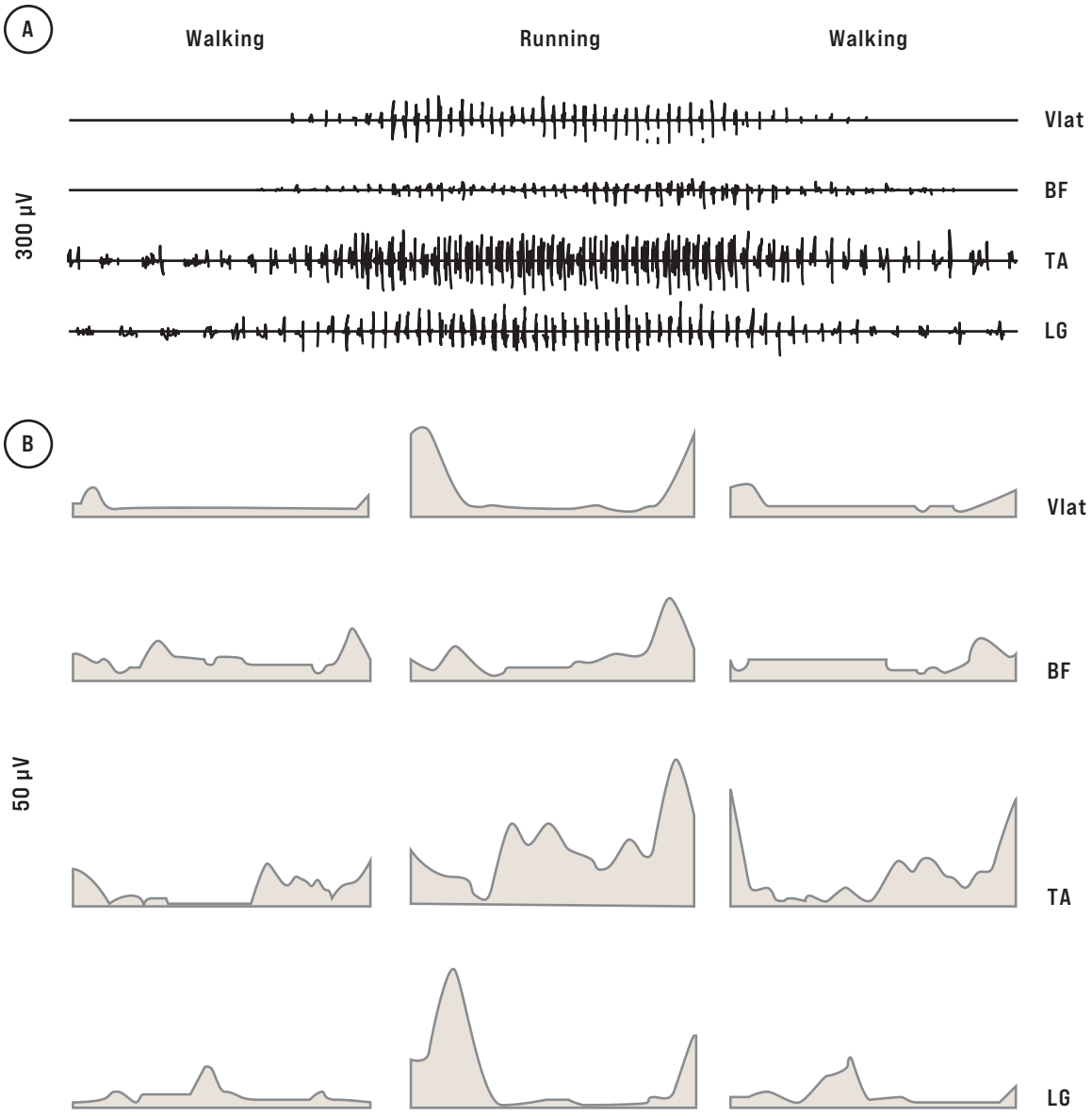


FIGURE 5.3 (A) EMG activity for various muscles in walking, running, and returning to walking. The higher the EMG amplitude, the greater the muscle activation. (B) EMG patterns for various muscles while walking, running, and returning to walking. The patterns of activation are different for walking, running, and then returning to a walk.

Note: Vlat = vastus lateralis; BF = biceps femoris; TA = tibialis anterior; LG = gastrocnemius lateralis. Adapted from Cappellini et al. 2006.

FIGURE 5.4 The hip, knee, and foot are all in different positions when walking or running on level ground, running uphill, and running downhill. Adapted from Guo et al. 2006; Hicheur et al. 2006; Yokozawa 2006.

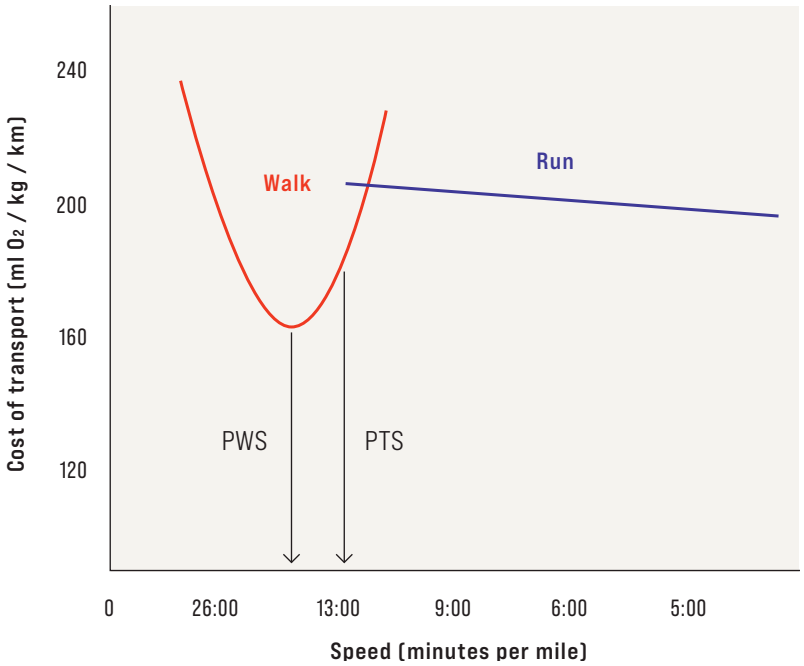


FIGURE 5.5 Representation of the metabolic cost of transport for walking and running as a function of speed. The vertical arrows represent the preferred walking speed (PWS) and preferred transition speed (PTS). Adapted from Bramble and Lieberman 2004.

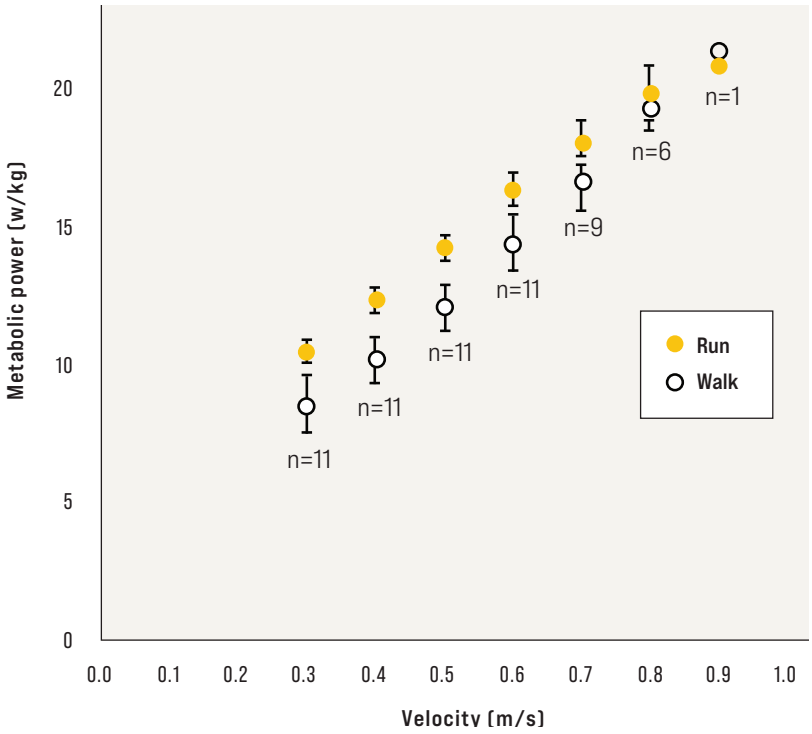


FIGURE 5.6 Metabolic power as a function of velocity for walking and running on a 58 percent grade. Adapted from Ortiz et al. 2017.

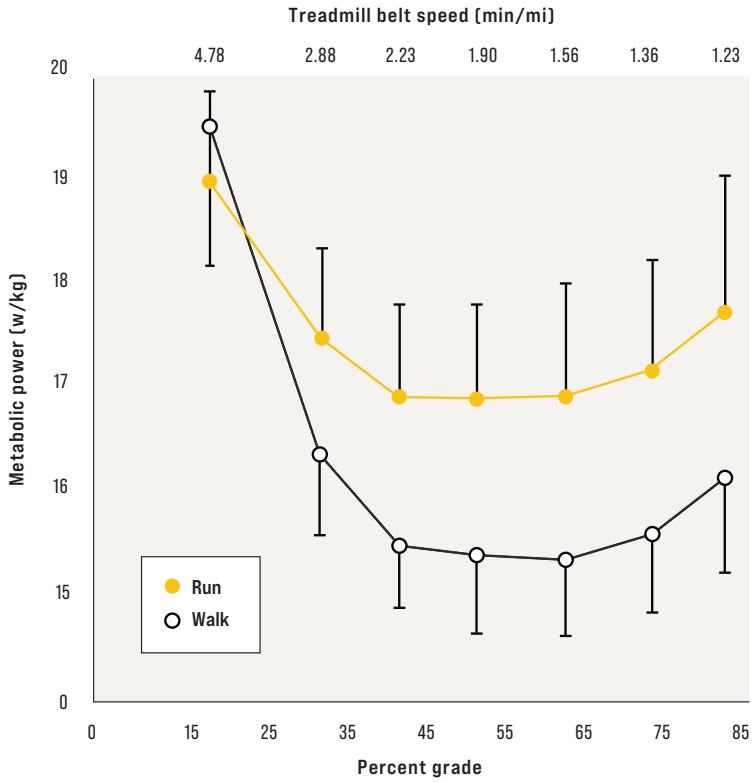


FIGURE 5.7 Metabolic power as a function of slope when the vertical speed is constant. Adapted from Giovanelli et al. 2015.

	GRADE	-10%		-6%		-2%		0%		2%		6%		10%	
		NGP	GAP	NGP	GAP	NGP	GAP	NGP	GAP	NGP	GAP	NGP	GAP	NGP	GAP
PACE PER MILE	8:00	15:18	11:27	11:13	10:05	8:51	8:40	8:00	8:00	7:19	7:22	6:14	6:16	5:26	5:21
	10:00	19:07	14:19	14:00	12:37	11:04	10:50	10:00	10:00	9:09	9:13	7:48	7:50	6:47	6:42
	12:00	22:56	17:11	16:48	15:08	13:17	13:00	12:00	12:00	10:59	11:04	9:21	9:24	8:08	8:02

TABLE 6.1 NGP and GAP for different grades and paces.

PLATFORM	NAME	INTENSITY DETERMINANT	METHOD OF SCORING
Strava	Relative Effort™	Heart rate	Threshold heart rate, duration of run, time spent at different intensities
TrainingPeaks	TSS™	Running Power	Threshold power, duration of run, NGP for run
TrainingPeaks	rTSS™	NGP	Threshold pace, duration of run, NGP for run
TrainingPeaks	hrTSS™	Heart rate	Threshold heart rate, duration of run, NGP for run

TABLE 6.2 Training stress scoring systems.

TYPE OF RUN	TSS/rTSS/hrTSS POINTS
60-min RecoveryRun	50-80
90-min EnduranceRun with 3 x 10 min TempoRun	100-150
90-min EnduranceRun with 6 x 3 min RunningIntervals	100-150
2.5-hr EnduranceRun	150-200
50-mile race	400-600

TABLE 6.3 Training stress scoring systems.

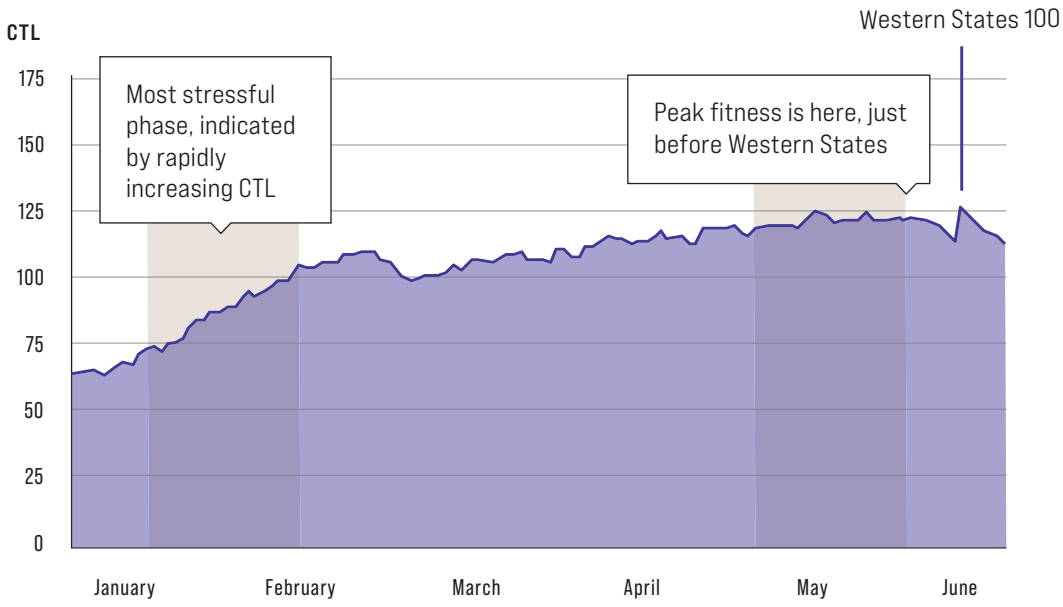


FIGURE 6.1 Analysis of an athlete's training for Western States. The CTL (blue-shaded area) is highest just before the Western States 100. This indicates that the athlete was most fit just before the race. The CTL also ramps up fastest during the tempo phases, indicating that they are generally the most stressful phases.

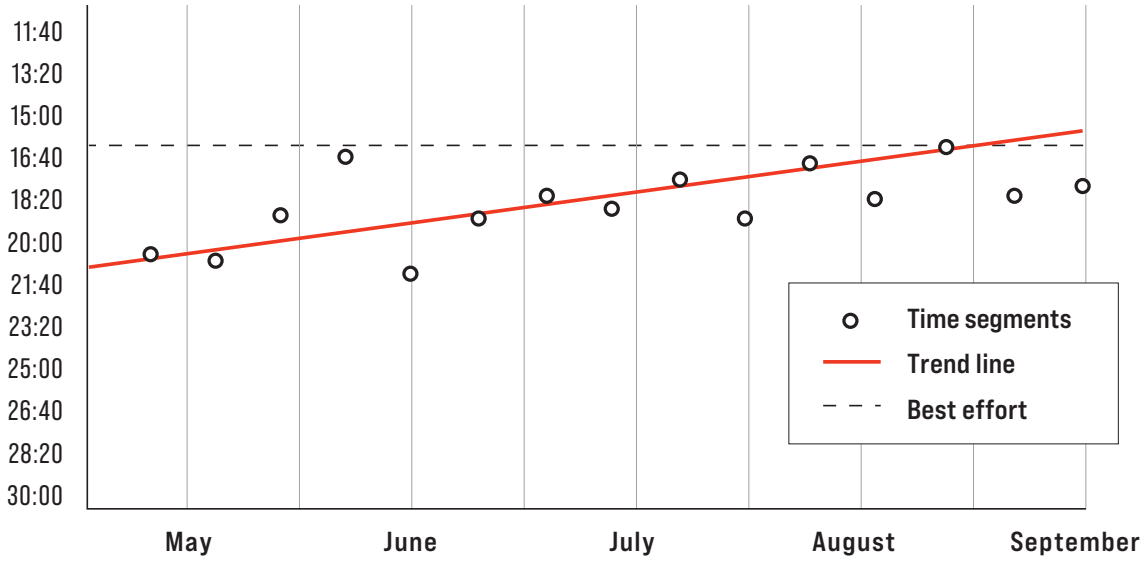


FIGURE 6.2 Strava segments with the trend line generally getting better over time.

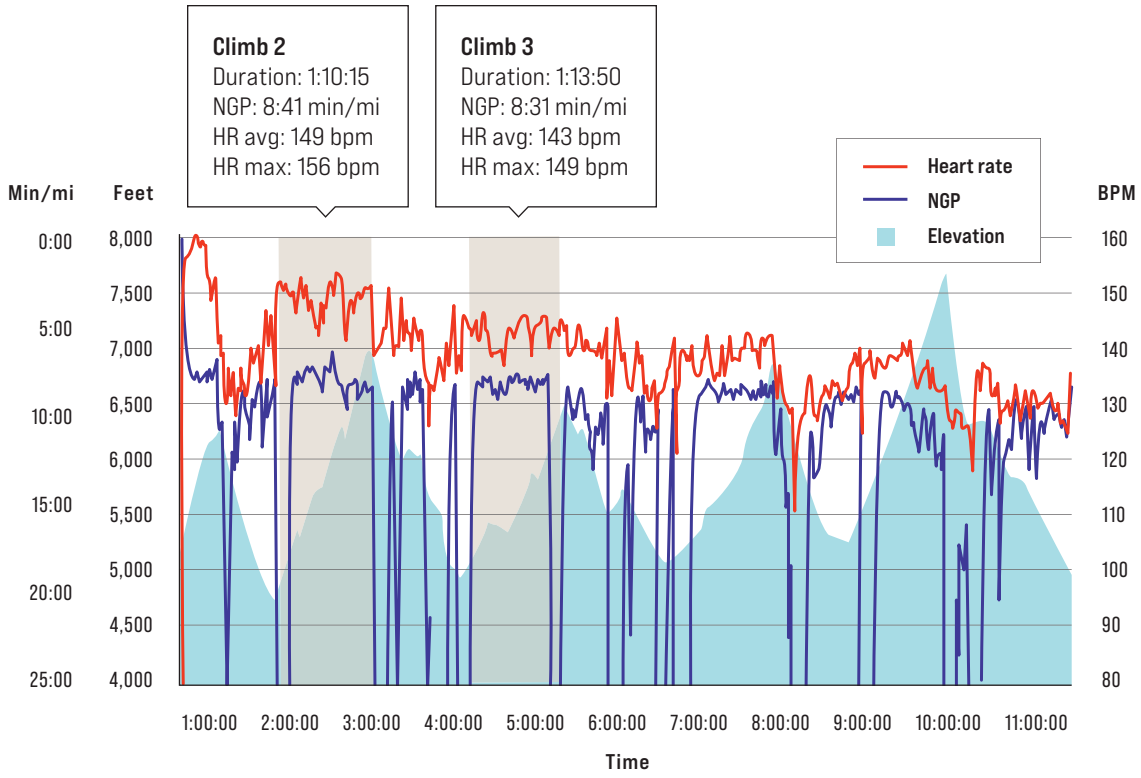


FIGURE 6.3 Example of how fatigue affects heart rate. Heart rate (red line) starts high due to freshness and then drops as fatigue sets in, even though NGP remains roughly the same for the first three climbs.

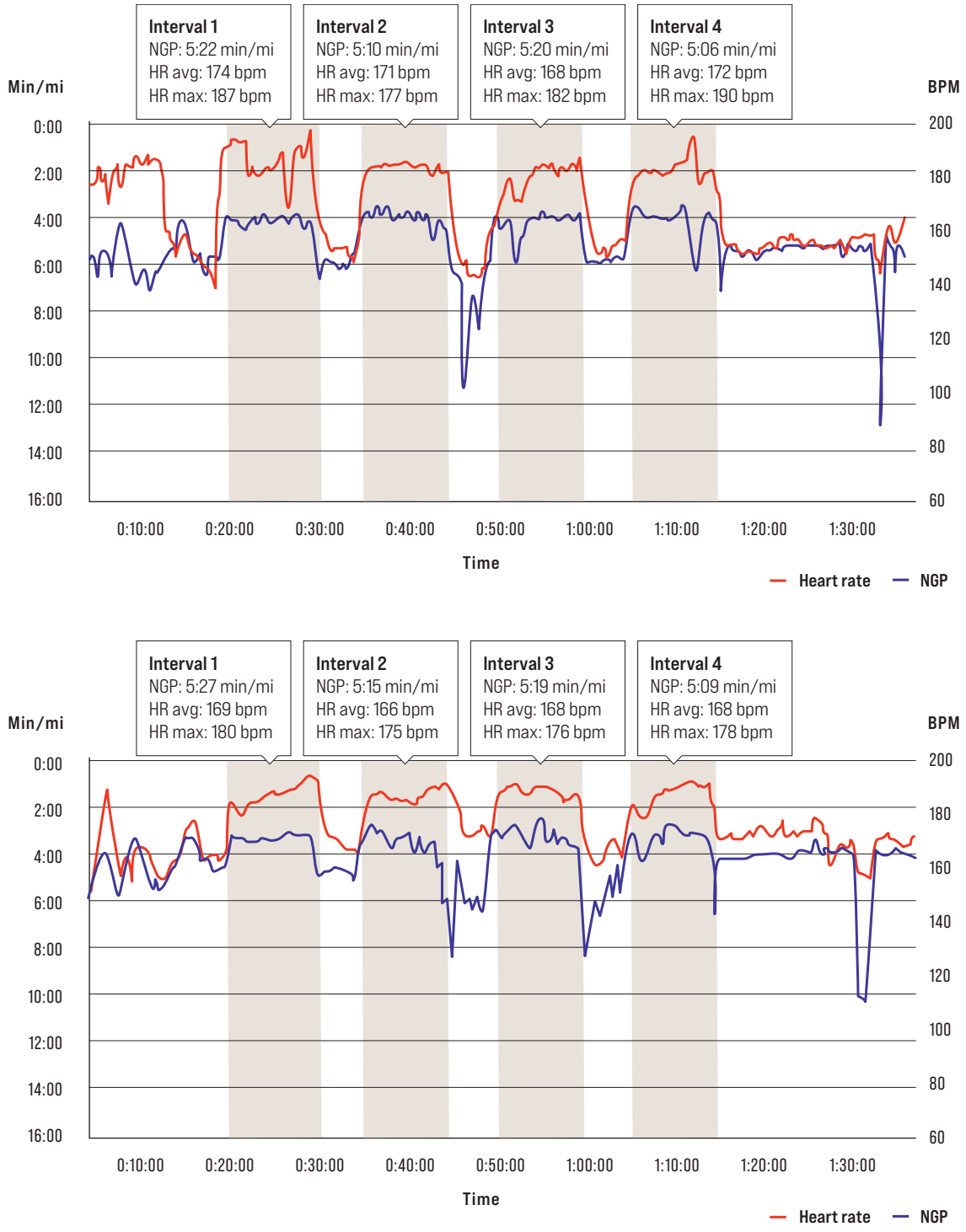


FIGURE 6.4 Two consecutive days of TempoRun intervals. While the normalized paces are similar, the heart rate is generally depressed on the second day. Had the athlete been training using heart rate, he either would not have been able to do the workout or would have pushed too hard.

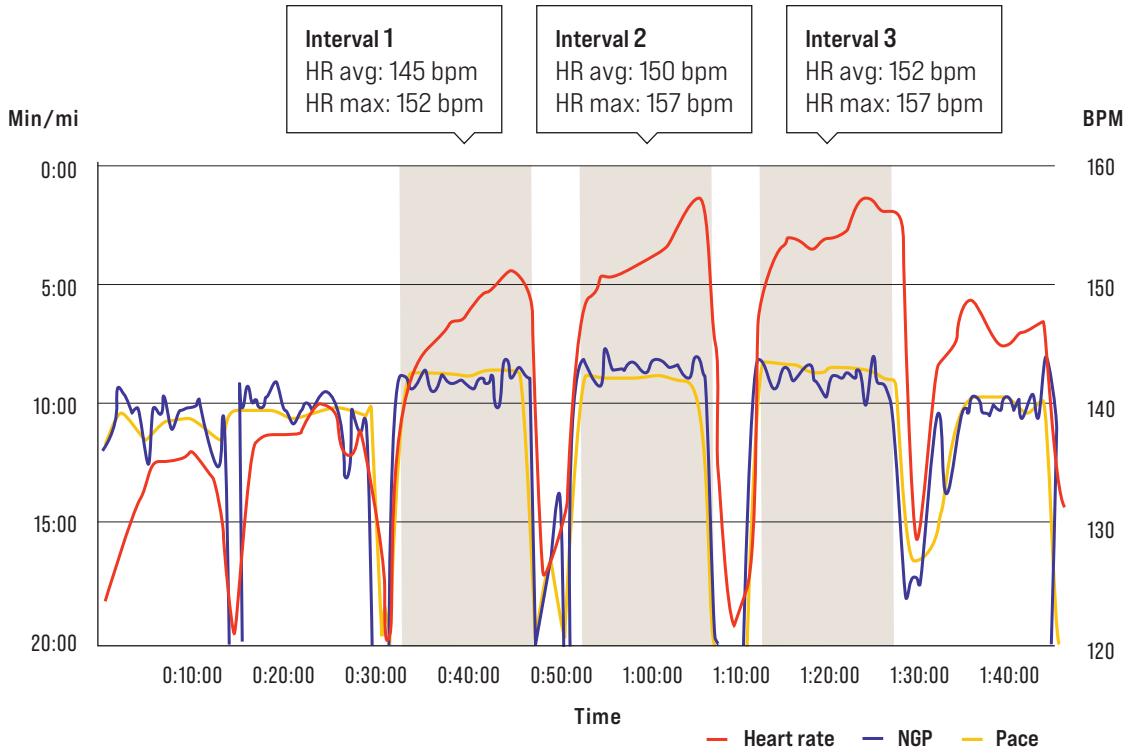


FIGURE 6.5 Impact of cardiac drift during a 3 × 10-minute TempoRun workout where the heart rate increases throughout each interval and from interval to interval.

RPE	ACTIVITY	TALKING ABILITY
1–3	Sitting on the couch	Uninhibited
4–5	Easy run	Story time!
5–6	Normal run	Comfortable conversation
7–8	Hard workout	2–3 sentences at a time
8–9	Very hard workout	5–7 words at a time
9–10	Extremely hard workout	Single word, probably four letters

TABLE 6.4 RPE and the Talk Test.

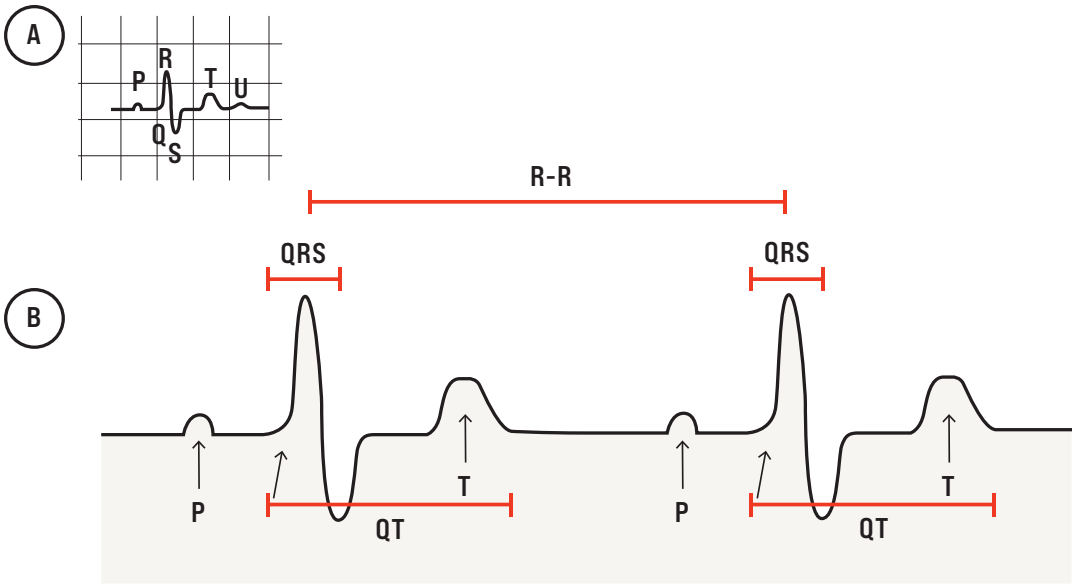


FIGURE 6.6 An EKG reading of the R-R interval across two heartbeats. Adapted from Dong (2016).

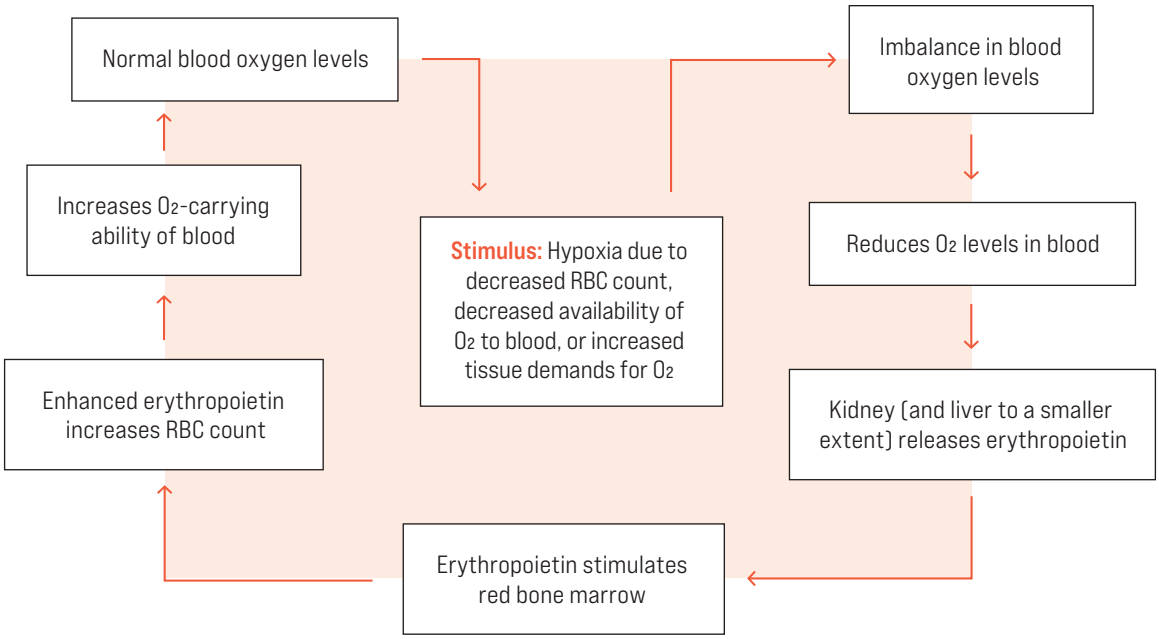


FIGURE 7.1 Hematologic effects to altitude exposure.

	LIVE HIGH, TRAIN HIGH	LIVE HIGH, TRAIN LOW	LIVE HIGH, TRAIN HIGH / LOW
Living	Living between 6,840–8,050 ft	Living between 6,840–8,050 ft	Living between 6,840–8,050 ft
Training	Training at or above 6,000 ft	Training below 4,100 ft	Train at low intensities between 6,840–8,050 ft, and high intensity workouts below 4,100 ft*
Duration of Protocol	~21–28 days	~21–28 days	~21-28 days

TABLE 7.1 Different altitude training protocols.

*Living between 6,840–8,050 ft is optimal for hematological responses while not impairing recovery and sleep. Moving high-intensity runs below 4,100 ft is also optimal because it allows you to preserve the ability to effectively deliver oxygen to working muscles, maintaining the quality of higher-intensity sessions.

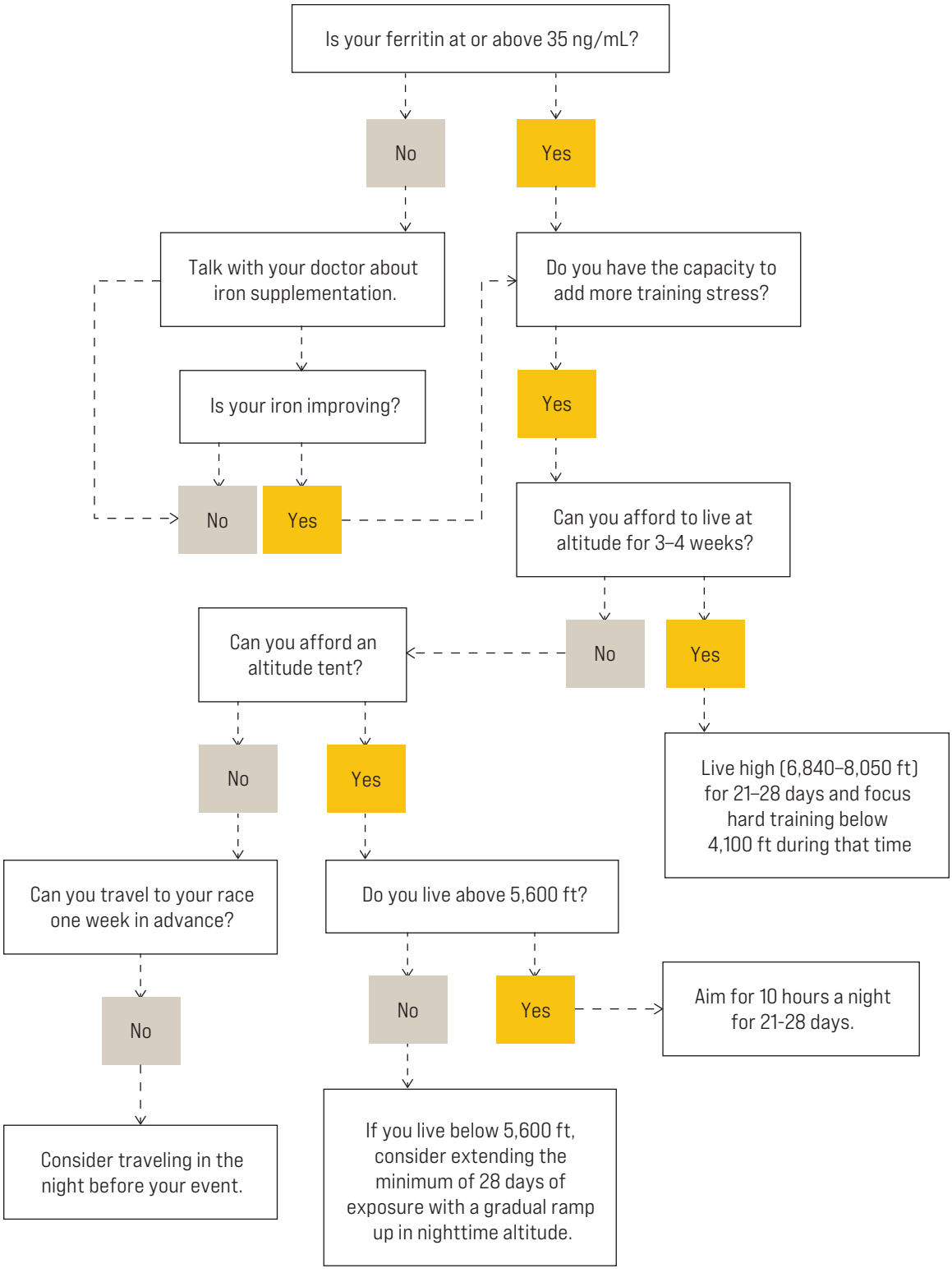


FIGURE 7.2 Are you a good candidate for altitude training?

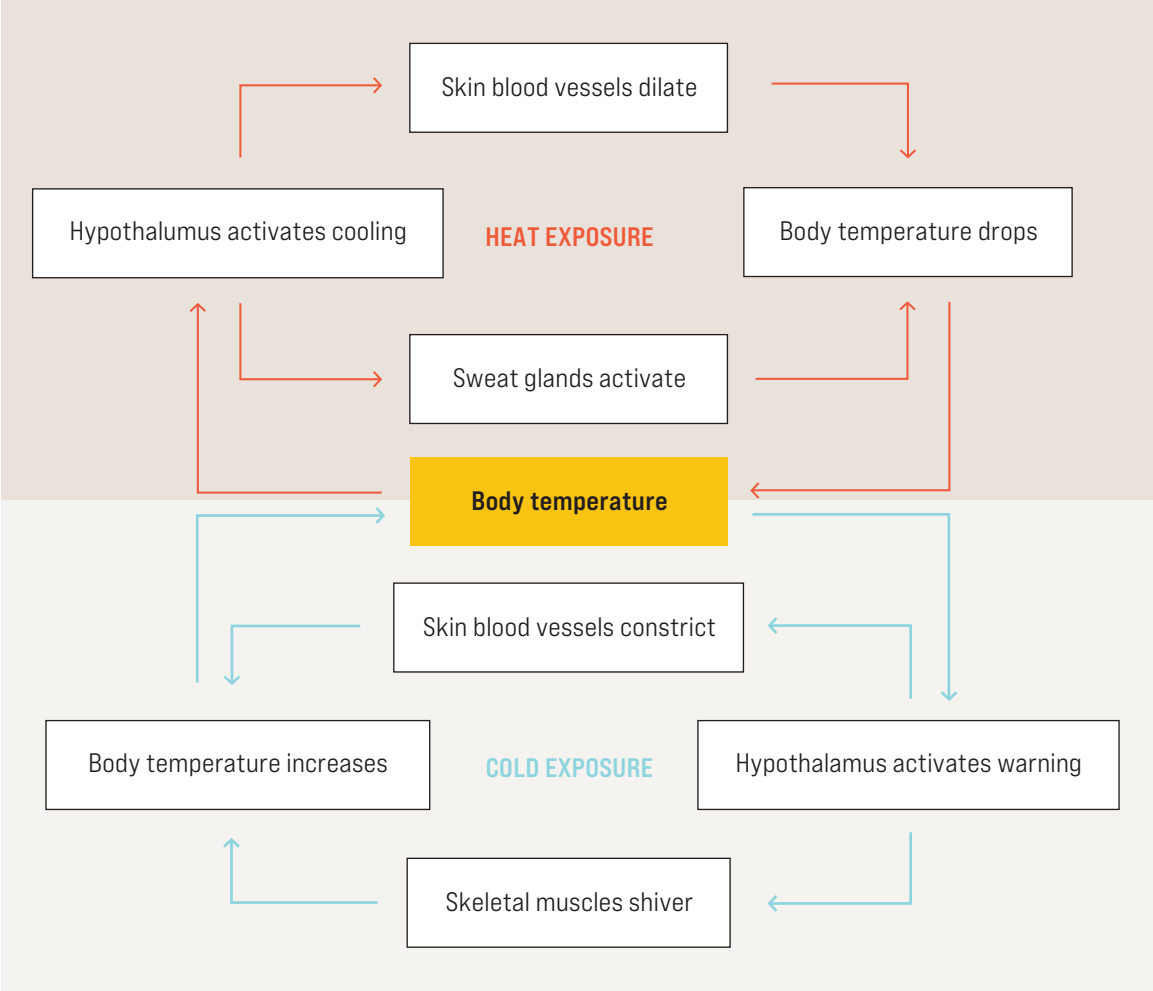


FIGURE 7.3 Physiological response to temperature change.

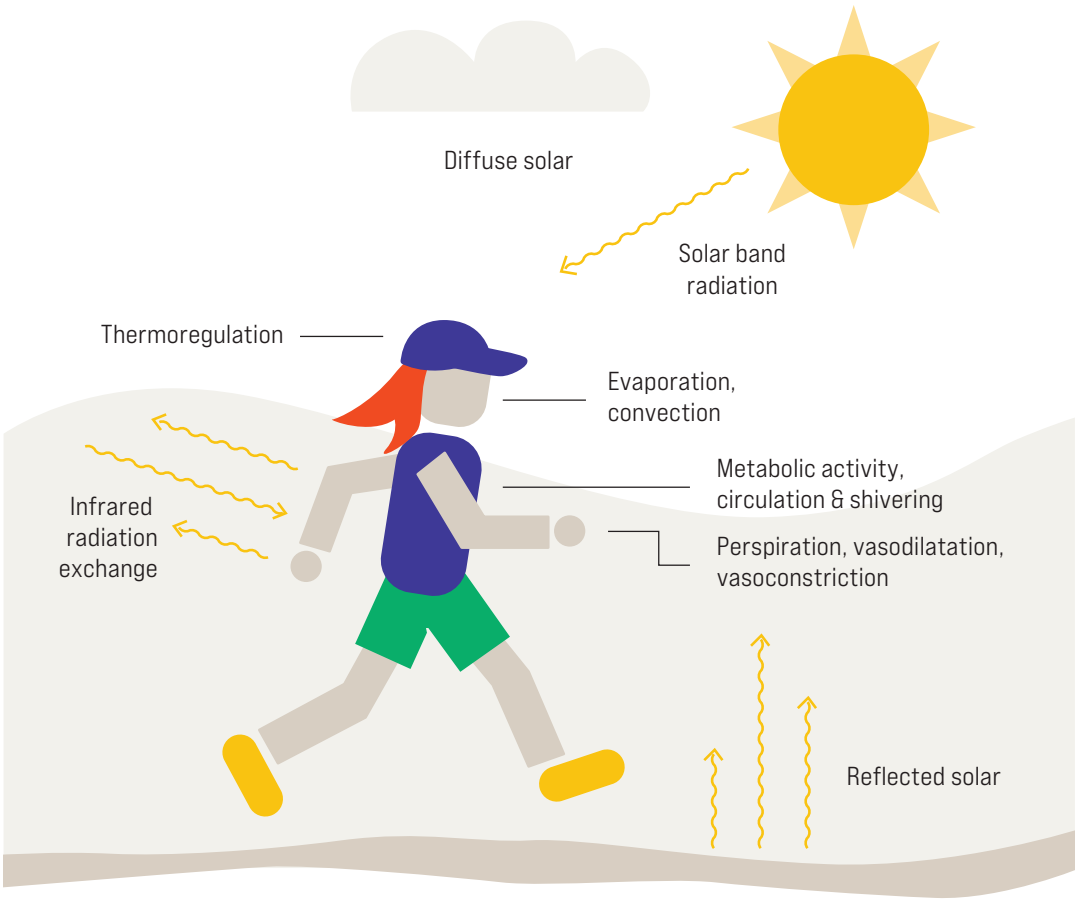


FIGURE 7.4 Thermoregulation of the human body.

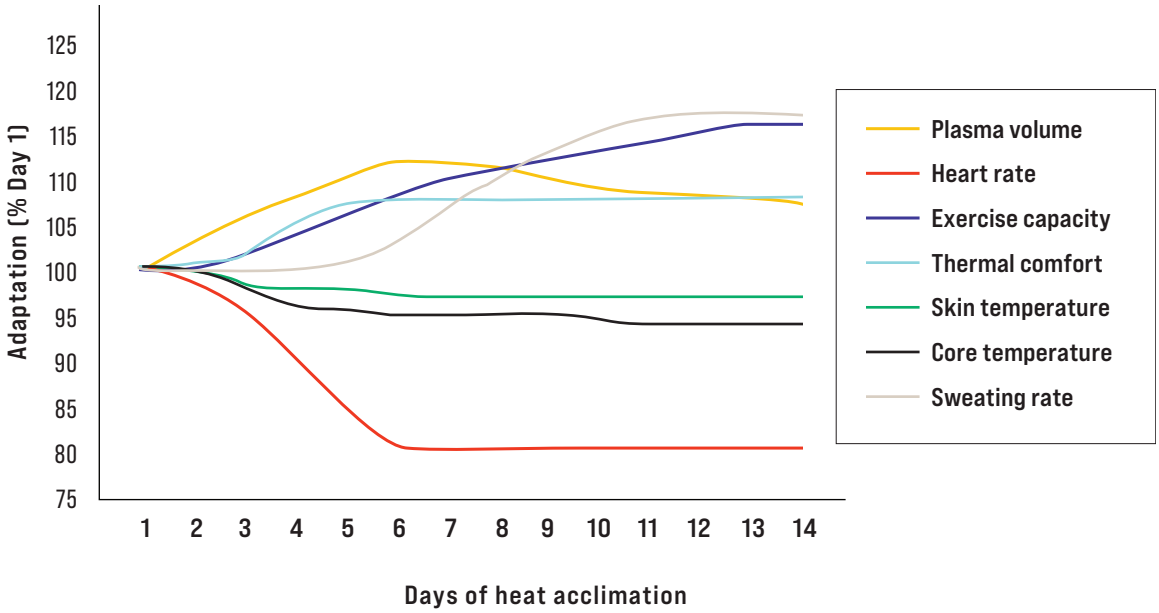
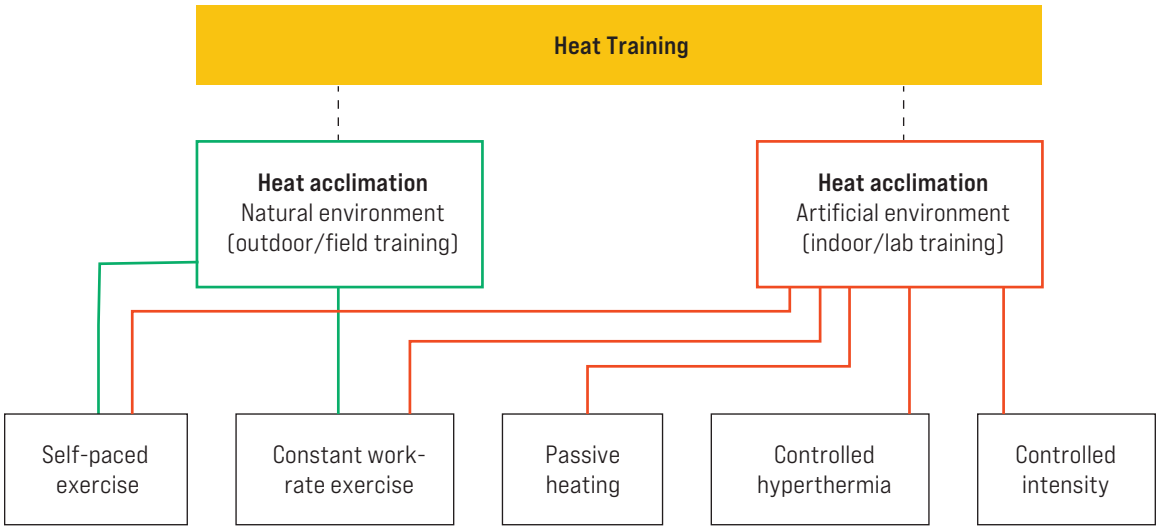


FIGURE 7.5 Time course of adaptations from heat acclimation. Adapted from Périard, Racinais, and Sawka 2015.



METHOD	ACTIVITY EXAMPLE	WORK RATE	CONDITIONS	DURATION
Self-paced exercise	Football, or running	Variable, or self-selected	Variable outdoor, or indoor 40°C/ 104°F, 40% relative humidity	60–90 min
Constant work-rate exercise	Cycling ergometer, or marching	60% VO_2 max (185 W) or 6 km/h	Indoor 40°C/104°F, 40% relative humidity, or variable outdoor	60–90 min
Passive heating	Water immersion, or sauna bathing	N/A	Water 40–42°C/ 104–107.6°F or sauna 70–90°C/158–194°F	45–60 min, or intermittent for 30 min
Controlled hyperthermia	Resting and/or exercising to maintain core temperature at 38.5°C	Variable	40°C/104°F, 40% relative humidity	60–90 min
Controlled intensity	Cycle ergometer	65% VO_2 max heart rate (145 bpm)	40°C/104°F, 40% relative humidity	60–90 min

FIGURE 7.6 Different heat acclimation methods. Adapted from Daanen, Racinais, and Périard 2017.

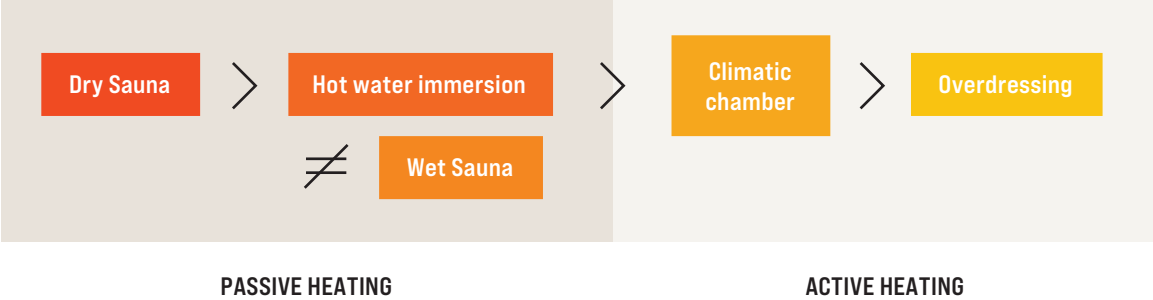


FIGURE 7.7 Hierarchy of heat acclimation protocols.

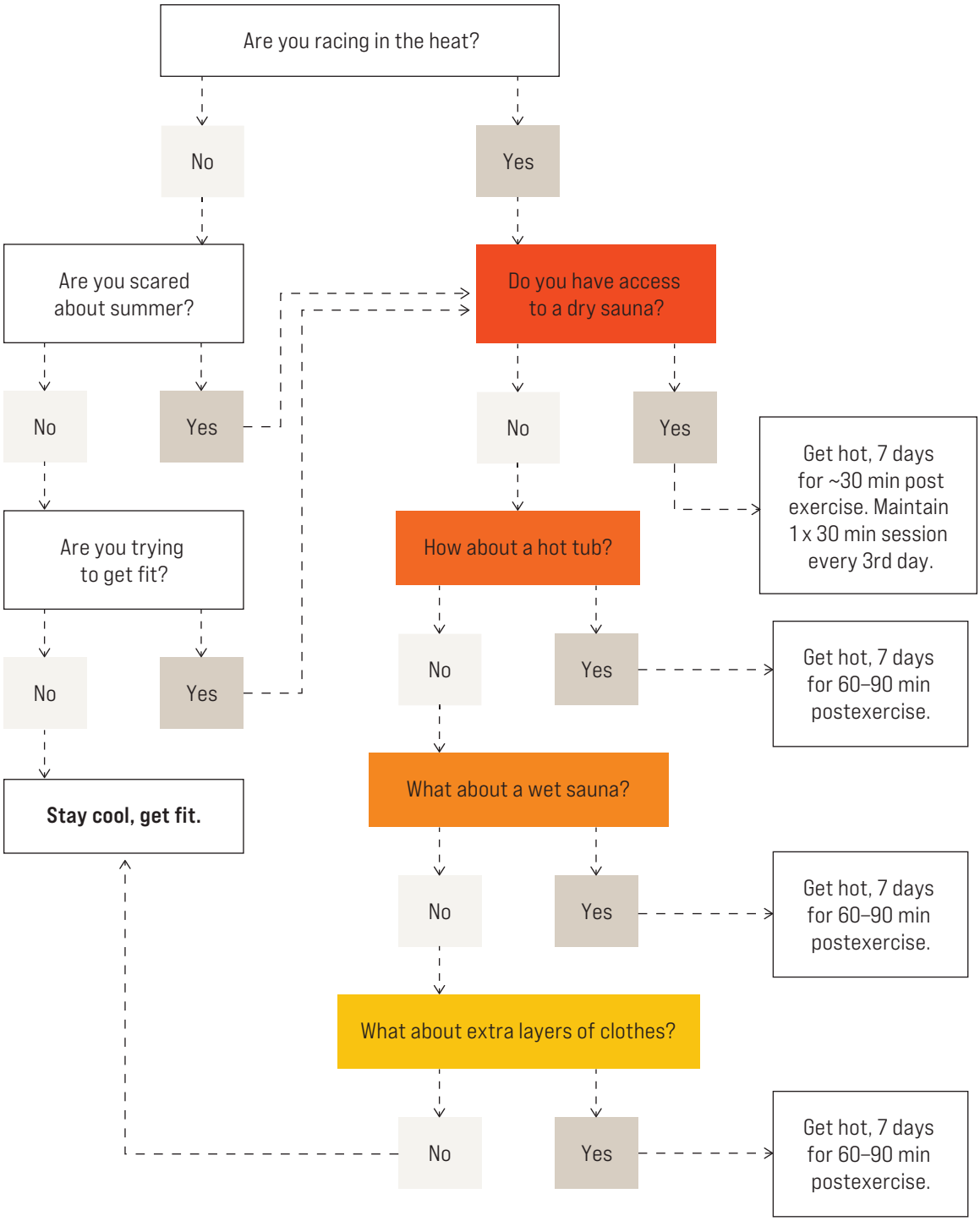


FIGURE 7.8 How to choose the right heat acclimation protocol.

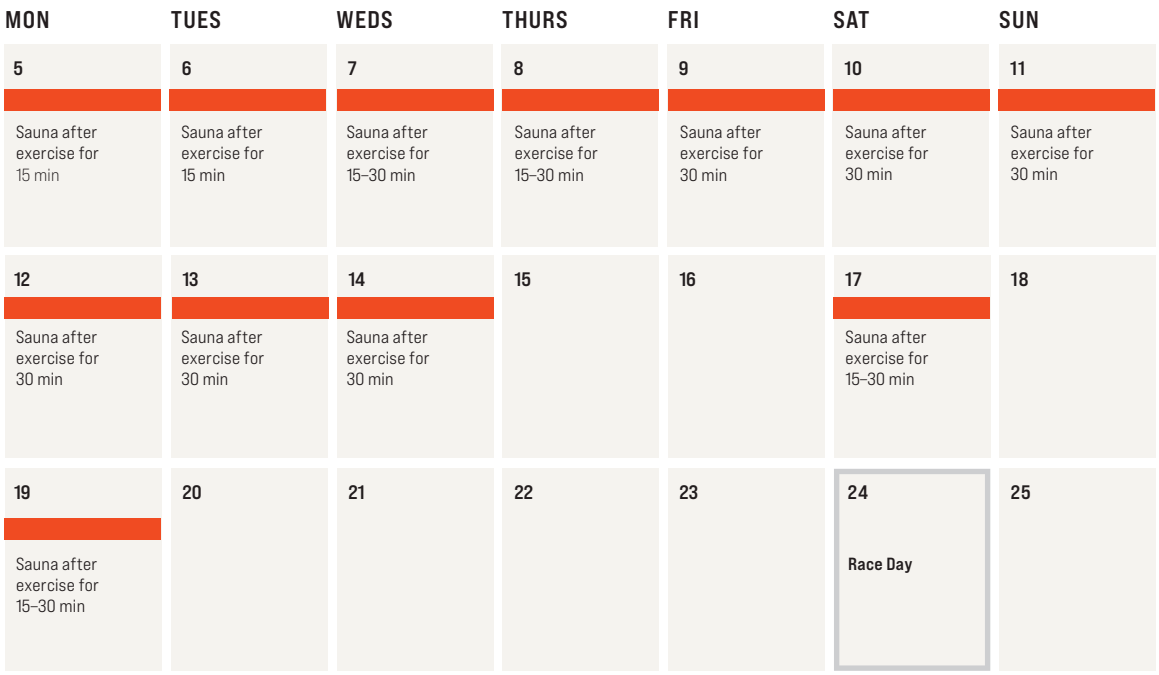


FIGURE 7.9 An example of a heat acclimation protocol using a sauna.

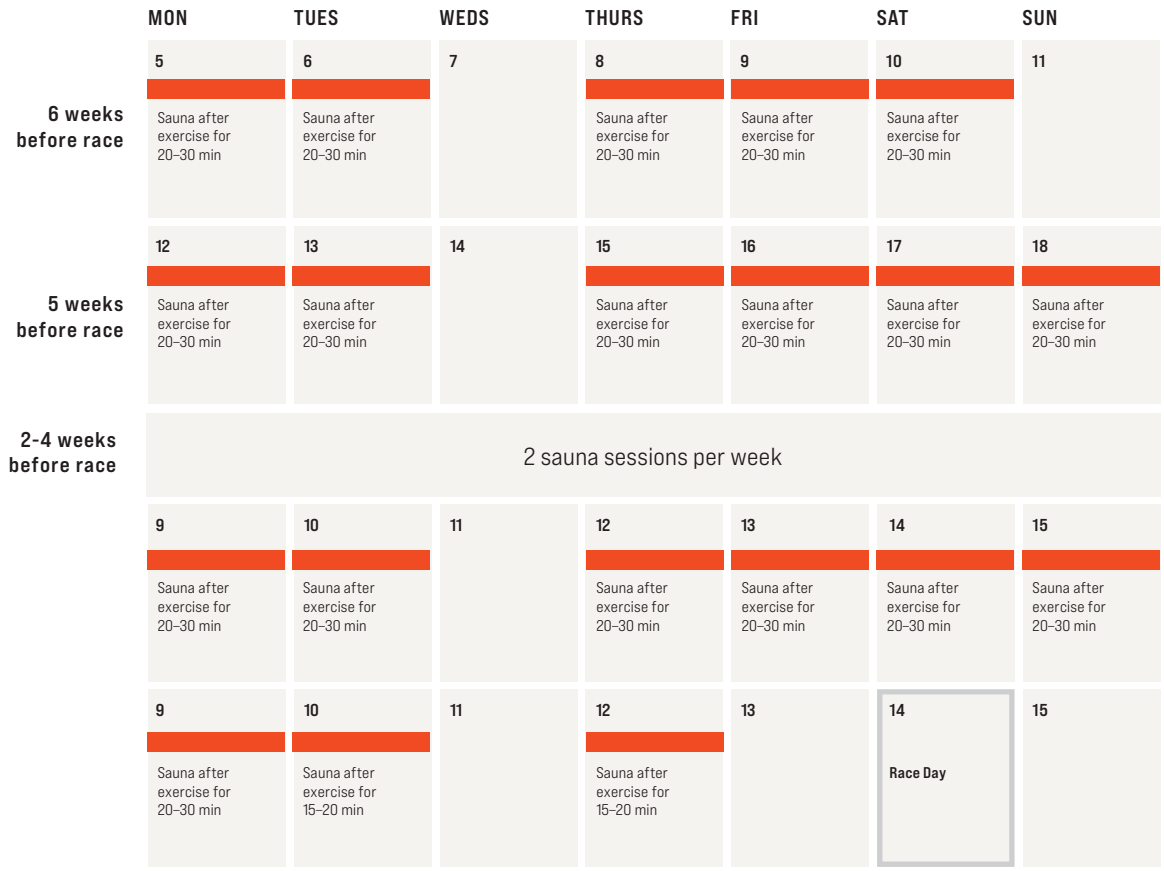


FIGURE 7.10 Two-phase sauna acclimation protocol.

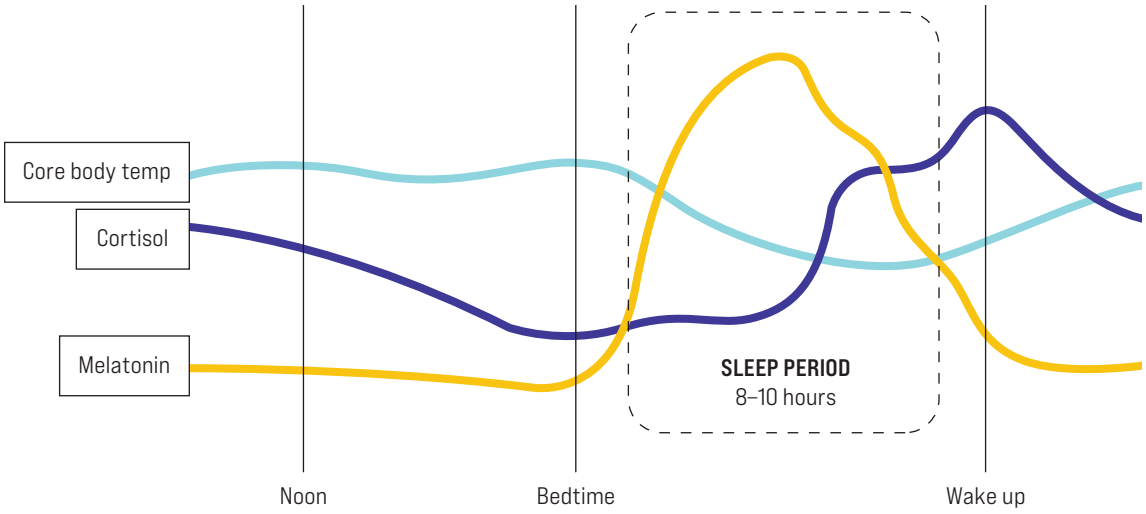


FIGURE 8.1 How core body temperature, cortisol, and melatonin fluctuate throughout the day.

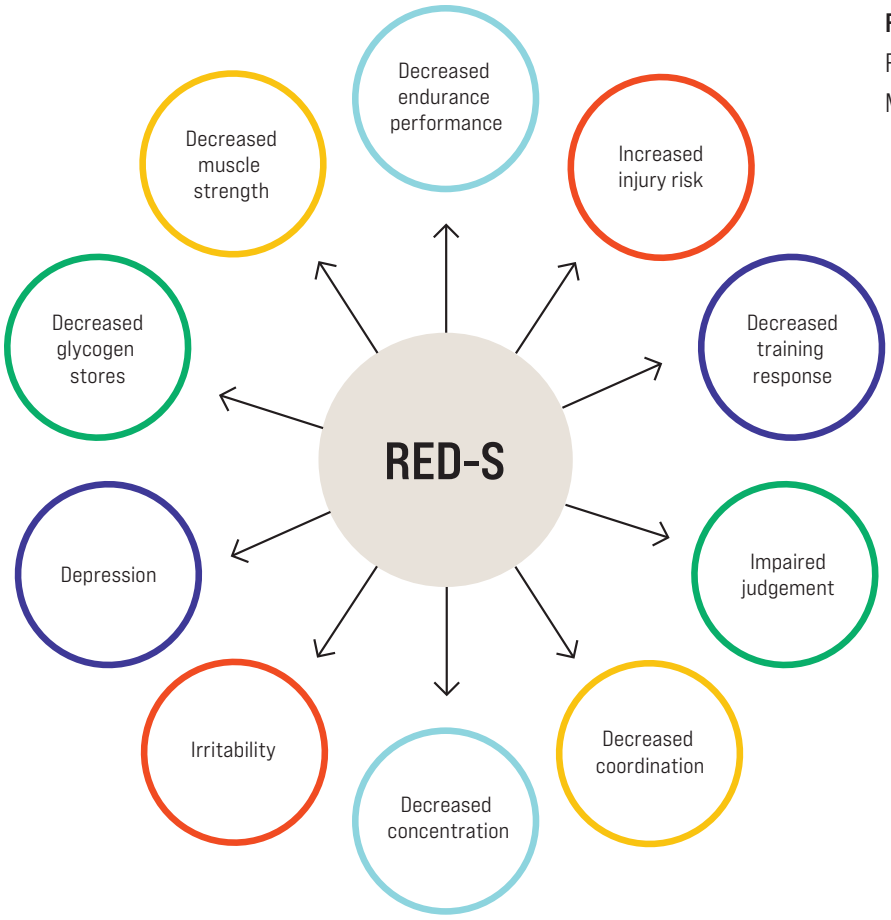


FIGURE 8.2 Effects of RED-S. Adapted from Mountjoy et al. 2018.

GROUP A

OVERVIEW OF CATEGORY	SUBCATEGORIES	EXAMPLES
Evidence level: Supported for use in specific situations in sport using evidence-based protocols	**Sports foods** Specialized products used to provide a convenient source of nutrients when it is impractical to consume everyday foods	**Sports drink** **Sports gel** **Sports confectionery** **Sports bar** **Electrolyte supplement** **Isolated protein supplement** **Mixed macronutrient supplement** (bar, powder, liquid meal)
	Medical supplements Supplements used to prevent or treat clinical issues including diagnosed nutrient deficiencies. Best used with advice from an appropriate medical/nutrition practitioner	**Iron supplement** **Calcium supplement** **Multivitamin supplement** **Vitamin D supplement** **Probiotics**
	Performance supplements Supplements/ingredients that can support or achieve an enhancement of sports performance Best used with an individualized and event-specific protocol, with the advice of appropriate sports science/nutrition practitioner	**Caffeine** **B-alanine** **Bicarbonate** **Beetroot juice/nitrate** **Creatine** **Glycerol**

TABLE 8.1 Various supplements and evidence. Adapted from "Supplements." Sport Australia. www.ais.gov.au/nutrition/supplements accessed September 2020.

GROUP B

OVERVIEW OF CATEGORY	SUBCATEGORIES	EXAMPLES
Evidence Level: Deserving of further research and could be considered for provision to athletes under a research protocol or case-managed monitoring situation	**Food polyphenols** Food compounds which may have bioactivity including antioxidant and anti-inflammatory properties May be consumed in food forms or as isolated chemicals	**Cherries, berries, and black currants** **Quercitin, ECGC, epicatechins, and others**
	Other Compounds which attract interest for potential benefits to body metabolism and function	**Collagen support products** **Carnitine** **HMB** **Ketone supplements** **Fish oils** **Phosphate** **Curcumin**
	Sick pack Multi-supplement approach to address an issue of health or well-being Best used with advice from an appropriate medical/nutrition practitioner	**Zinc lozenges and Vitamin C**
	Amino acids Constituents of protein which may have effects when taken in isolation, or may be consumed individually by the athlete to fortify an existing food/supplement that is lacking in this amino acid	**BCAA/Leucine** **Tyrosine**
	Antioxidants Compounds often found in foods which protect against oxidation or reactions with free-radical chemicals May be consumed in food forms or as isolated chemicals	**Vitamin C and E** **N-acetyl cysteine**

TABLE 8.1 Various supplements and evidence. Adapted from "Supplements." Sport Australia. www.ais.gov.au/nutrition/supplements accessed September 2020.

	RPE	TYPICAL INTERVAL TIME	TOTAL TIME AT INTENSITY	WORK : REST	TYPICAL WORKOUT	FREQUENCY PER WEEK
RecoveryRun (RR)	4 to 5	NA	20–60 min	NA	40–min RR	2–3
EnduranceRun (ER)	5 to 6	NA	30 min–6+ hours	NA	2–hr ER	2–6
SteadyStateRun (SSR)	7 to 8	20–60 min	30 min–2 hours	5 to 8:1	2–hr ER with 2 x 30 min SSR, 5–min recovery between intervals	2–4
TempoRun (TR)	8 to 9	8–20 min	30–75 min	2:1	2–hr ER with 3 x 12 min TR, 6–min recovery between intervals	2–3
RunningIntervals (RI)	9 to 10	1–3 min	12–24 min	1:1	90–min ER with 6 x 3 min RI, 3–min recovery between intervals	2–3

TABLE 9.1 The five critical workouts.

RUNNER EXPERIENCE	WORKOUT STRUCTURE	RPE	TOTAL TIME AT INTENSITY
Beginner	1 x 40 minutes hard	7 to 8	40 min
Intermediate	2 x 25 minutes hard with 4 minutes recovery	7 to 8	50 min
Advanced	2 x 30 minutes hard with 4 minutes recovery	7 to 8	60 min
Pro	2 x 45 minutes hard with 4 minutes recovery	7 to 8	90 min

TABLE 9.2 SteadyStateRun examples.

RUNNER EXPERIENCE	WORKOUT STRUCTURE	RPE	TOTAL TIME AT INTENSITY
Beginner	3 x 12 minutes hard with 6 minutes recovery	8 to 9	36 min
Intermediate	4 x 12 minutes hard with 6 minutes recovery	8 to 9	48 min
Advanced	4 x 15 minutes hard with 7 minutes recovery	8 to 9	60 min
Pro	5 x 15 minutes hard with 7 minutes recovery	8 to 9	75 min

TABLE 9.3 TempoRun examples.

RUNNER EXPERIENCE	WORKOUT STRUCTURE	RPE	TOTAL TIME AT INTENSITY
Beginner	4 x 3 minutes hard with 3 minutes recovery	9 to 10	12 min
Intermediate	5 x 3 minutes hard with 3 minutes recovery	9 to 10	15 min
Advanced	6 x 3 minutes hard with 3 minutes recovery	9 to 10	18 min
Pro	5 x 4 minutes hard with 4 minutes recovery	9 to 10	20 min

TABLE 9.4 RunningIntervals examples.

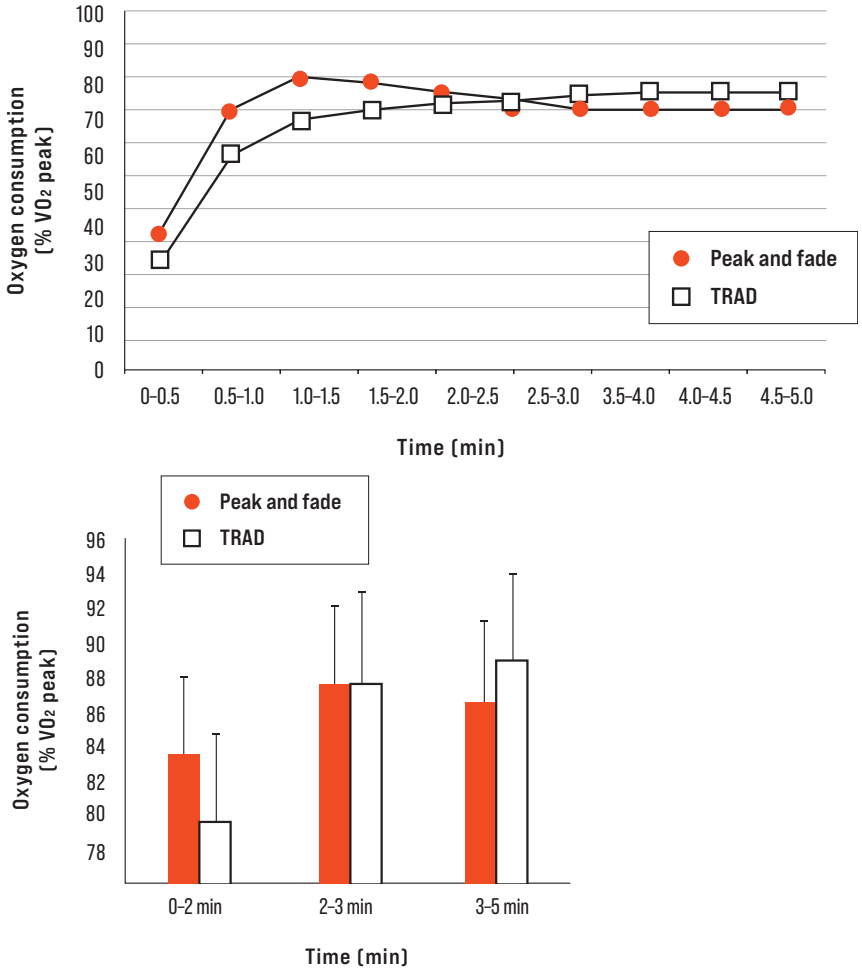


FIGURE 9.1 Oxygen consumption response from traditional, evenly paced intervals (TRAD) and peak and fade intervals. Adapted from Rønnestad et al. 2019.

	Racing Intensity	Ultramarathon Zone				Maybe if you are an elite				
	% VO_2 max	50	60	70	75	80	85	90		
	Workouts	**RecoveryRun**	**EnduranceRun**	**SteadyStateRun**		**TempoRun**		**RunningIntervals**	**Traditional speed workouts** (e.g., 6 x 200 m)	
Adaptation	Plasma volume	✓		✓	✓	✓	✓	✓	✓	✓
	Mitochondrial enzyme activity	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Lactate threshold	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Capillarization	✓		✓	✓	✓	✓	✓	✓	✓
	Conversion of Type IIB muscle fibers to Type IIA	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Stroke volume and cardiac output	✓		✓	✓	✓	✓	✓	✓	✓
	VO_2 max	✓		✓	✓	✓	✓	✓	✓	✓
	Lactate tolerance/ anaerobic capacity							✓	✓	✓
	ATP/PCr stores								✓	✓
	Muscle glycogen storage	✓	✓	✓	✓	✓	✓	✓		
	Neuromuscular power								✓	✓

TABLE 9.5 Physiological effects of different workouts.

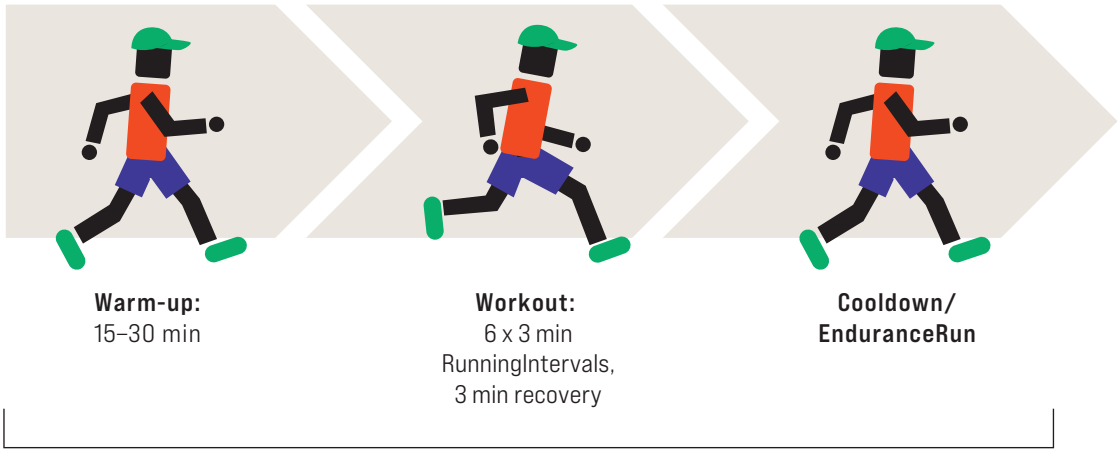
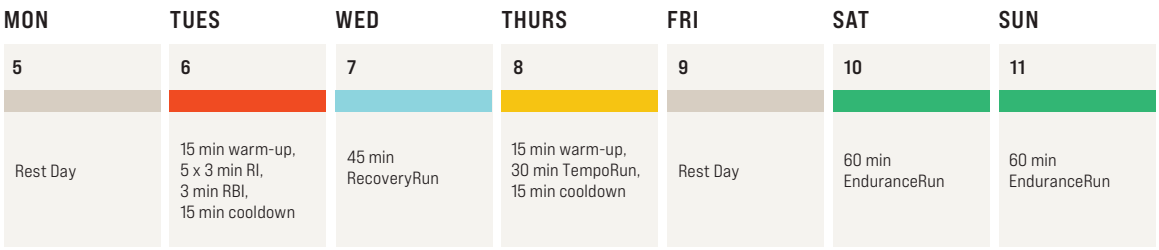


FIGURE 9.2 The right structure for warm-up, workout, and cooldown.



RBI= REST BETWEEN INTERVALS

FIGURE 10.1 Example of mixed-intensity periodization: a way of organizing training where an athlete does workouts at a few or several different intensities during the week.

MON	TUES	WED	THURS	FRI	SAT	SUN
5	6	7	8	9	10	11
Rest Day	15 min warm-up, 5 x 3 min RI, 3 min RBI, 15 min cooldown	45 min RecoveryRun	15 min warm-up, 5 x 3 min RI, 3 min RBI, 15 min cooldown	Rest Day	60 min EnduranceRun	60 min EnduranceRun

FIGURE 10.2 Example of block intensity periodization plan: a way of organizing training where an athlete does workouts at similar intensities during the week.

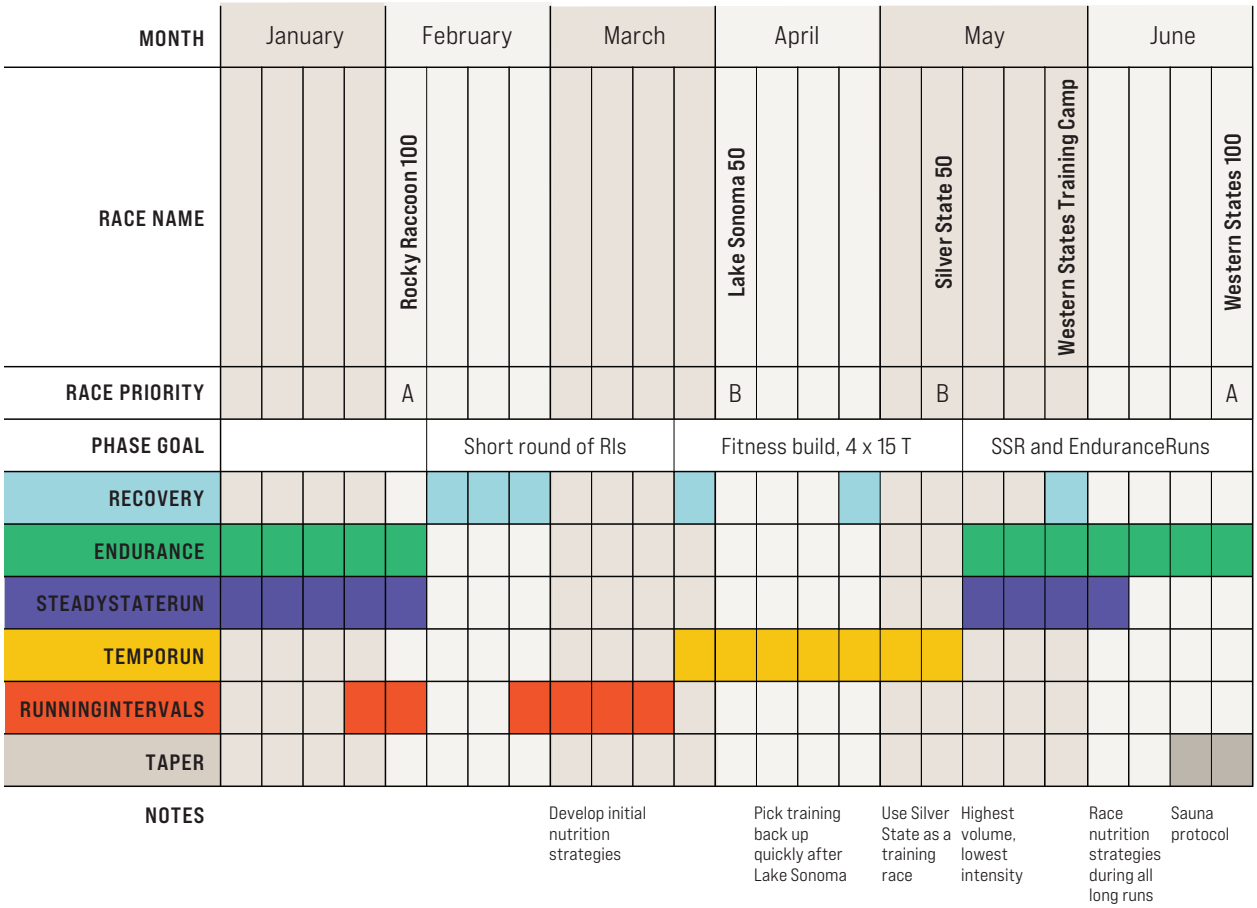


FIGURE 10.3 An example of a Long-Range Plan.

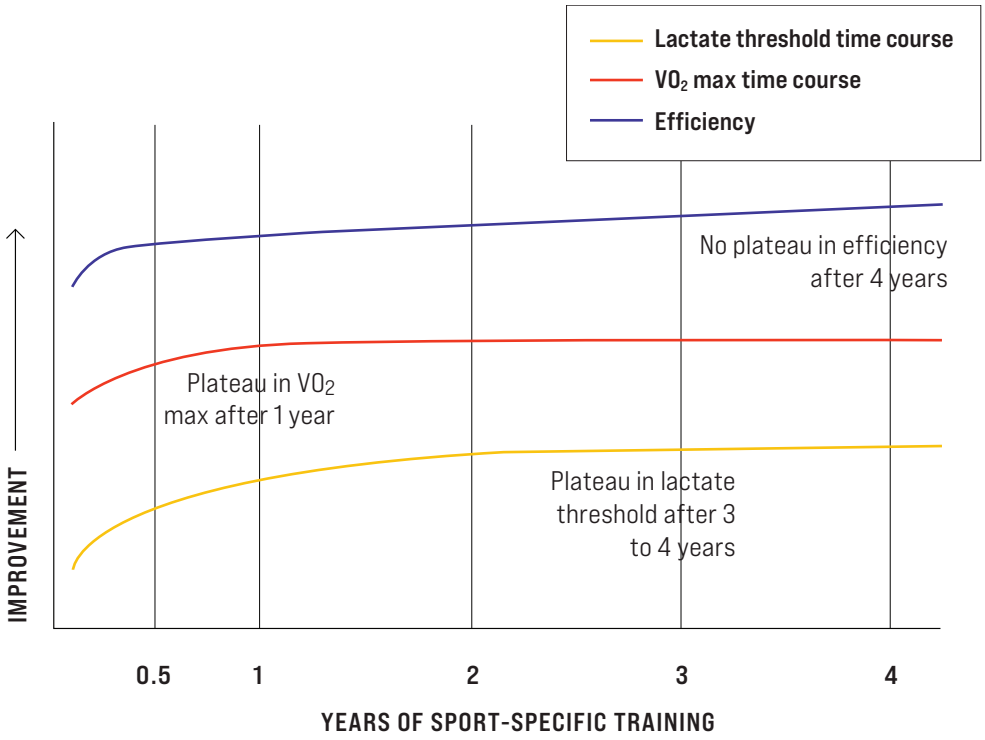


FIGURE 10.4 Time course for training adaptation. Adapted from Seiler 2006.

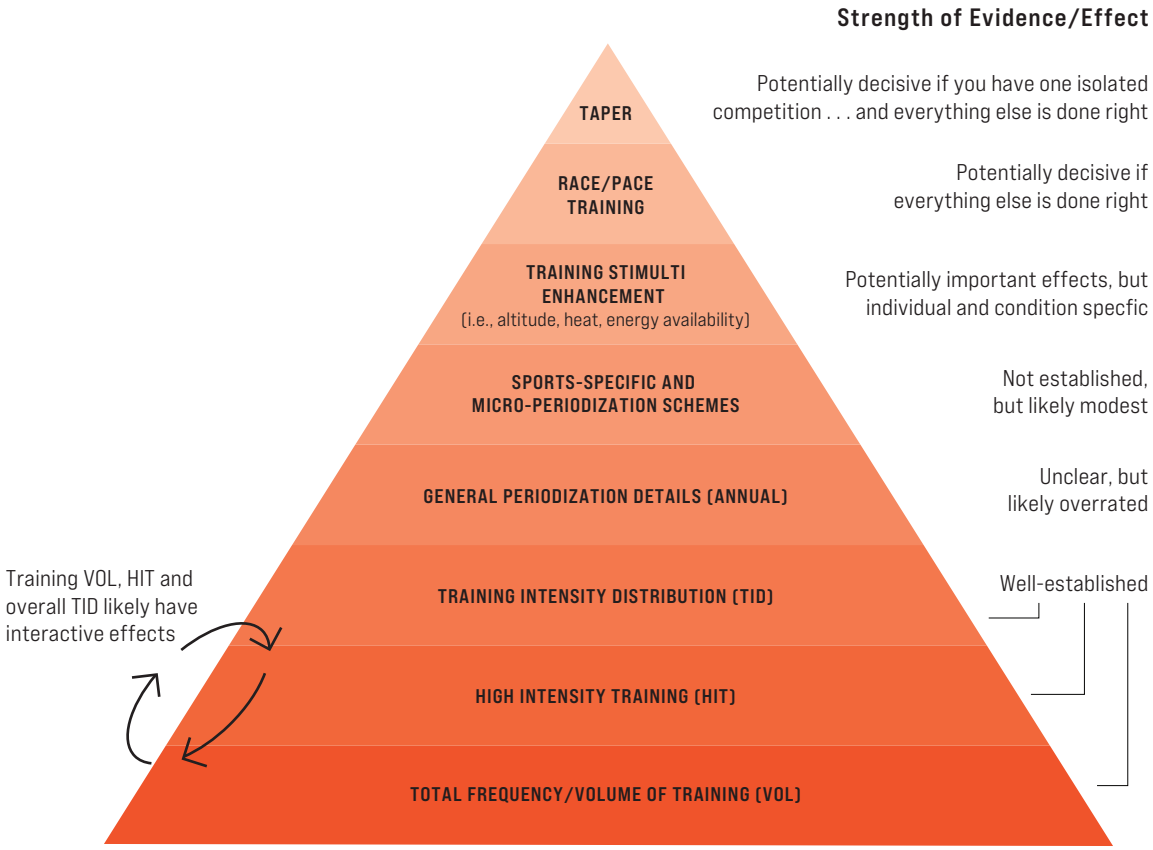


FIGURE 10.5 Hierarchy of Endurance Training Needs. Source: Seiler and Sjusren 2004.

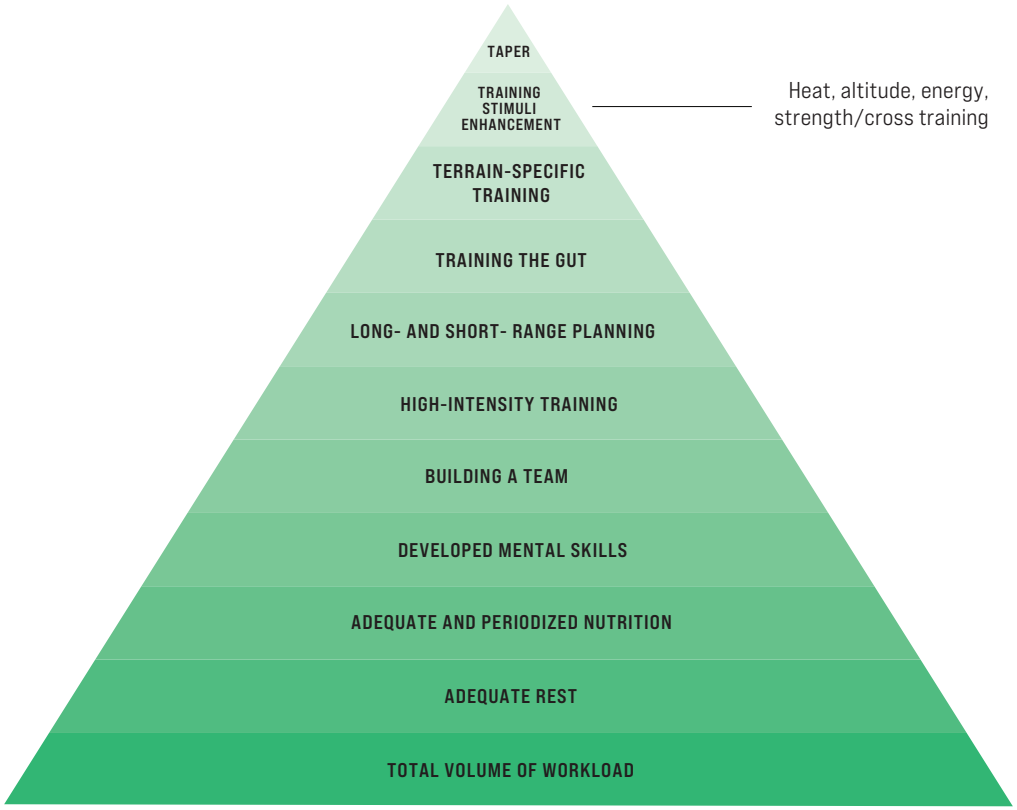


FIGURE 10.6 Koop's hierarchy of ultramarathon training needs.

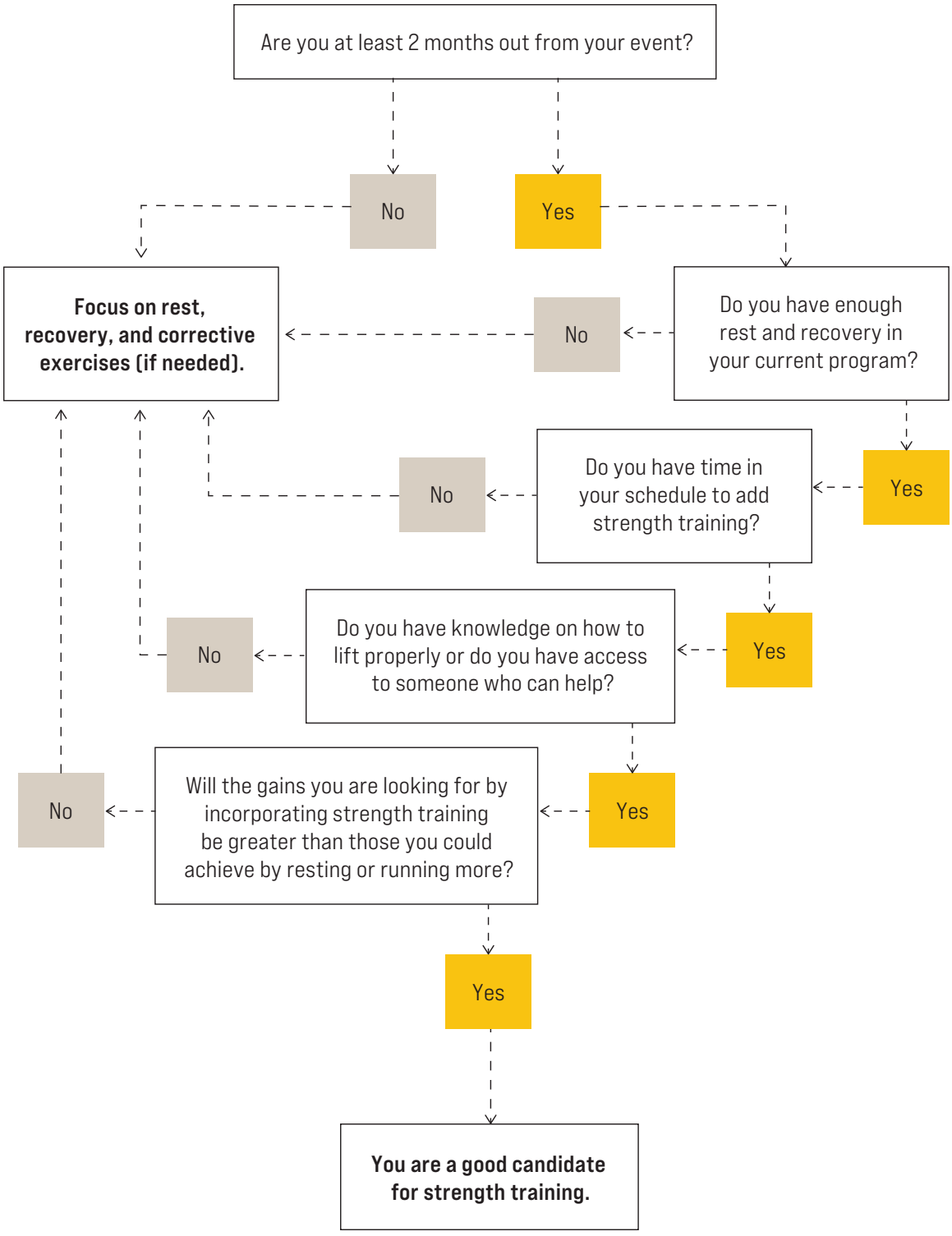


FIGURE 11.1 Are you a good candidate for strength training?

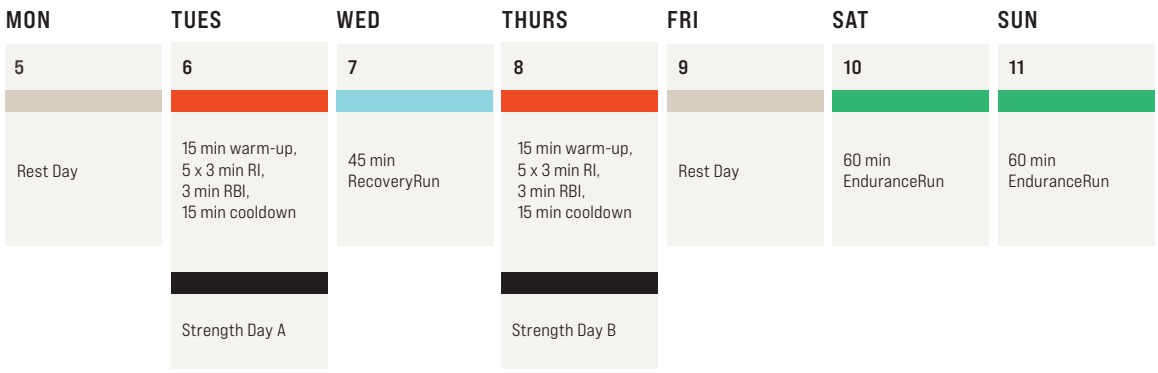


FIGURE 11.2 Example training week with two scheduled strength-training workouts.

PART OF TRAINING	SETS	REPS	REST	FREQUENCY
Early	1–5	1–5	90+ sec	3x week
Mid	3	8–12	45–60 sec	2–3x week
Late	2–3	10–15 or time-based	As needed	1–2x week

TABLE 11.1 Overview of strength-training programming.

MON	TUES	WED	THURS	FRI	SAT	SUN
5	6	7	8	9	10	11
Rest Day	1:30 EnduranceRun with 5 x 3 min RunningIntervals, 3 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 5 x 3 min RunningIntervals, 3 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 5 x 3 min RunningIntervals, 3 min recovery between intervals	2:00 EnduranceRun
12	13	14	15	16	17	18
Rest Day	1:30 EnduranceRun with 5 x 3 min RunningIntervals, 3 min recovery between intervals	1:00 RecoveryRun	1:00 RecoveryRun	1:30 EnduranceRun with 4 x 3 min RunningIntervals, 3 min recovery between intervals	1:00 EnduranceRun	2:00 EnduranceRun
19	20	21	22	23	24	25
Rest Day	1:00 RecoveryRun	1:30 EnduranceRun with 4 x 3 min RunningIntervals, 3 min recovery between intervals	0:45 RecoveryRun	0:45 RecoveryRun	1:00 RecoveryRun	1:00 RecoveryRun

FIGURE 12.1 A RunningIntervals phase where the hardest workouts are the first four.

A

MON	TUES	WED	THURS	FRI	SAT	SUN
5	6	7	8	9	10	11
Rest Day	1:45 EnduranceRun with 2 x 30 min SteadyStateRun, 5 min recovery between intervals	1:00 RecoveryRun	1:45 EnduranceRun with 2 x 20 min SteadyStateRun, 5 min recovery between intervals	1:00 RecoveryRun	2:00 EnduranceRun with 2 x 30 min SteadyStateRun, 5 min recovery between intervals	3:00 EnduranceRun
12	13	14	15	16	17	18
Rest Day	1:45 EnduranceRun with 2 x 30 min SteadyStateRun, 5 min recovery between intervals	1:00 RecoveryRun	1:45 EnduranceRun with 2 x 20 min SteadyStateRun, 5 min recovery between intervals	1:00 RecoveryRun	2:00 EnduranceRun with 2 x 20 min SteadyStateRun	3:30 EnduranceRun
19	20	21	22	23	24	25
Rest Day	1:45 EnduranceRun with 2 x 20 min SteadyStateRun, 5 min recovery between intervals	1:00 RecoveryRun	1:45 EnduranceRun with 1 x 30 min SteadyStateRun, 5 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 1 x 30 min SteadyStateRun	4:00 EnduranceRun
26	27	28	29	30	31	1
Rest Day	1:00 RecoveryRun	1:00 RecoveryRun	1:00 RecoveryRun	1:00 RecoveryRun	2:00 EnduranceRun with 2 x 30 min SteadyStateRun, 5 min recovery between intervals	3:00 EnduranceRun

B

MON	TUES	WED	THURS	FRI	SAT	SUN
5	6	7	8	9	10	11
Rest Day	1:30 EnduranceRun with 5 x 3 min RunningIntervals, 3 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 5 x 3 min RunningIntervals, 3 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 5 x 3 min RunningIntervals, 3 min recovery between intervals	2:00 EnduranceRun
12	13	14	15	16	17	18
Rest Day	1:30 EnduranceRun with 5 x 3 min RunningIntervals, 3 min recovery between intervals	1:00 RecoveryRun	1:00 RecoveryRun	1:30 EnduranceRun with 4 x 3 min RunningIntervals, 3 min recovery between intervals	1:00 RecoveryRun	2:00 EnduranceRun
19	20	21	22	23	24	25
Rest Day	1:00 RecoveryRun	1:30 EnduranceRun with 4 x 3 min RunningIntervals, 3 min recovery between intervals	0:45 RecoveryRun	0:45 RecoveryRun	1:00 RecoveryRun	1:00 RecoveryRun

FIGURE 12.2 (A) A typical SteadyStateRun phase; (B) a typical RunningInterval phase. Note that the SteadyStateRun phase is longer and includes less recovery between the workouts than the RunningInterval phase.

MON	TUES	WED	THURS	FRI	SAT	SUN
5	6	7	8	9	10	11
Rest Day	1:30 EnduranceRun with 3 x 10 min TempoRun, 5 min recovery between intervals	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	1:00 RecoveryRun	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 10 min TempoRun, 5 min recovery between intervals	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals
12	13	14	15	16	17	18
Rest Day	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 10 min TempoRun, 5 min recovery between intervals	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	2:00 EnduranceRun
19	20	21	22	23	24	25
Rest Day	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	1:00 RecoveryRun	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals
26	27	28	29	30	31	1
Rest Day	1:00 RecoveryRun	1:00 RecoveryRun	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 12 min TempoRun, 6 min recovery between intervals	1:30 EnduranceRun with 3 x 10 min TempoRun, 5 min recovery between intervals	2:00 EnduranceRun

FIGURE 12.3 A back-to-back-style training plan. There is one additional hard workout, as compared to Figure 12.4. Even in this example, the hardest workouts are still early in the phase.

MON	TUES	WED	THURS	FRI	SAT	SUN
5	6	7	8	9	10	11
Rest Day	1:30 EnduranceRun with 3 x 10 min TempoRun, 5 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 10 min TempoRun, 5 min recovery between intervals	2:00 EnduranceRun
12	13	14	15	16	17	18
Rest Day	1:30 EnduranceRun with 3 x 10 min TempoRun, 5 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 10 min TempoRun, 5 min recovery between intervals	2:00 EnduranceRun
19	20	21	22	23	24	25
Rest Day	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 8 min TempoRun, 4 min recovery between intervals	2:00 EnduranceRun
26	27	28	29	30	31	1
Rest Day	1:00 RecoveryRun	1:00 RecoveryRun	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 12 min TempoRun, 6 min recovery between intervals	1:00 RecoveryRun	1:30 EnduranceRun with 3 x 10 min TempoRun, 5 min recovery between intervals

FIGURE 12.4 A non-back-to-back-style training example. There are only nine hard workouts, as compared to the ten in the back-to-back style.

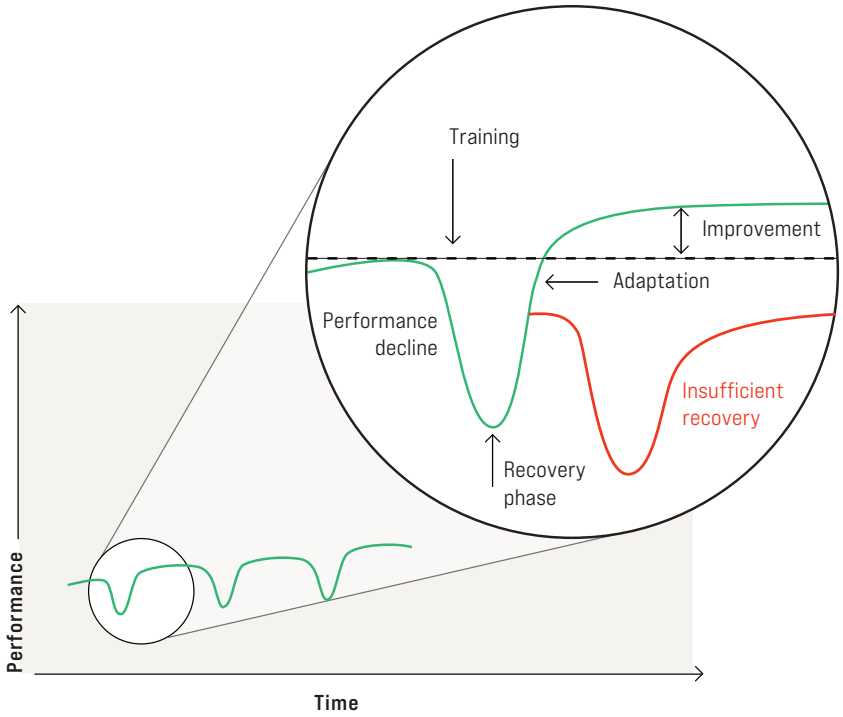


FIGURE 12.5 How fitness (green line) is affected over time from the applications of training stress and recovery.

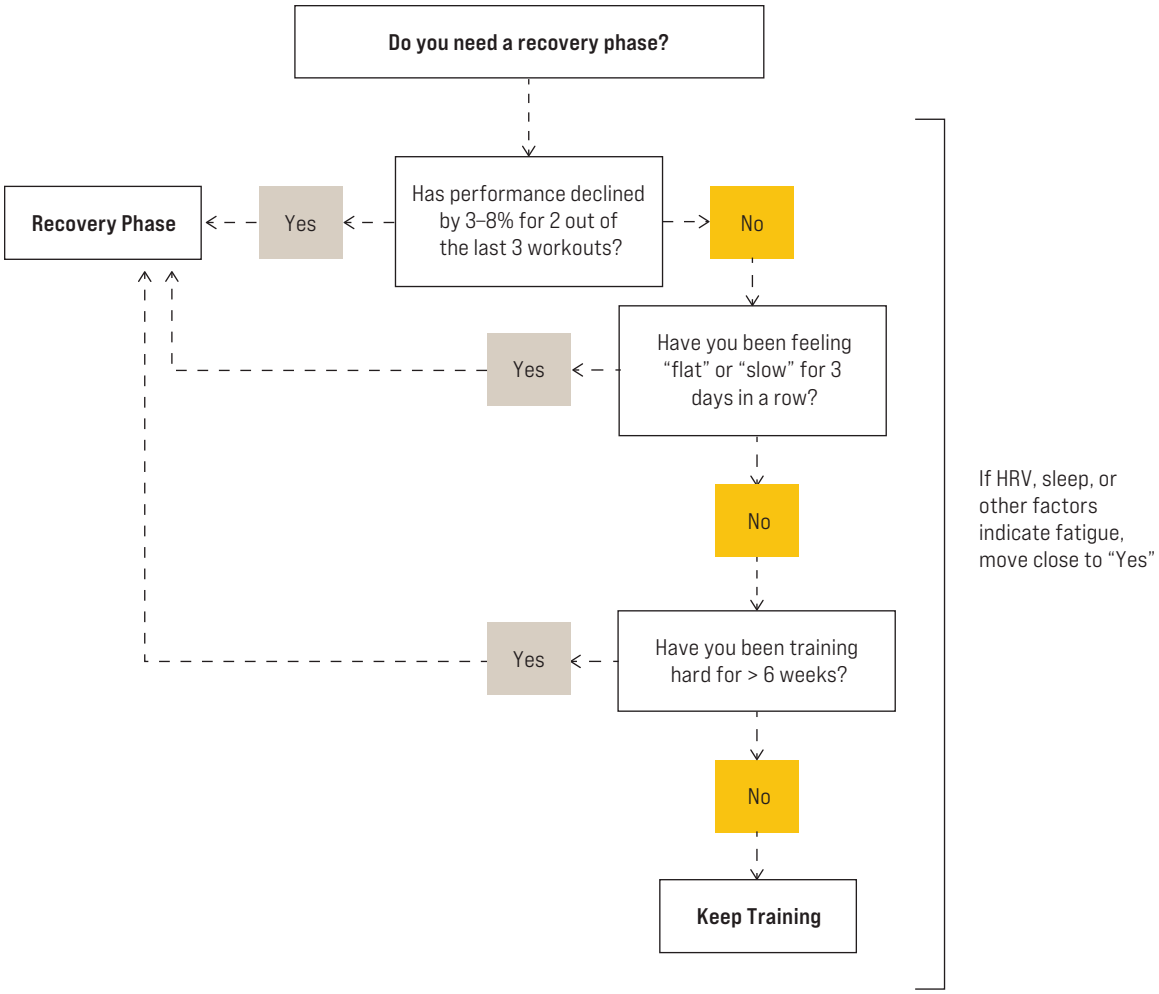


FIGURE 12.6 Flowchart for determining whether it is time to incorporate a recovery phase.

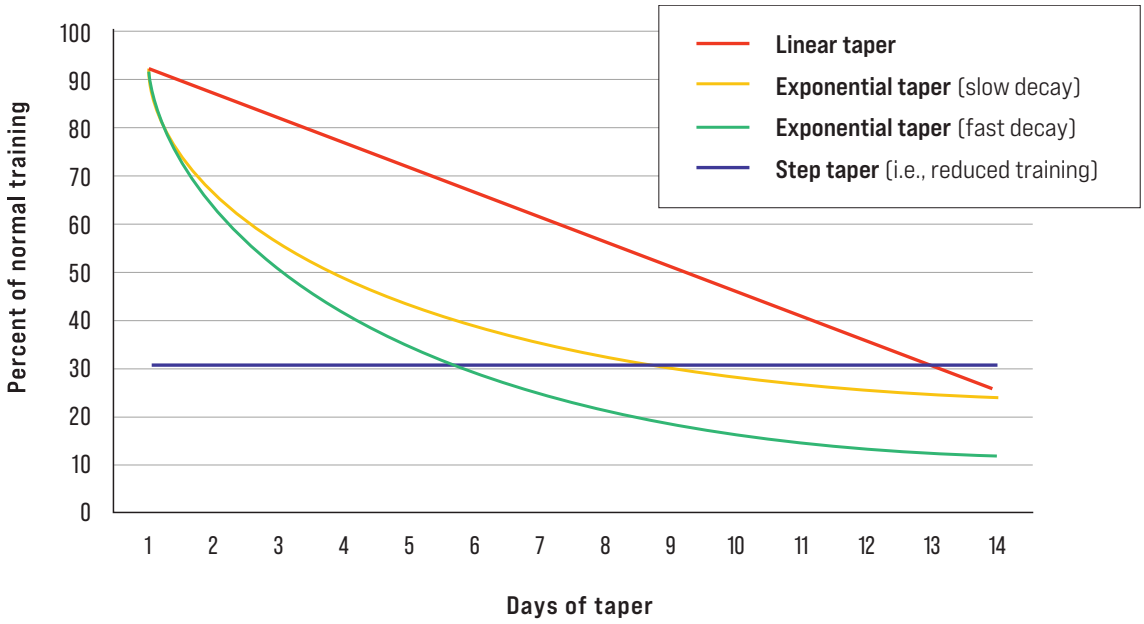


FIGURE 12.7 Schematic representation of the different types of tapers. Adapted from Mujika and Padilla 2003.

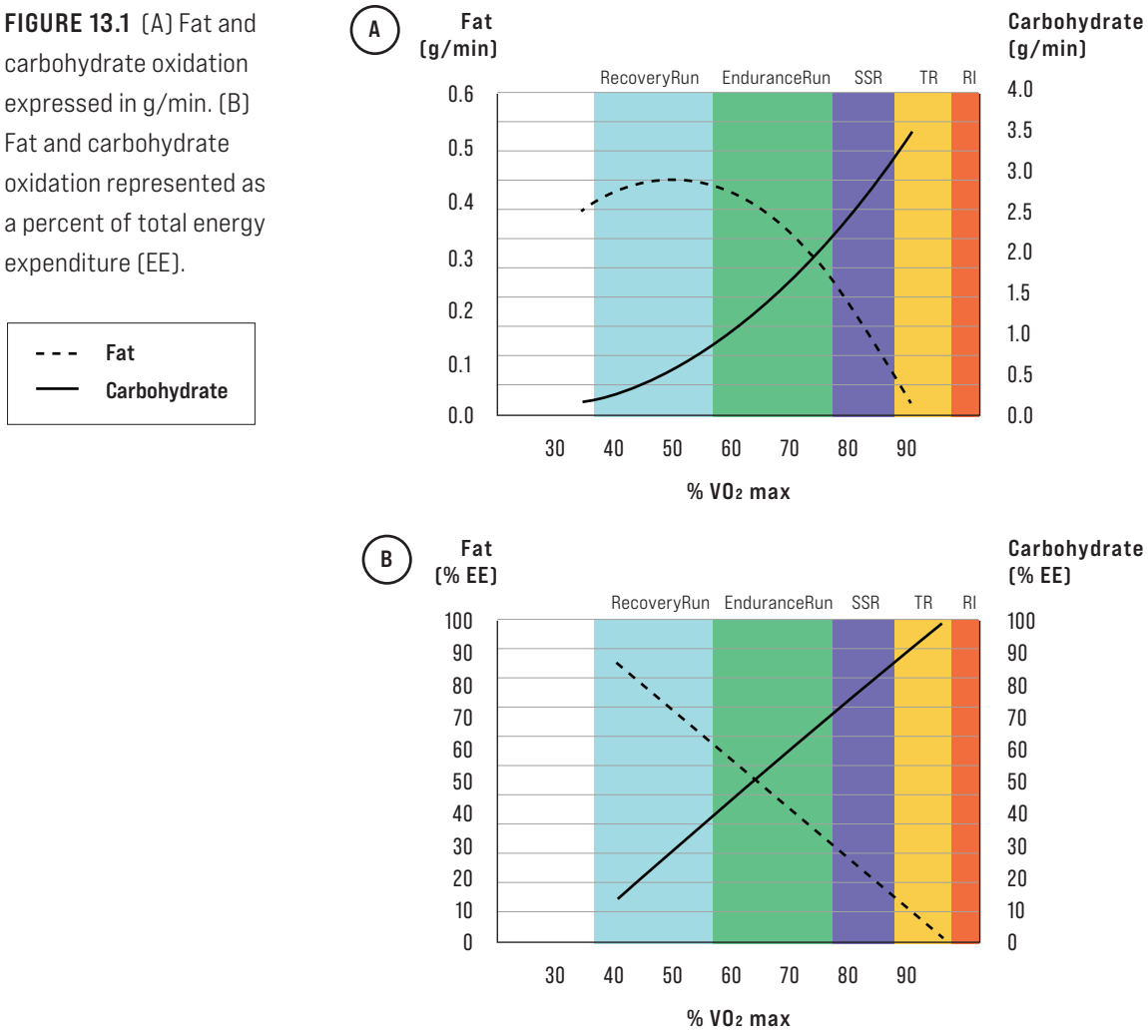


FIGURE 13.1 (A) Fat and carbohydrate oxidation expressed in g/min. (B) Fat and carbohydrate oxidation represented as a percent of total energy expenditure (EE).

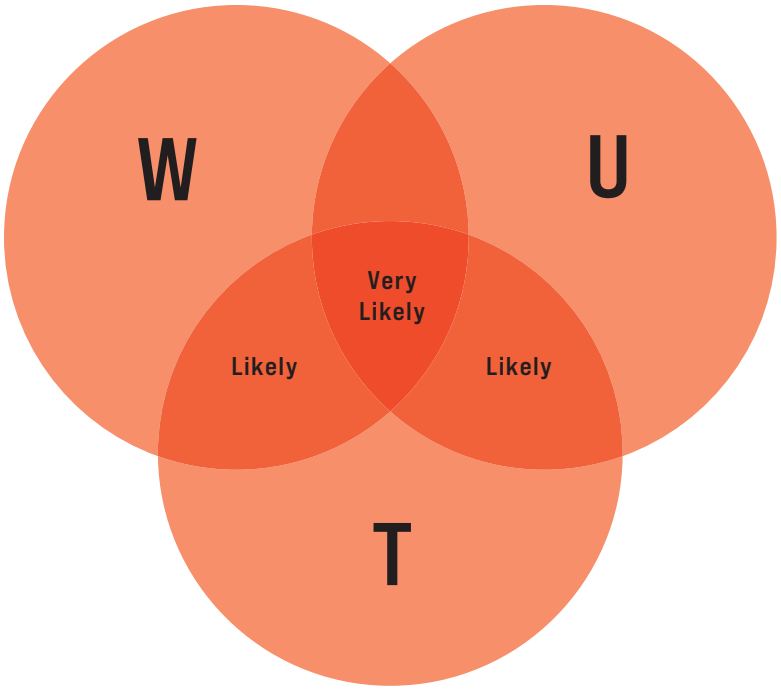


FIGURE 13.2 The WUT diagram helps you monitor your daily hydration status and the likelihood of dehydration. A change in two of the three areas—weight (W), urine color (U), and thirst (T)—indicates that you are likely dehydrated. A change in all three indicates that you are very likely to be dehydrated. Adapted from Cheuvront and Sawka 2005.

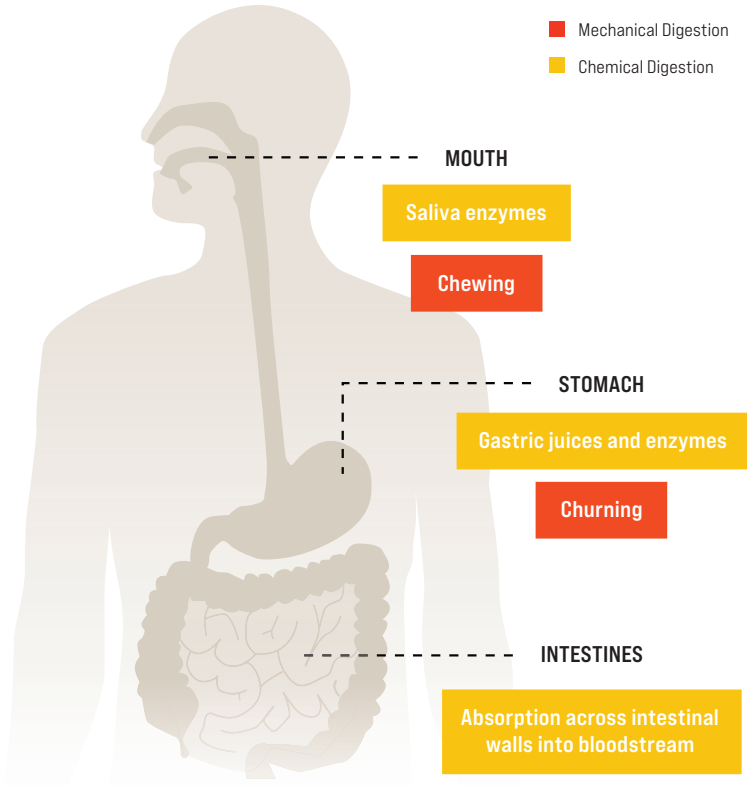


FIGURE 13.3 How and where digestion takes place.

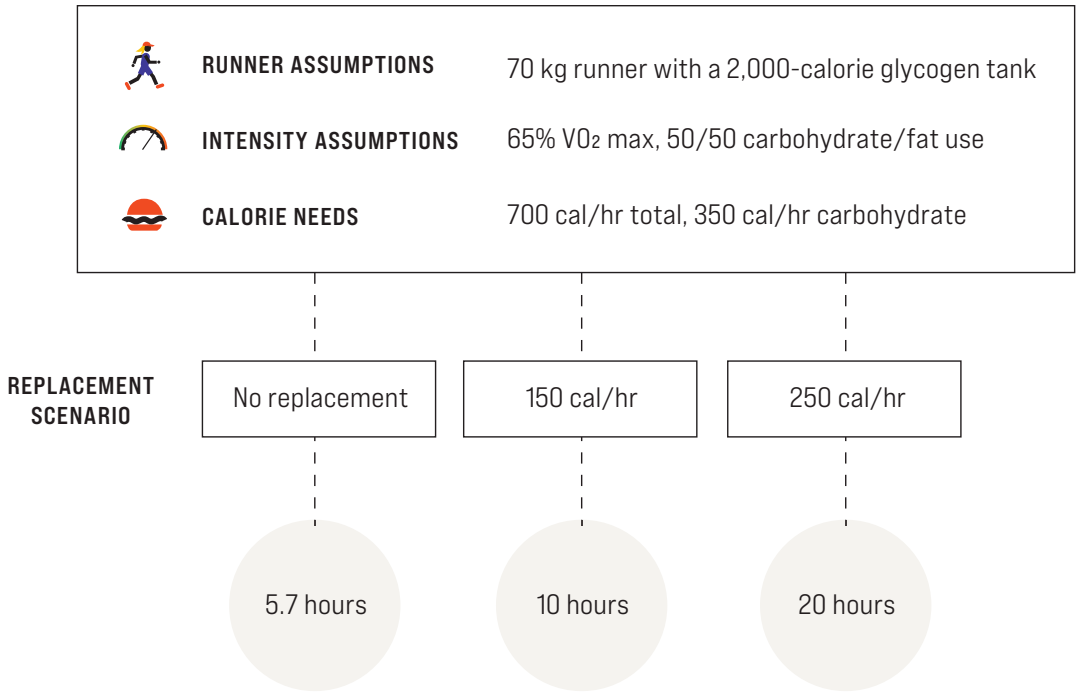


FIGURE 13.4 How long can you run with reasonable assumptions about intensity and caloric replacement?

1	Weigh yourself nude right before a run.
2	Go do a one-hour run at EnduranceRun intensity.
3	After the run, strip down, wipe down any sweat, and weigh yourself nude again.
4	Subtract your end weight from your beginning weight. Convert the weight to ounces (one pound equals 16 ounces). This is your hourly sweat rate in those specific conditions.
5	Aim to replace ~95–98% **(not 100%)** of those fluids during a race for those conditions. Why not 100%? Because in an ultra, weight loss from water stored in fat and carbohydrate are significant and does not need to be replaced. We don't quite know exactly how much fluid needs to be replaced, we just know it's not 100% as some of the fluid loss stems from metabolic processes not related to hydration status. Replacing 100% of the sweat loss in an ultra can lead to hyponatremia, or low blood sodium.
6	Repeat the test in different conditions. I recommend using steps of 10 degrees Fahrenheit.

FIGURE 13.5 The Sweat Test.

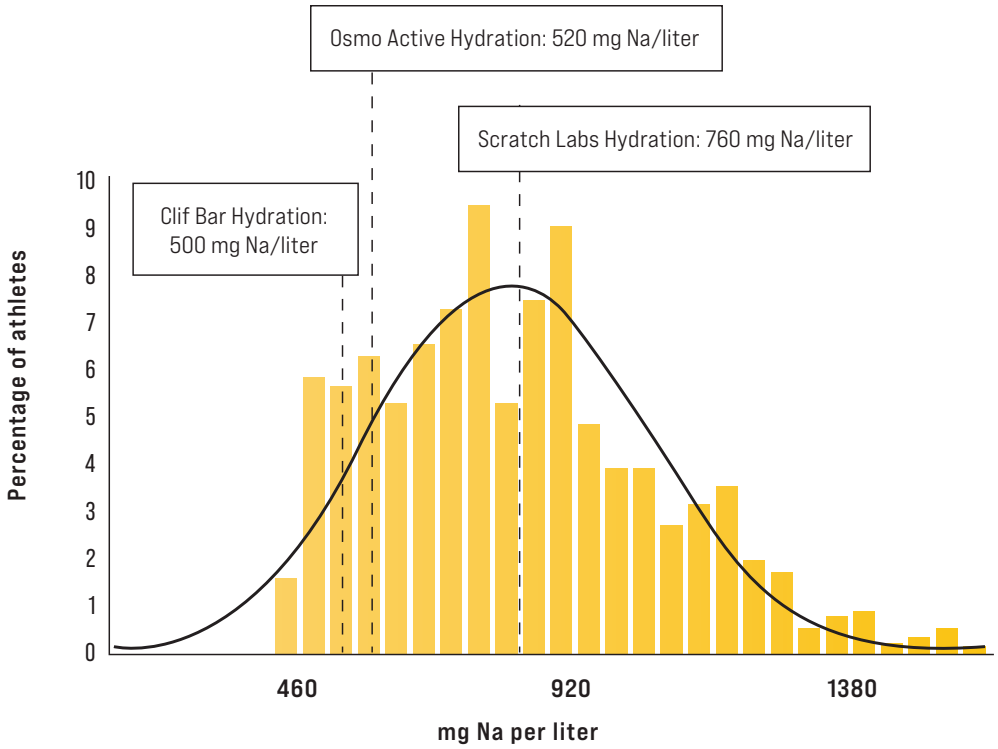


FIGURE 13.6 Typical sweat sodium concentrations. Adapted from Baker 2017.

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CARBOHYDRATE RECOMMENDATIONS	Upwards of 90 g/hr (2:1 glucose to fructose) although such a high level likely unnecessary
FLUID RECOMMENDATIONS	Provided sufficient fluids/volumes are available, "drink to thirst," “ad libitum"
SODIUM RECOMMENDATIONS	Avoid excessive sodium supplementation during running. Consume sodium based on food cravings. Do not use highly visible salt losses as a signal for increasing sodium intake.
OTHER RECOMMENDATIONS	Use trial and error with foods/fluid quality/quantity to determine what is optimal. Try to simulate race day (and thus know what foods are available at race) by eating similar foods/fluids and in similar quantities in training that you will use in race. Use "B" or "C" races to determine how other contributing factors (travel, weather, pacing, competition, stress, changes in normal food availability) influence optimal nutritional strategy. Consume slightly more early (first 2 hrs) as GI symptoms tend to develop later. In longer (greater than 8 hrs) races, avoid excess protein, fat, fiber, or FODMAP-heavy foods; can mouth rinse with carbohydrate beverage in longer events when consuming enough becomes an issue.

TILLER ET AL. 2019

CARBOHYDRATE RECOMMENDATIONS	30–50 g/hr
FLUID RECOMMENDATIONS	450–750 ml/hr (by drinking every 20 min), greater in hot and humid conditions
SODIUM RECOMMENDATIONS	> 575 mg/L
OTHER RECOMMENDATIONS	In training: Individualized, periodized, food-first approach. Moderate-to-high carbohydrate diet (~ 60% of energy intake, 5–8 g/kg/d) to limit chronic glycogen depletion. Limit carbohydrate before occasional easy sessions and/or moderating daily carbohydrate intake, which may enhance fat oxidative capacity. This may compromise high-intensity efforts. Also, if doing this, implement with sufficient time to permit adaptations that enhance fat oxidative capacity. Protein intakes of ~ 1.6 g/kg/d up to 2.5 g/kg/d may be warranted during demanding training. In racing: 5–10 g/hr of protein. Eat (carbohydrate and protein) from variety of sources, more savory foods in longer races. Use progressive gut training and/or low-FODMAP diets to minimize GI distress. Ketogenic diets and/or ketone esters to improve ultramarathon performance are not currently evidence based, but further research needed. Strategically use caffeine in latter stages, particularly with sleep deprivation.

TABLE 13.1 Nutrition recommendations for ultrarunning in scientific literature.

ACSM (AMERICAN COLLEGE OF SPORTS MEDICINE) POSITION STATEMENT 2016	
CARBOHYDRATE RECOMMENDATIONS	Up to 90 g/hr while exercising (ultra specific), 6–10 g/kg/d (for endurance athletes, not ultra specific)
FLUID RECOMMENDATIONS	Drink 5–10 ml/kg in the 2-4 hrs before exercise (pale yellow urine color). Drink enough during to limit day's weight loss to < 2% of body weight. Drink 1.25–1.5 L for every kg of weight lost after; none of these are specific for ultra-endurance.
SODIUM RECOMMENDATIONS	Keep blood sodium above 135 mmol/L; doesn't say how to achieve it, nor is it ultra specific
OTHER RECOMMENDATIONS	Nitrates improve exercise tolerance, economy, and performance in at least non-elite athletes.

TABLE 13.1 Nutrition recommendations for ultrarunning in scientific literature.

	INVENTORY	FLUID	CALORIES	SODIUM
HOUR 1	1 BoBo Bar (peanut butter)	16 oz water	330 cal	95 mg Na
HOUR 2	1 GU (vanilla bean)	16 oz Skratch Hydration	180 cal	440 mg Na
HOUR 3	1 Clif Bar (blueberry crisp)	16 oz Skratch Hydration	340 cal	560 mg Na
HOUR 4	1 Clif Shot (razz)	16 oz Skratch Hydration	180 cal	475 mg Na
TOTAL		64 oz	1030 cal	1570 mg Na
TARGET		16-32 oz / hour	200-300 cal/hour (MINUS FIRST HOUR)	600-800 mg/ 32oz fluid
GRADE		A B C D F	A B C D F	A B C D F

Overall Grade: A

FIGURE 13.7 A nutrition report card.

BODY WEIGHT (KG)	3-4 HOURS PRIOR	2-3 HOURS PRIOR	1-2 HOURS PRIOR	0-60 MINUTES PRIOR
	1.5-2.0 g/kg	1.0-1.5 g/kg	0.5-1.0 g/kg	0.25-0.5 g/kg
55 (121 lb.)	83-110	55-83	28-55	14-28
60 (132 lb.)	90-120	60-90	30-60	15-30
65 (143 lb.)	98-130	65-98	33-65	16-33
70 (154 lb.)	105-140	70-105	35-70	18-35
75 (165 lb.)	113-150	75-113	38-75	19-38
80 (176 lb.)	120-160	80-120	40-80	20-40
85 (187 lb.)	128-170	85-128	43-85	21-43

TABLE 13.2 Carbohydrate recommendations prior to exercise.

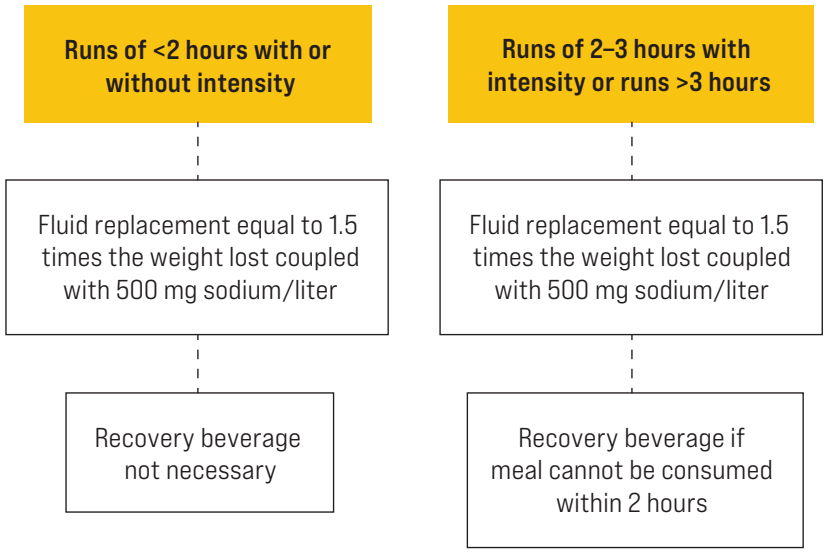


FIGURE 13.8
When a recovery drink is useful.

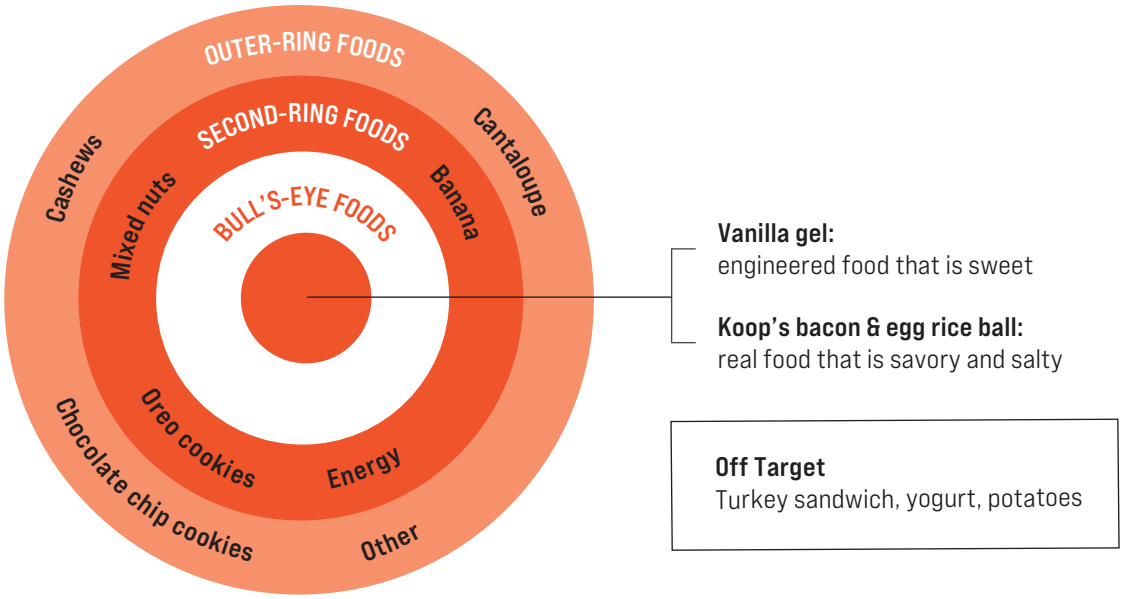


FIGURE 14.1 A sample bull's-eye nutrition strategy.

DIETARY STRATEGY	CARBOHYDRATE CONTENT
Very low-carbohydrate ketogenic diet	<50g carbohydrate/day
Low-carbohydrate diet	15–30% of calories from carbohydrate
High-carbohydrate diet	60–65% of calories from carbohydrate
Consensus from International Society of Sports Nutrition	60% of calories from carbohydrate

TABLE 14.1 Carbohydrate content of different dietary strategies. Adapted from Burke 2020; Tiller et al. 2019; Wylie-Rosette 2016.

DIETARY STRATEGY	ADVANTAGES	DISADVANTAGES
Low-carbohydrate high-fat or Ketogenic (defined by less than 50g CHO/day)	Increased fat oxidation, sparing endogenous glucose Lower need for exogenous carbohydrates during activity Decreased body fat percentage	Inability to train and race at higher intensities Less efficient at transporting carbohydrates across gut membrane Increase risk of bone-stress injuries from hormonal changes affecting bone remodeling Restricted sources of food, specifically fruits and vegetables Can lead to low energy availability
High-carbohydrate low-fat	Consistently high training quality Trains the gut to facilitate more glucose absorption	Possible overreliance on carbohydrate as a fuel source
Periodized carbohydrates	Matches training intensity/duration to substrate needs Enhanced fat oxidation due to cellular changes in the muscle No diminished training quality	Logistically difficult to implement

TABLE 14.2 Advantages and disadvantages of dietary strategies to manipulate substrate utilization. Adapted from Burke 2020; Tiller et al. 2019; Wylie-Rosette 2016.

TRAINING STRATEGY	STEP 1	STEP 2	STEP 3	STEP 4
Two-a-day	Running interval session	Restrict carbohydrate immediately post run	Second session of 1.5–2-hour EnduranceRun performed without fuel	Refuel with carbohydrate post run
Fasted run	Overnight fast	EnduranceRun of 1.5–2-hour upon waking. Performed without fuel	Refuel with carbohydrate post run	

TABLE 14.3 Training strategies to enhance fat oxidation.

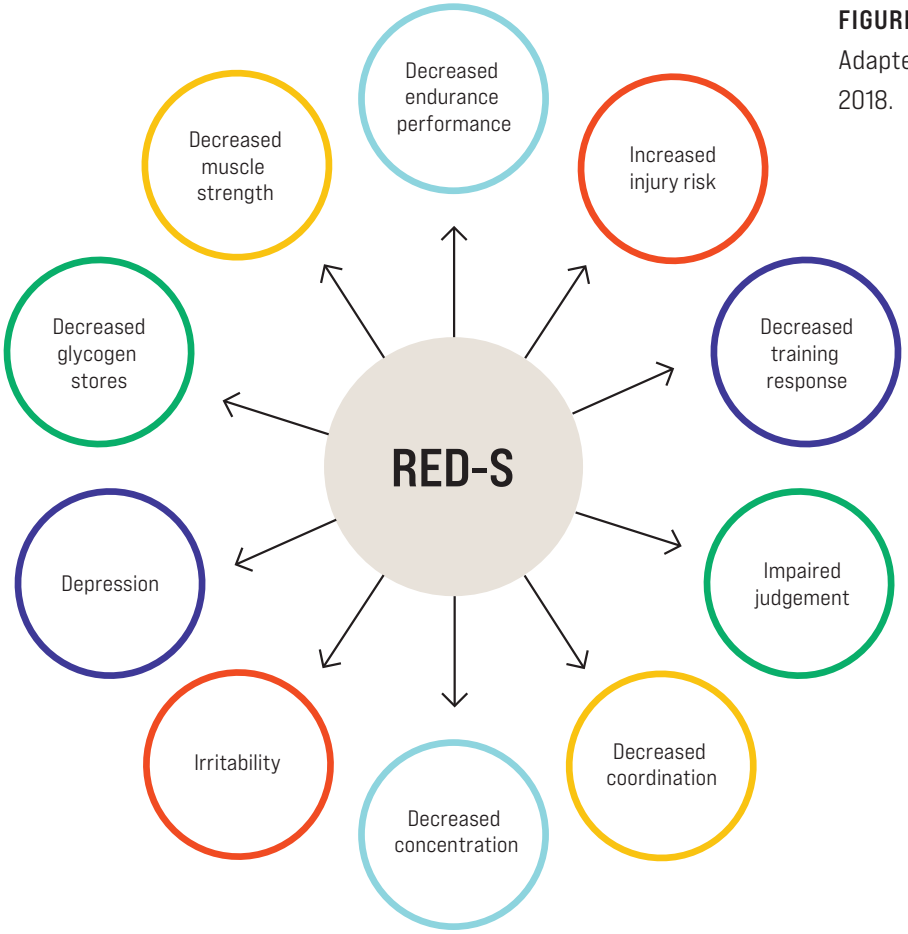


FIGURE 14.2 Effects of RED-S. Adapted from Mountjoy et al. 2018.

Hydration State			Natremic States: Low	Natremic States: Normal	Natremic States: High
			Hyponatremic	**Normonatremic**	**Hypernatremic**
Low	**Dehydrated**		Dehydrated and hyponatremic	Dehydrated and normonatremic	Dehydrated and hypernatremic
Normal	**Euhydrated**		Euhydrated and hyponatremic	Euhydrated and normonatremic	Euhydrated and hypernatremic
High	**Overhydrated**		Overhydrated and hyponatremic	Overhydrated and normonatremic	Overhydrated and hypernatremic

TABLE 14.4 How hydration and natremic states converge.

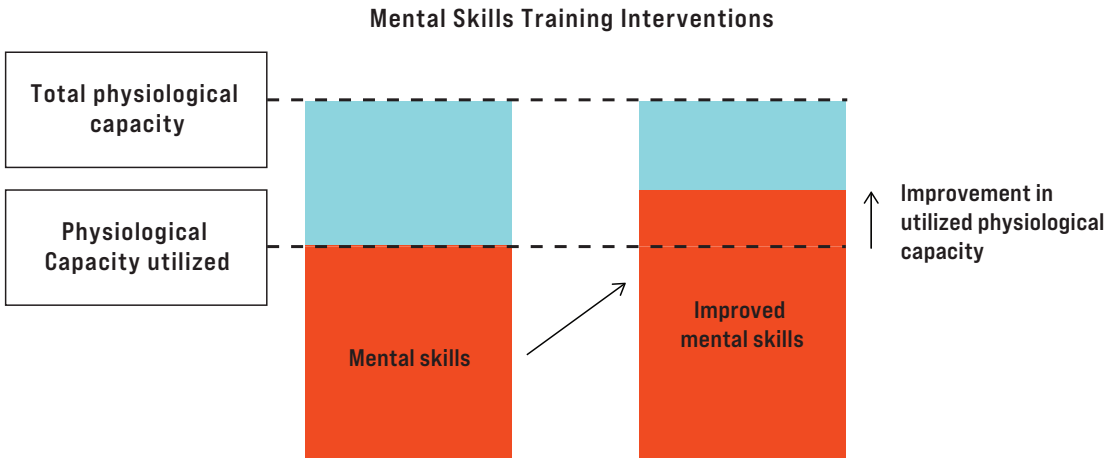


FIGURE 15.1 How improved mental skills can help you utilize more of your total physiological capacity.

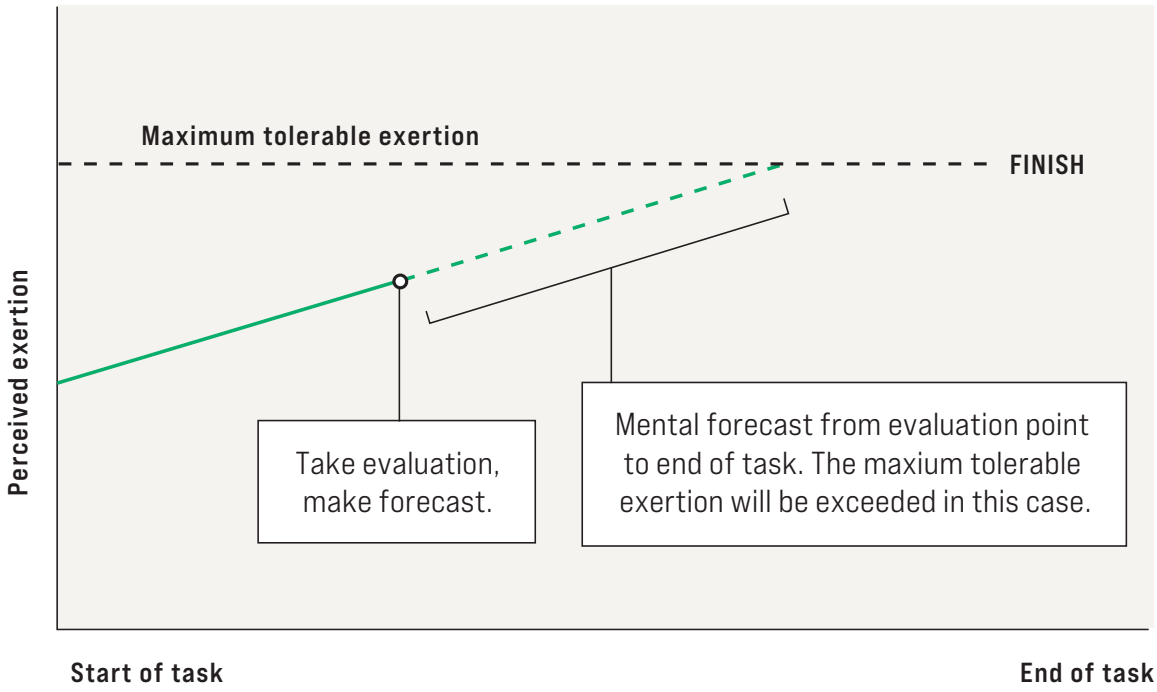


FIGURE 15.2 Schematic of the perceived end point interaction.

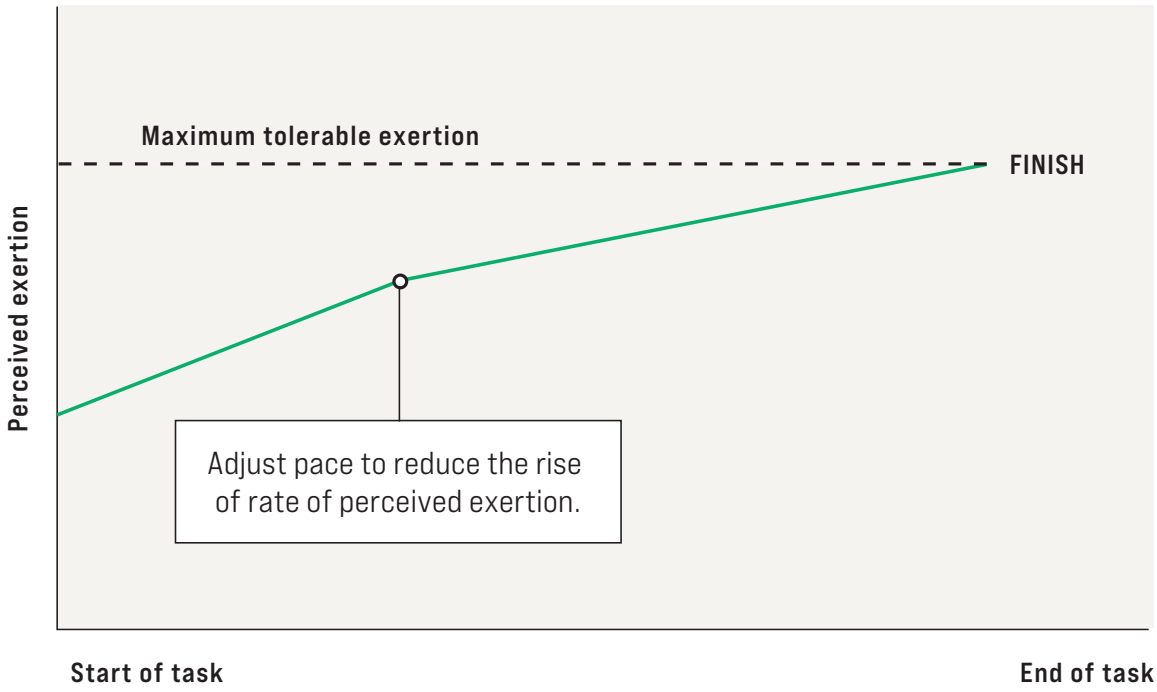


FIGURE 15.3 How an athlete adjusts pacing due to perceived end point interactions.

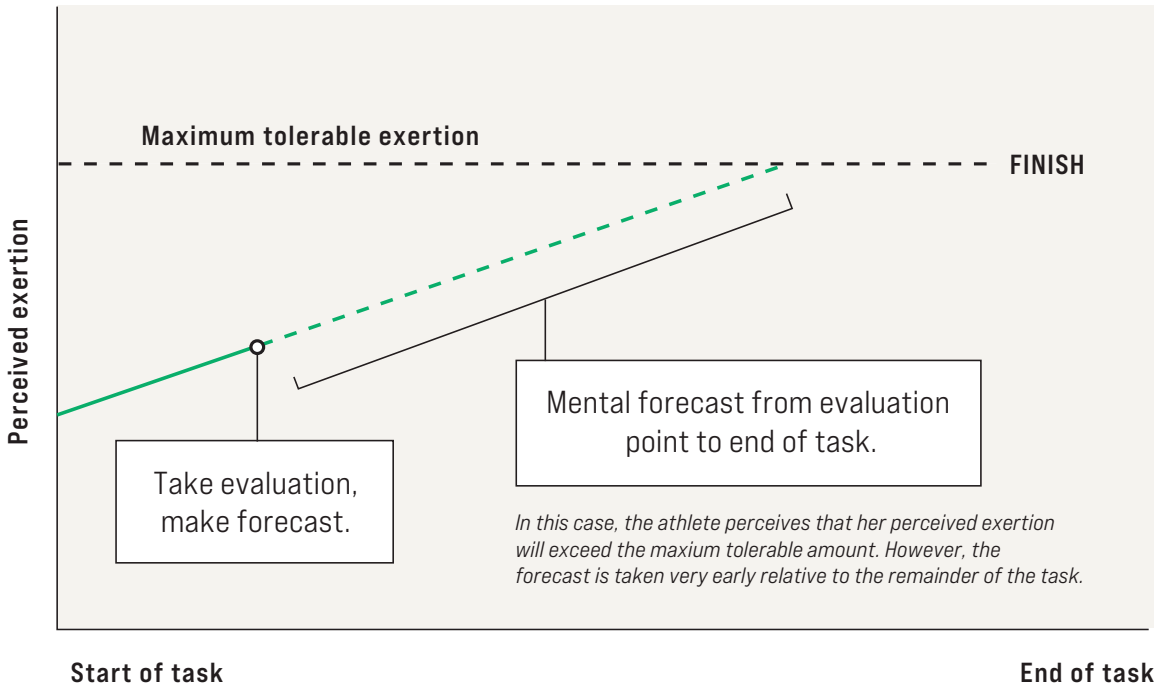


FIGURE 15.4 How an athlete can go awry with an early perceived end point interaction forecast.

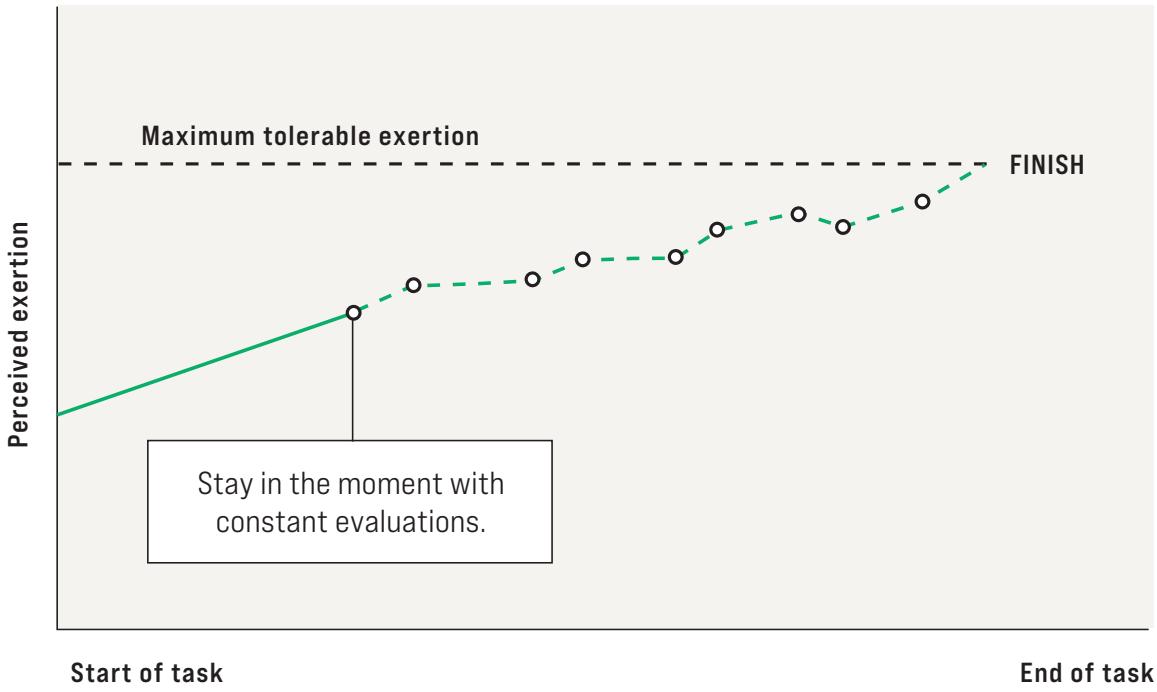


FIGURE 15.5 How staying in the moment avoids inaccurate forecasting.

THINGS TO BE MINDFUL OF	THINGS THAT WILL DISTRACT YOU
Rate of perceived exertion	Looking at the pace on your watch
Internal confidence	Where you are compared to others
Taking things one mile at a time	Calculating the distance to the next aid station

TABLE 15.1 An example inventory of attentional cues to be mindful of and what thoughts can be distractive.

At home, imagery of training situations	During training, imagery of simple race situations	At home, imagery of complex race situations	During training, imagery of complex race situations
Effort of intervals, running smooth, etc.	*Running up a climb*	*Solving puking, blisters, and falling behind your pace*	*Solving puking, blisters, and falling behind your pace*

FIGURE 15.6 Sequence of imagery exercises.

IDENTIFY WHAT YOU WANT TO ACHIEVE	MATCH SELF-TALK
Keep pushing when the race gets hard	"You've trained hard enough," "You've got this"
Run your own race	"Relax, focus on your effort"
Maximize effort during a training session	"Keep pushing, almost there"
Pole-strike effectively	"Plant your pole firmly, follow all the way through"

TABLE 15.2 Matching self-talk strategies to what you want to achieve.

FIGURE 15.7 Step one in finding your why.

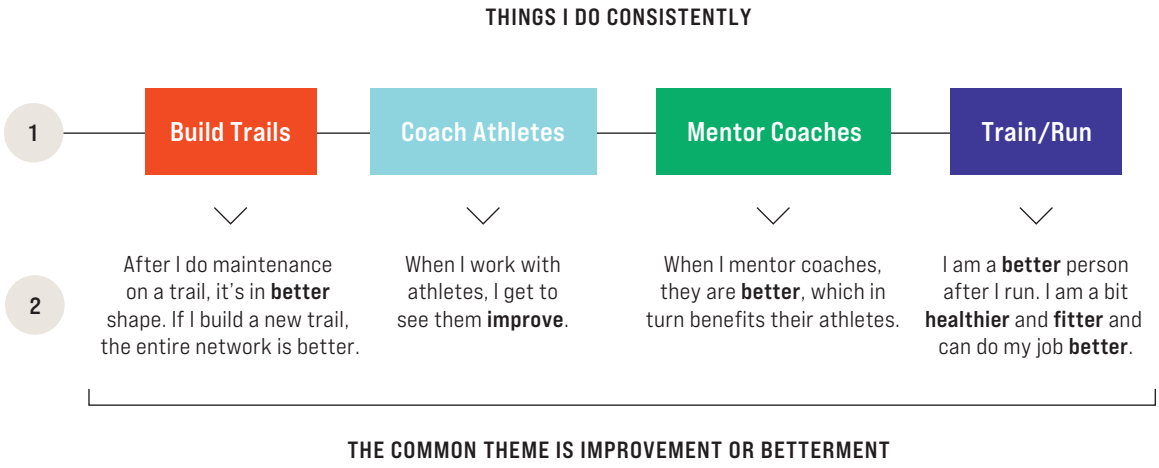


FIGURE 15.8 Step two in finding your why.

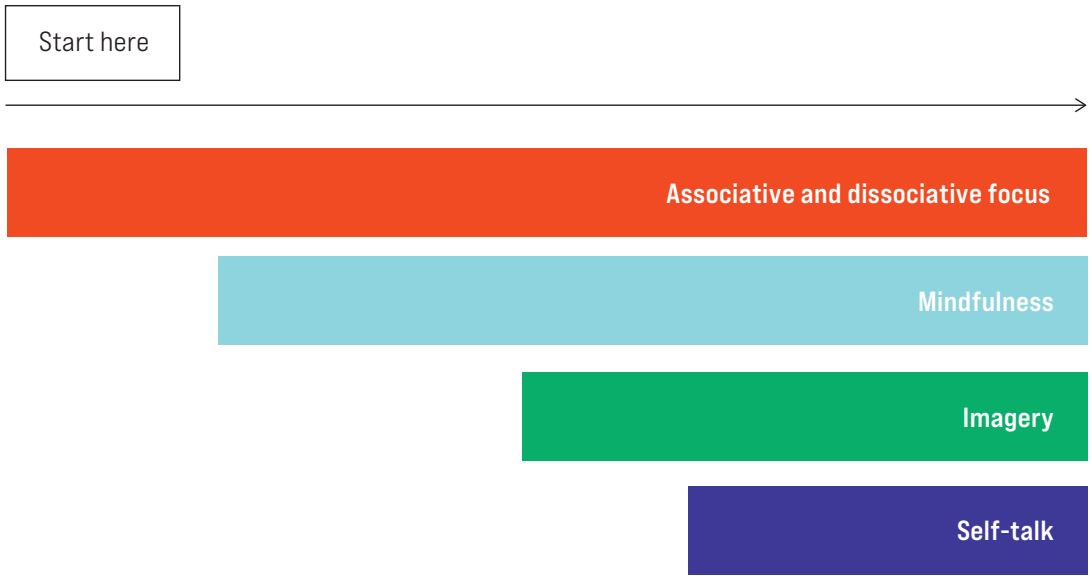


FIGURE 15.9 Where to start and how to incorporate mental skills.

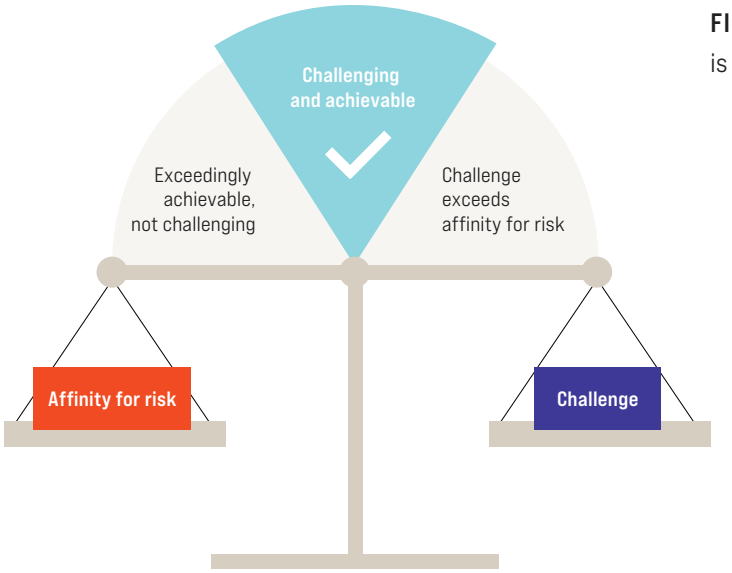


FIGURE 16.1 A goal where the challenge is balanced with the affinity for risk.

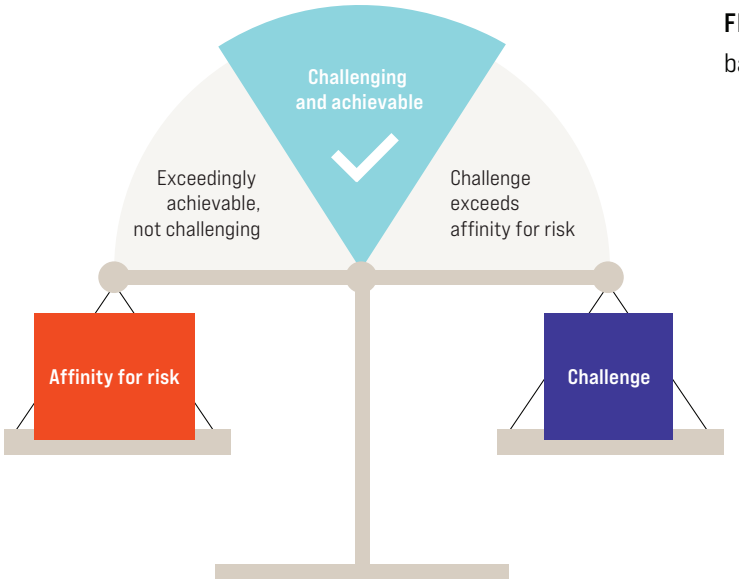


FIGURE 16.2 A bigger challenge that is balanced with a larger affinity for risk.

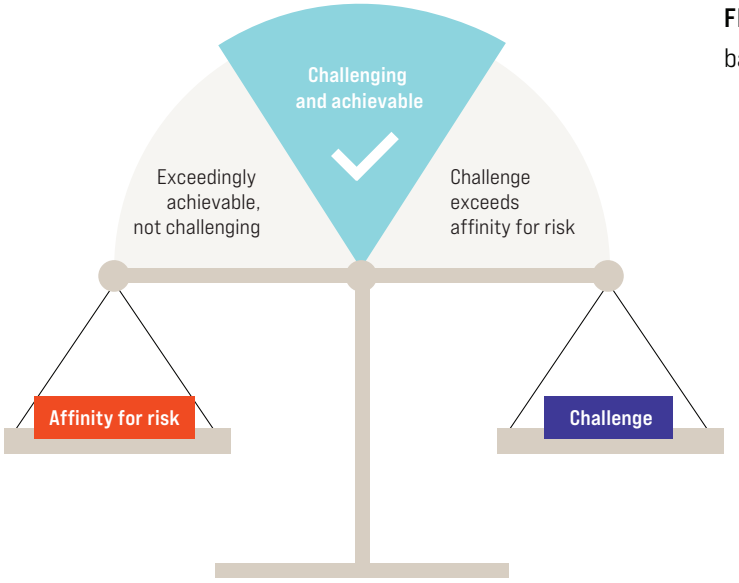


FIGURE 16.3 An easier challenge that is balanced with a smaller affinity for risk.

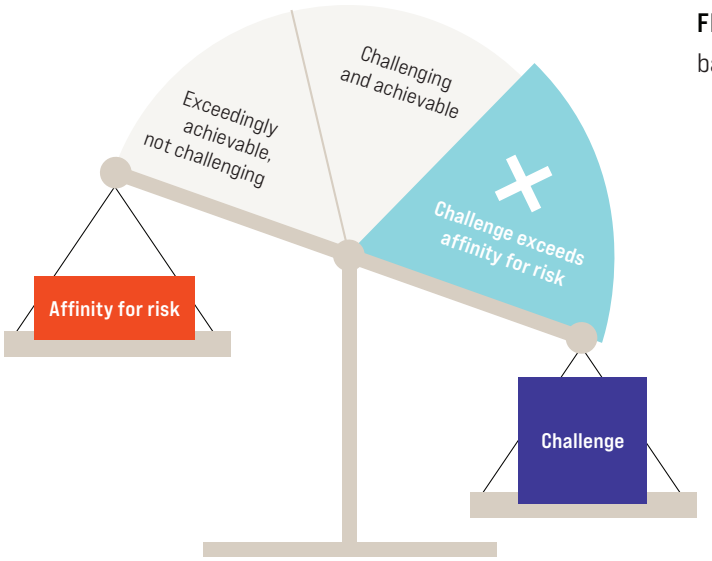


FIGURE 16.4 A bigger challenge that is not balanced with a larger affinity for risk.

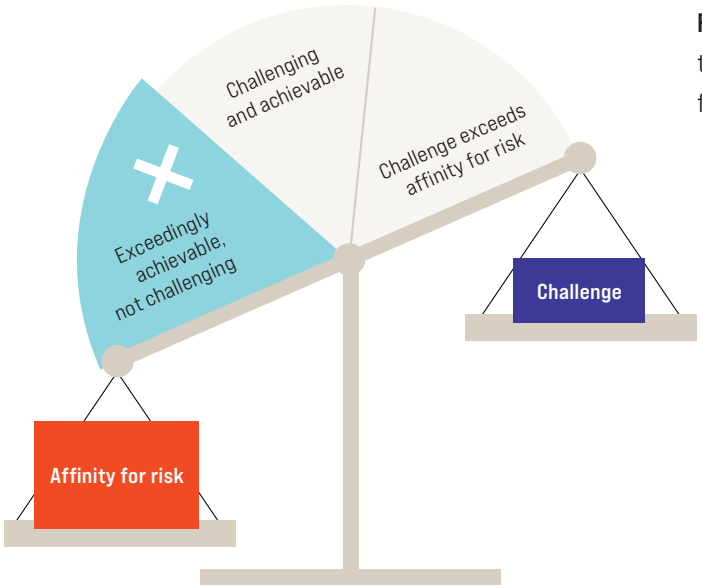


FIGURE 16.5 An easy challenge that is thrown out of balance with a large affinity for risk.

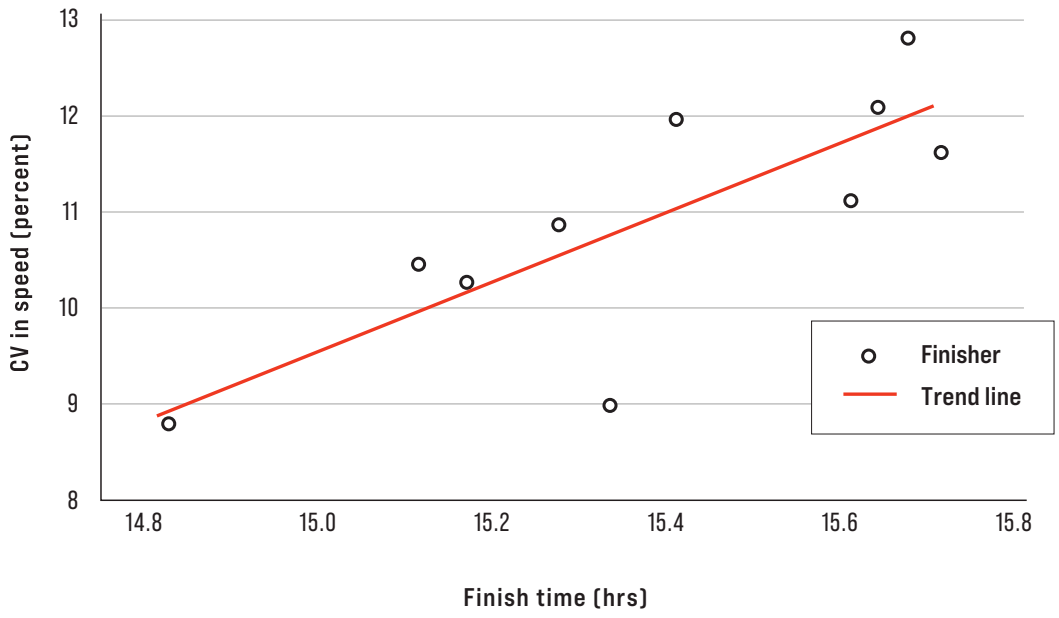


FIGURE 16.6 Relationship between coefficient of variation (CV) in speed and finish time for the ten fastest finishers of the Western States 100. The fastest finishers had the lowest variation in speed. Source: Hoffman 2014.

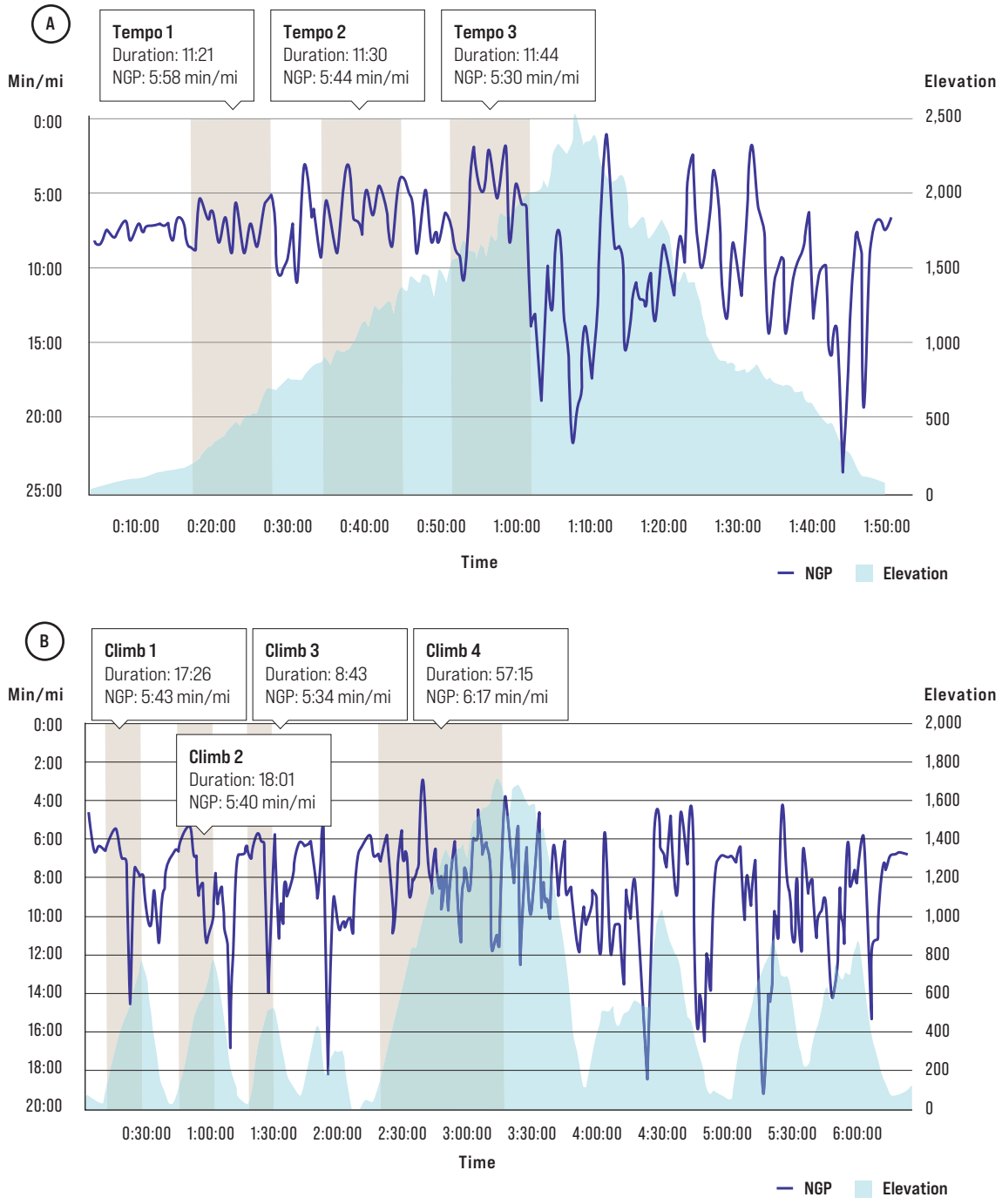


FIGURE 16.7 Comparison of Tempo intervals done in (A) in training to (B) the climbs in a race.

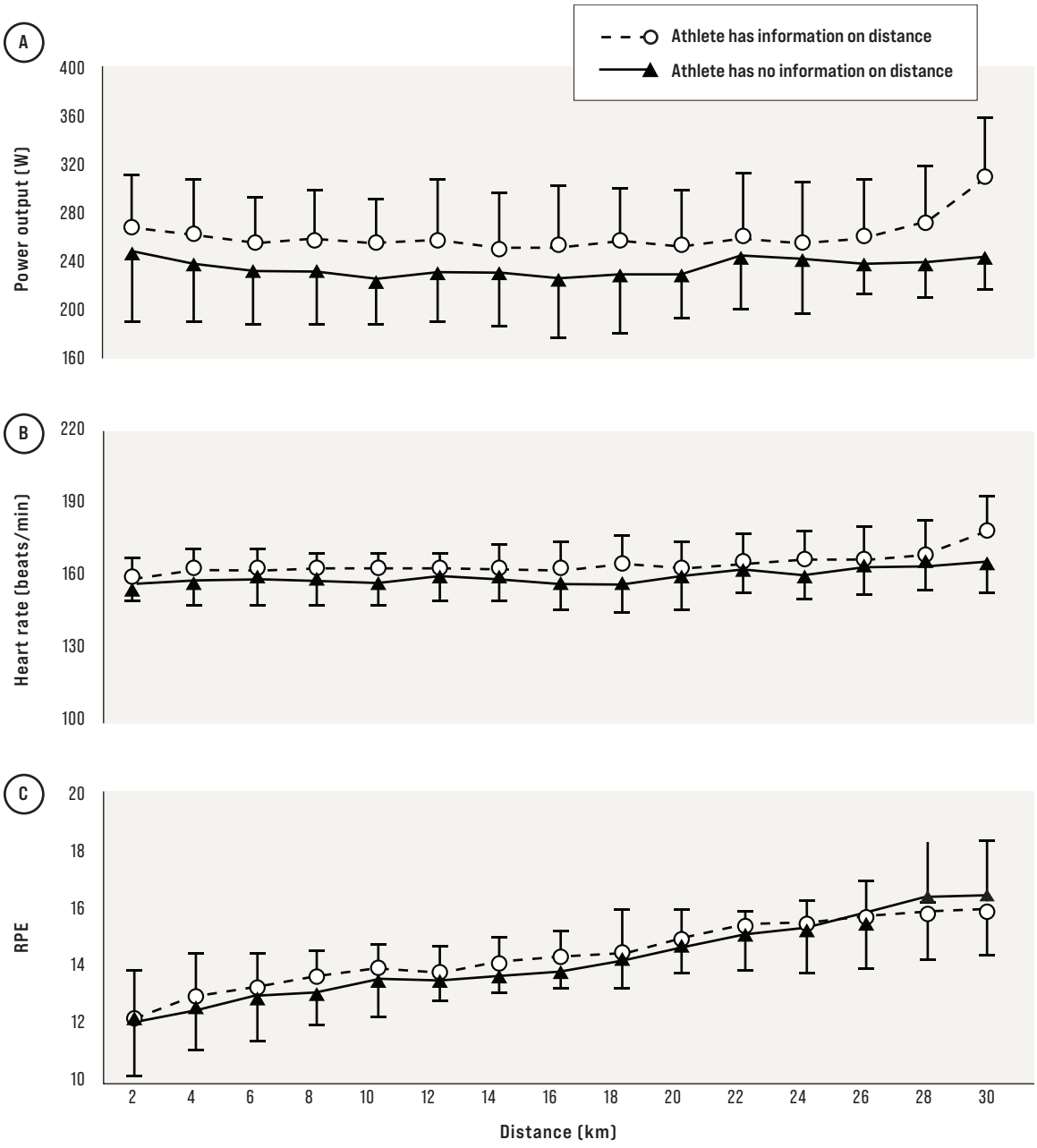


FIGURE 16.8 A 30K cycling time trial done with information on distance and without. Source: Wingfield 2018.

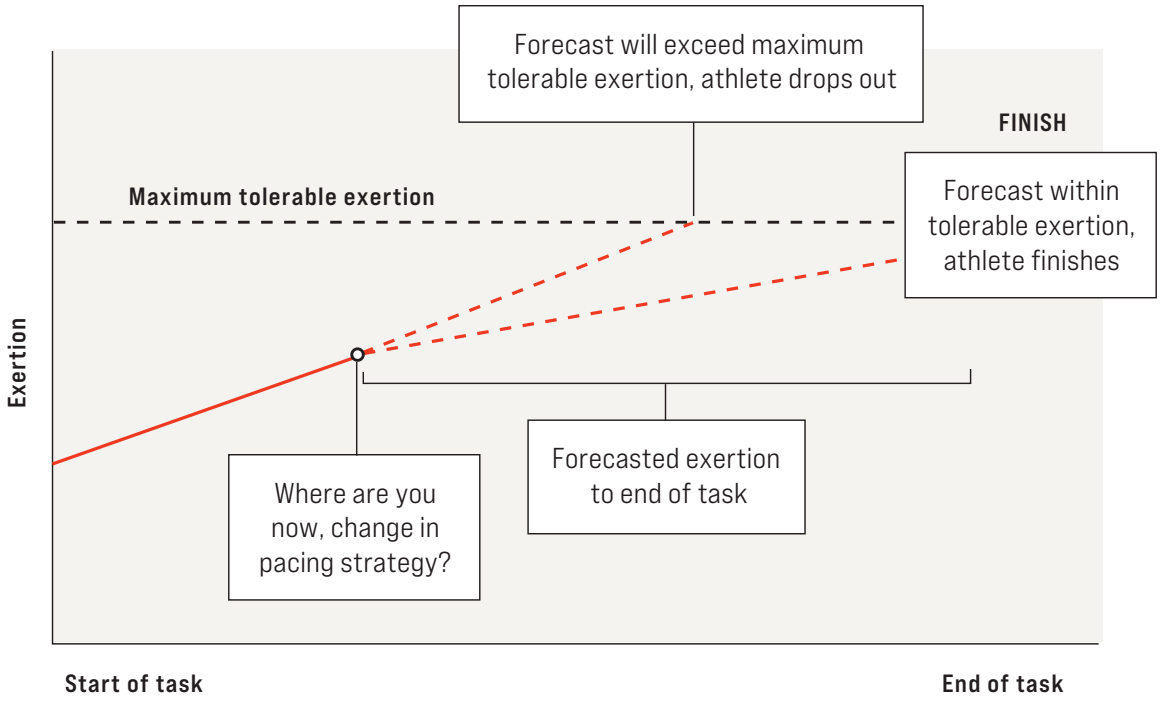


FIGURE 16.9 Perceived exertion end point interaction.

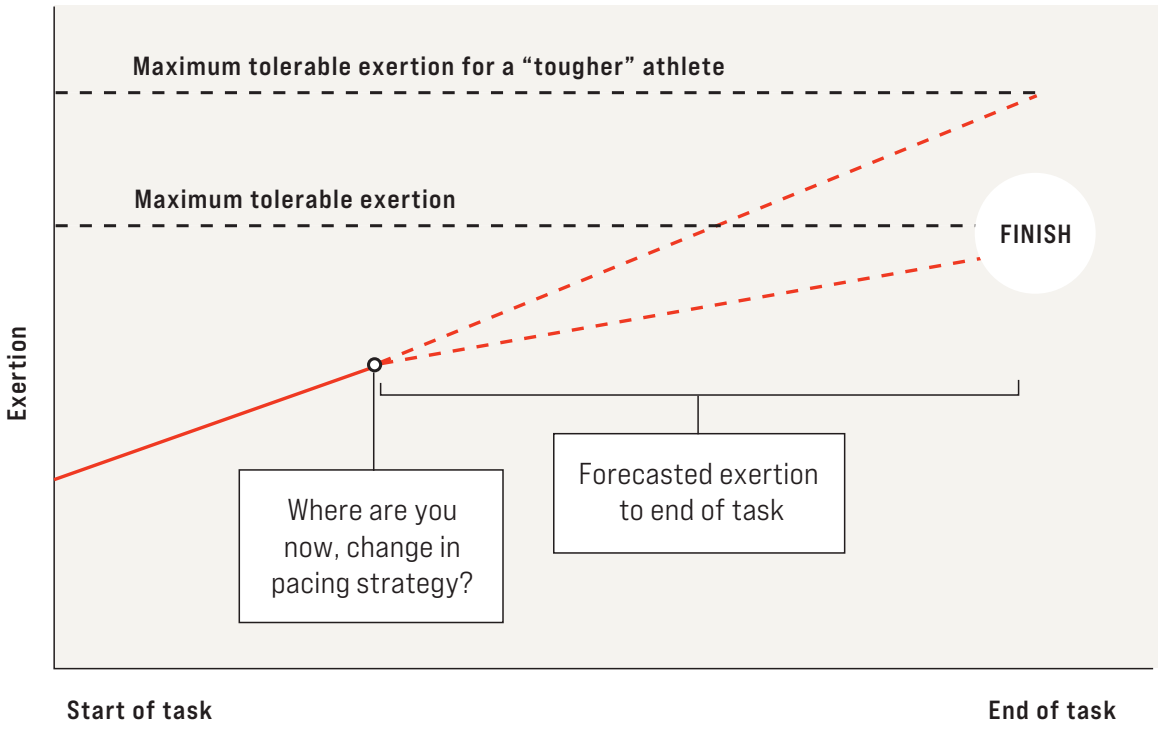


FIGURE 16.10 How a “tougher” athlete fares better.

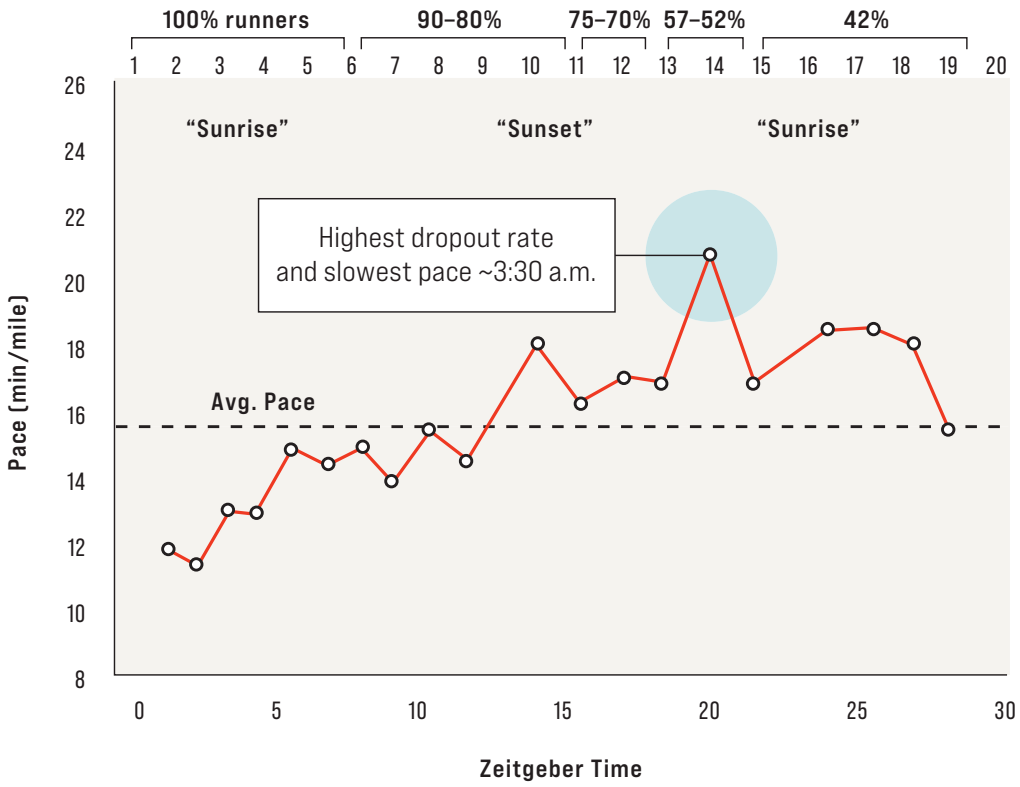


FIGURE 16.11 When athletes drop out in a 100-mile race. Source: Brager et al. 2020.

RACE SECTION	FOOD	FLUID	SUPPLEMENTS
Start to aid station 1	2 gels	1 drink mix in bottle 1	1 salt tab
		1 drink mix in bottle 2	1 amino acid capsule
Aid station 1 to aid station 2	2 gels	Water in bottle 1	1 salt tab
	1 energy bar	1 electrolyte tablet in bottle 2	
		Coke in aid station	
Aid station 2 to aid station 3	1 pack energy chews	½ drink mix, ½ scoop whey protein in bottle 1	2 salt tabs
	½ pack energy chews	Water in bottle 2	
		Ginger ale in aid station	
Aid station 3 to finish	2 gels	½ drink mix, ½ Coke in bottle 1	1 salt tab
	1 pack energy chews	1 electrolyte tablet in bottle 2	1 amino acid capsule

TABLE 16.1 An overcomplicated nutrition plan.

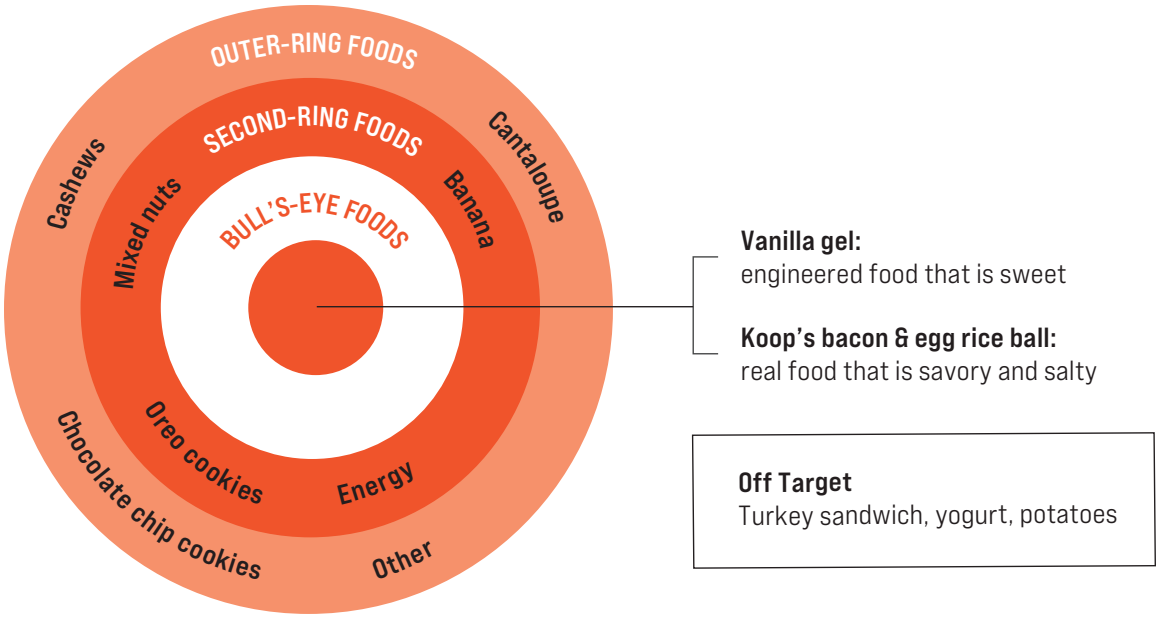


FIGURE 16.12 Example of a bull's-eye nutrition plan.

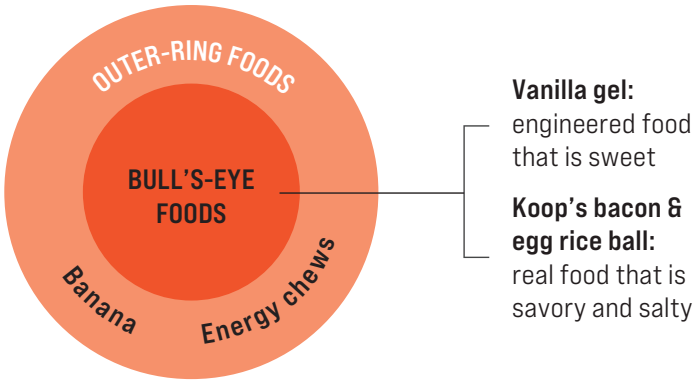


FIGURE 16.13 Target customization for a shorter, more intense ultra.

RACE SECTION	FOOD	FLUID	SUPPLEMENTS
Start to aid station 1 (2 hours)	100 calories total (1 gel)	20-30 oz. total (water)	None
Aid station 1 to aid station 1 (2 hours)	400-500 calories total (gels and prepackaged bar)	30-50 oz. total (water and drink mix)	None
Aid station 2 to aid station 3 (3 hours)	600-750 calories total (rice balls, gels, energy chews)	50-70 oz. total (water and drink mix)	1 salt tab
Aid station 3 to finish (2 hours)	400-500 calories total (gels and prepackaged bar)	~50 oz. total (water and drink mix)	Ginger chews or antacid if necessary

TABLE 16.2 A simplified nutrition plan.

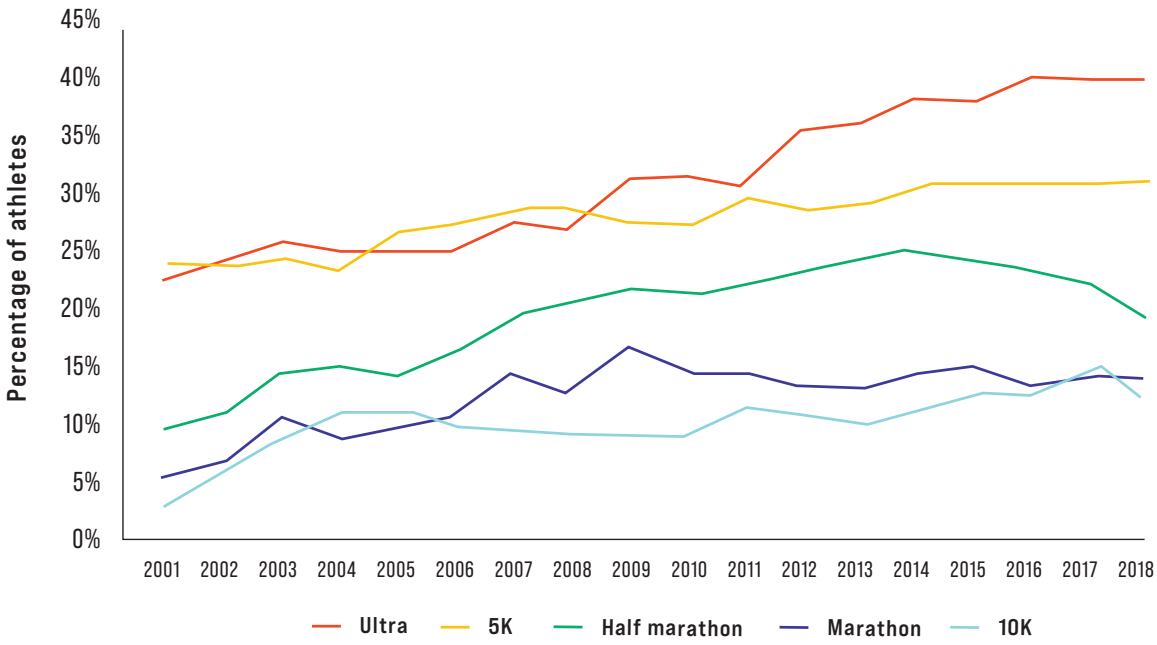
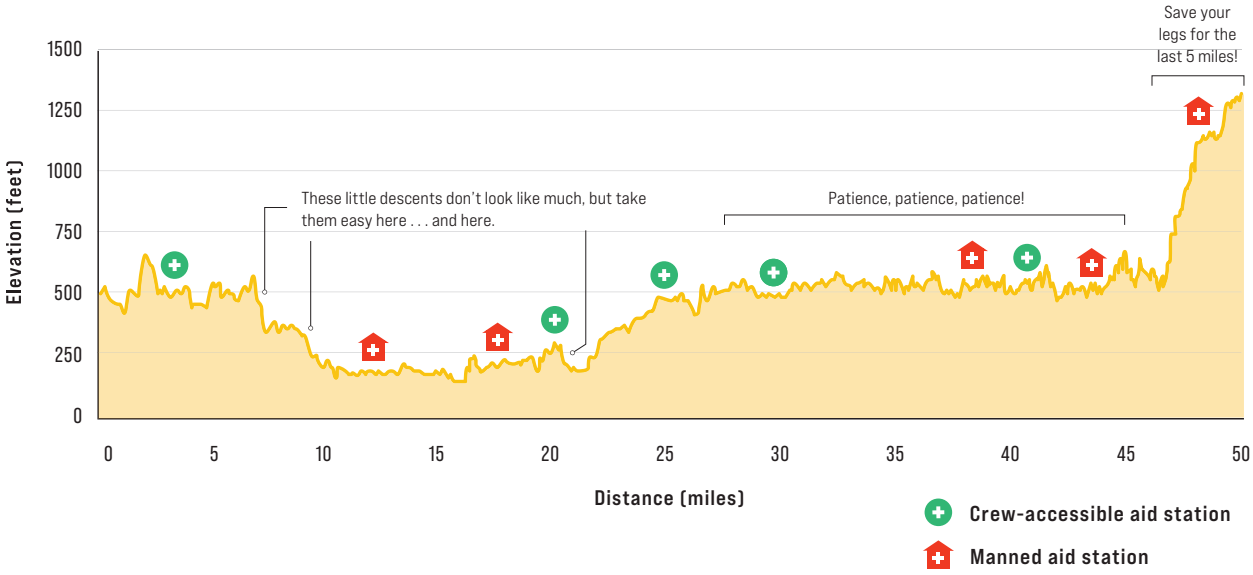
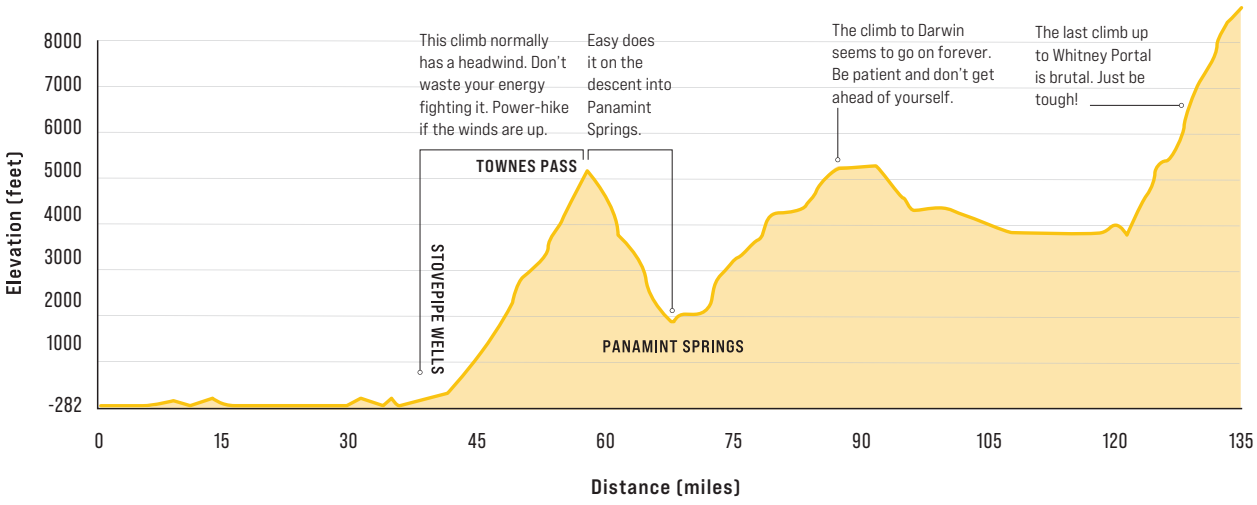


FIGURE 17.1 Percentage of racers competing in multiple races per year. Adapted from Andersen 2020.

AMERICAN RIVER 50

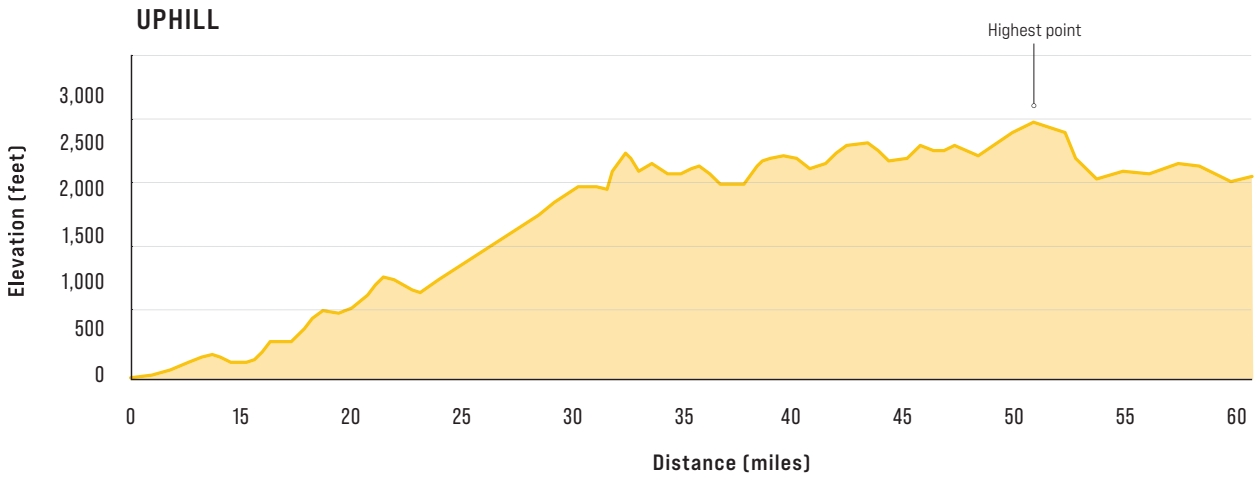


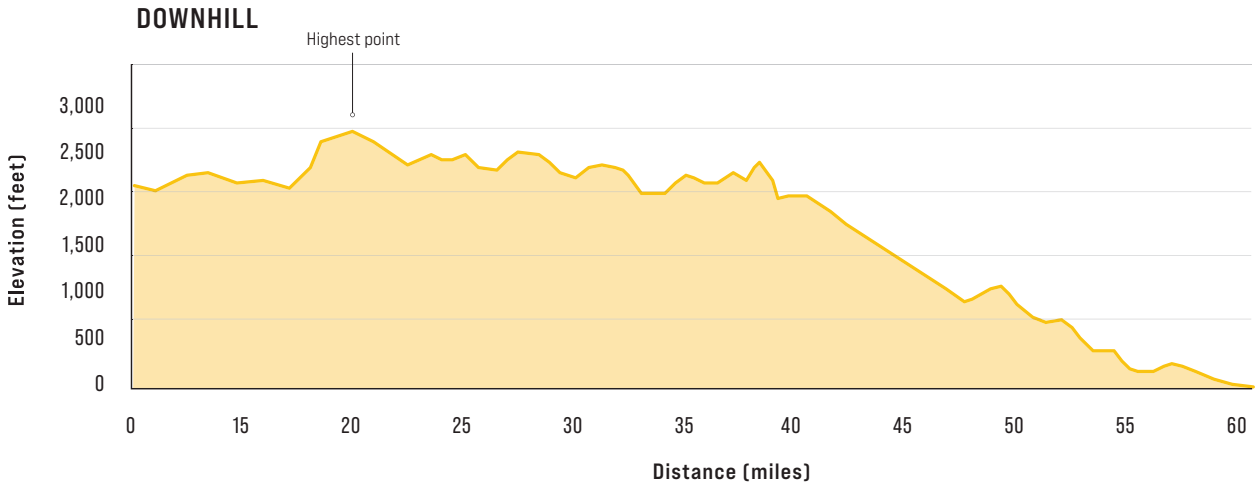
BADWATER 135



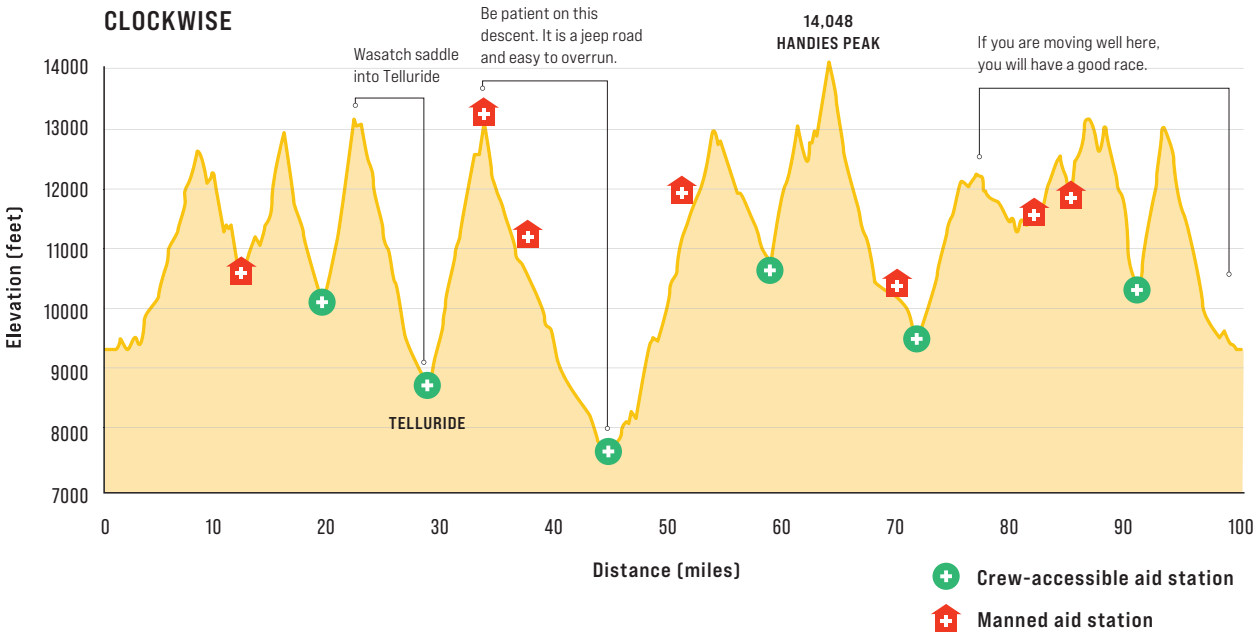
COMRADES MARATHON

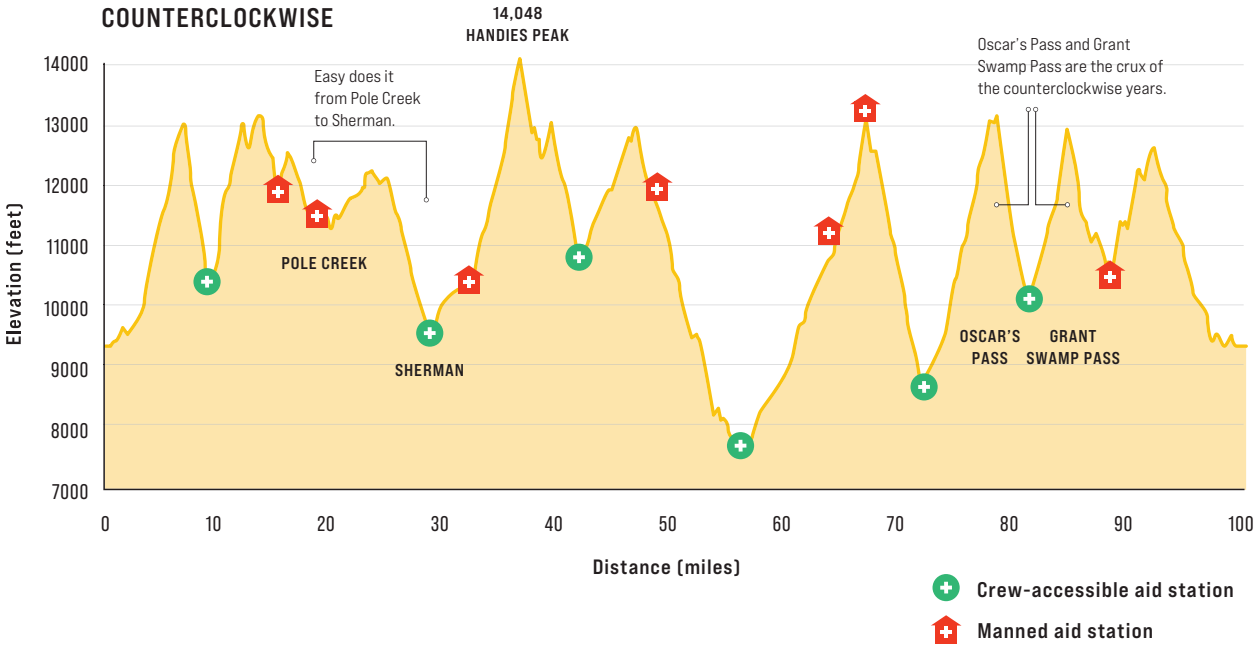
Aid stations are located every 2k of the race (43 in total)





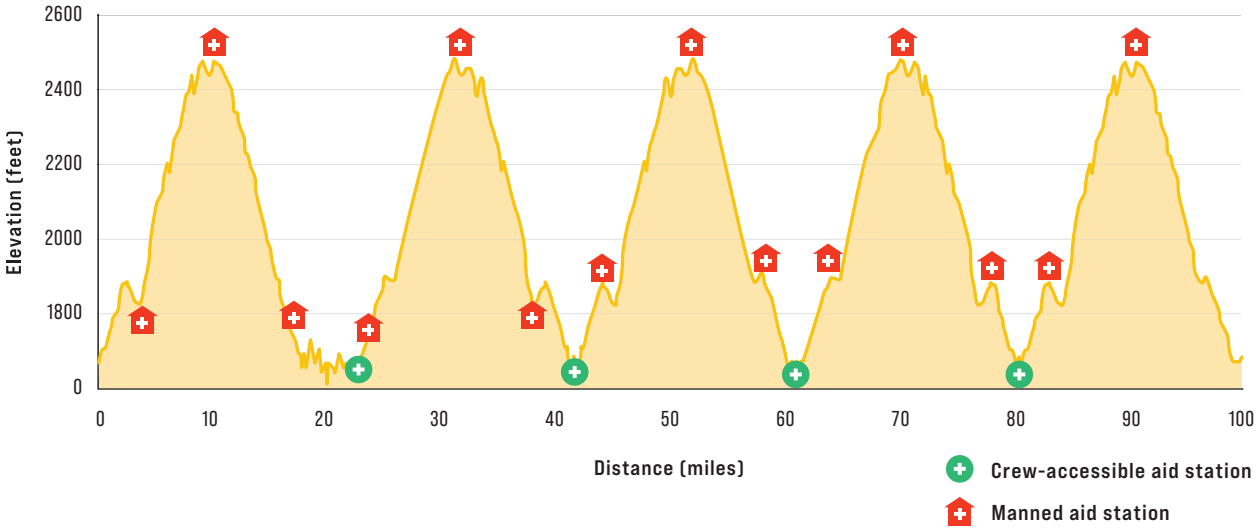
HARDROCK 100



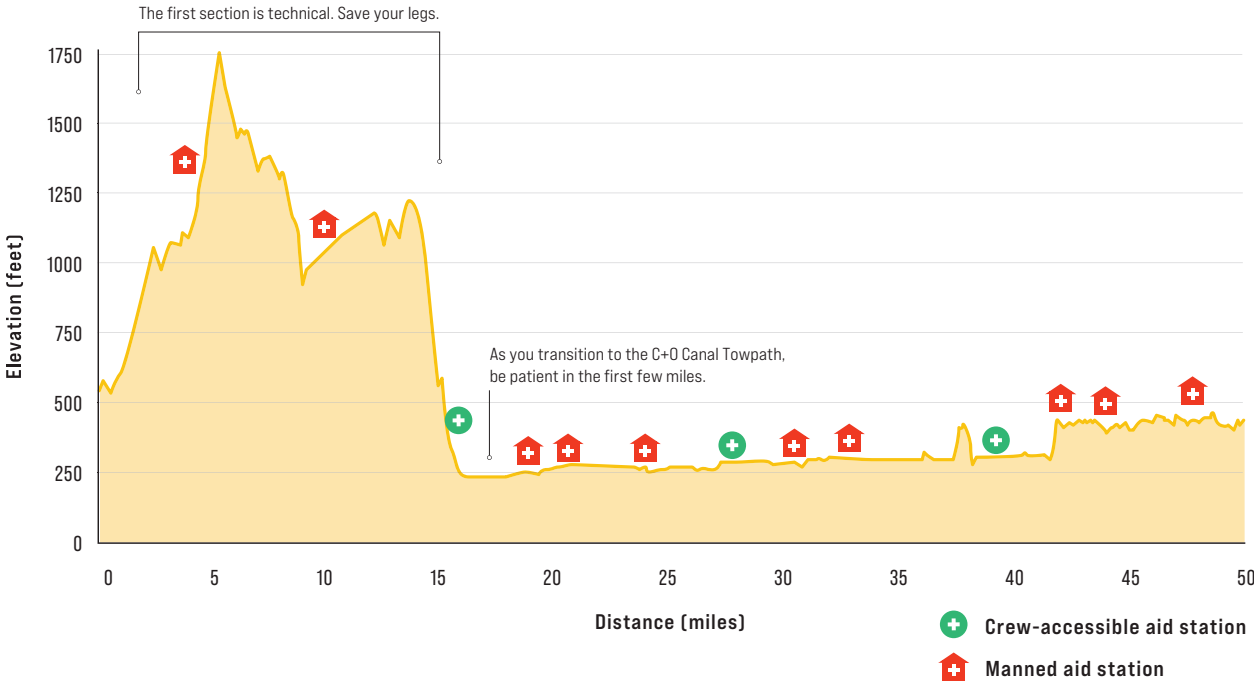


JAVELINA JUNDRED

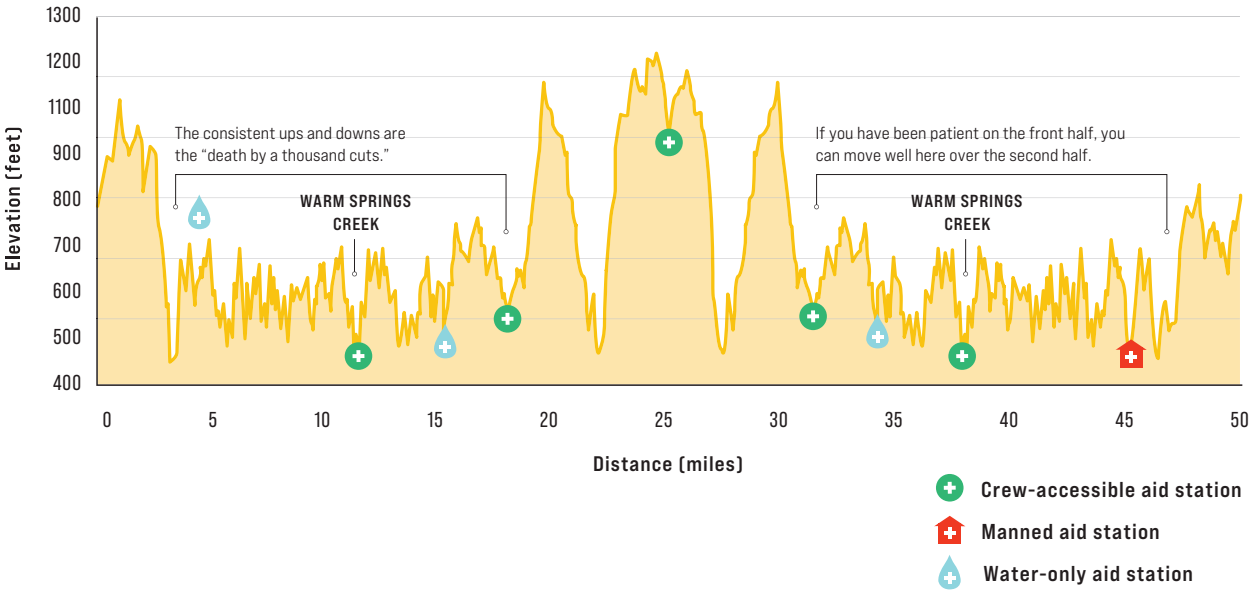
The course features gradual climbs and descents on both sides of the loop. You are constantly climbing and descending, and climbing and descending a gradual grade.



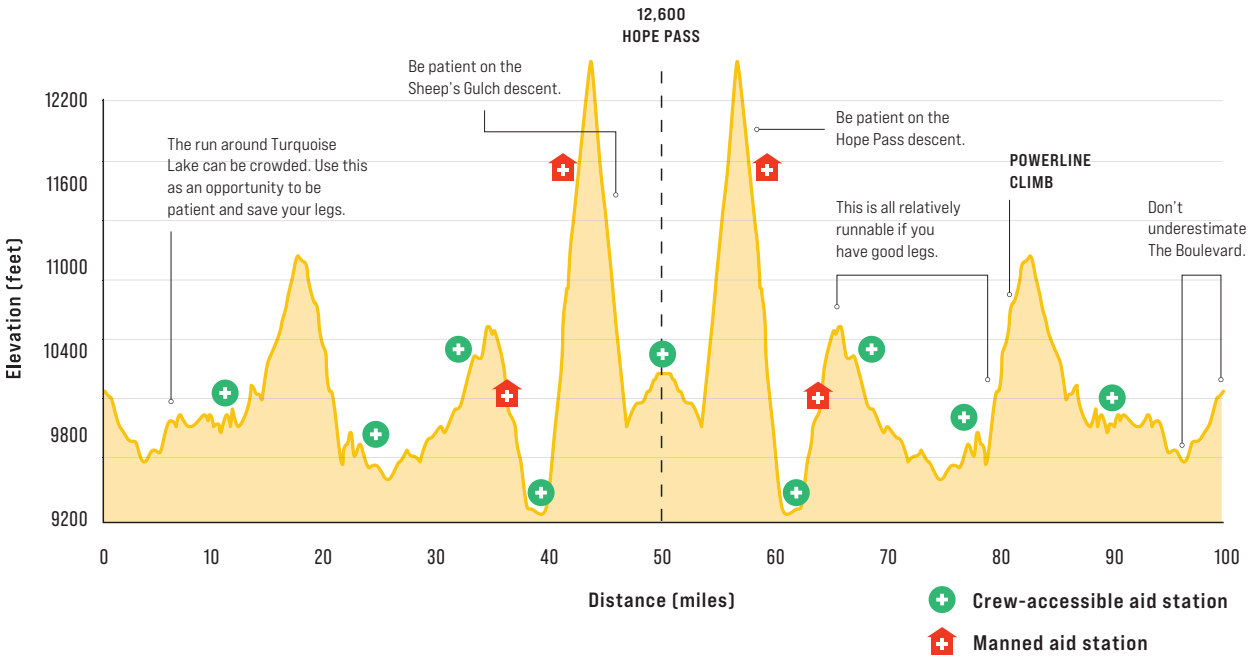
JFK 50


The first section is technical. Save your legs.
As you transition to the C+O Canal Towpath, be patient in the first few miles.
Elevation (feet)
1750
1500
1250
1000
750
500
250
0
0
5
10
15
20
25
30
35
40
45
50
Distance (miles)
Crew-accessible aid station
Manned aid station

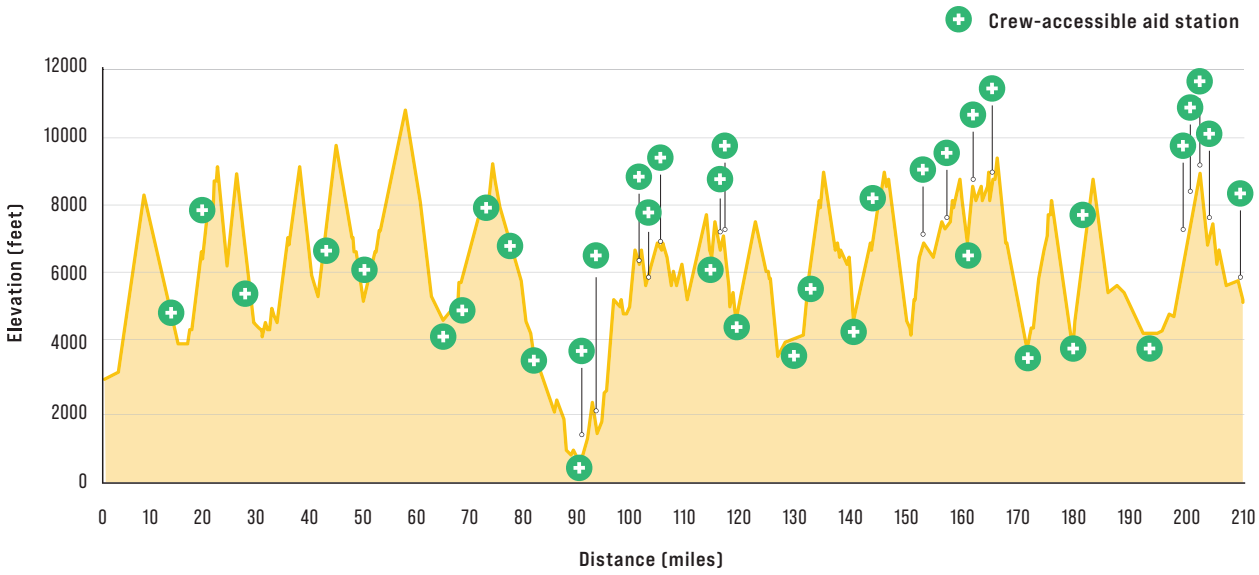
LAKE SONOMA 50



LEADVILLE TRAIL 100

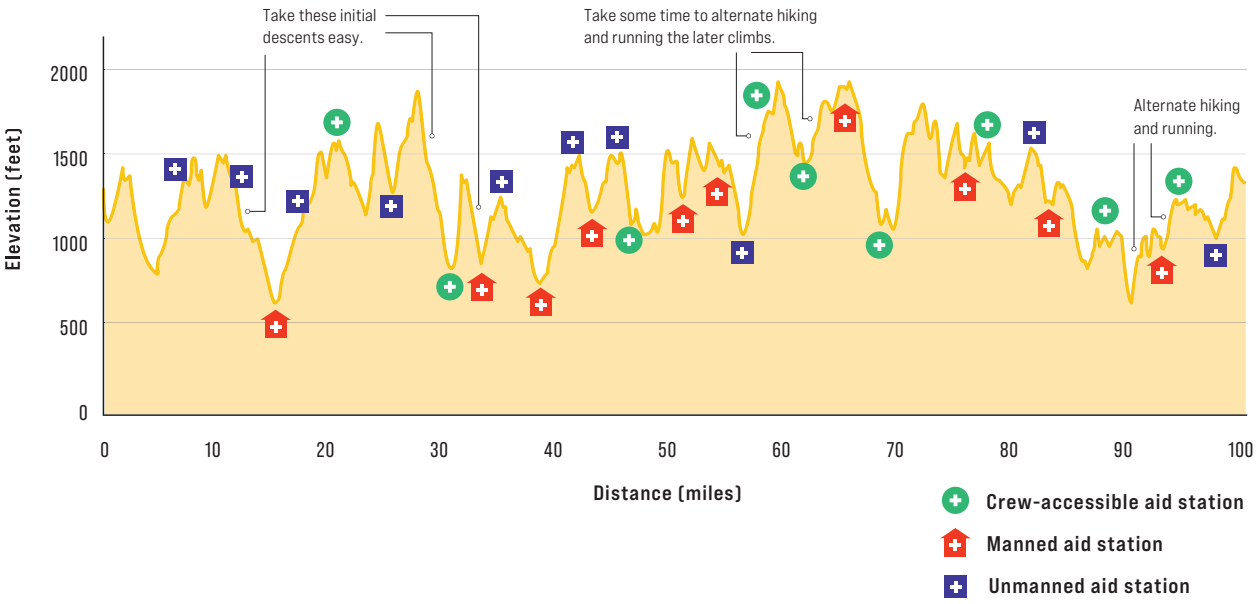


TOR DES GÉANTS

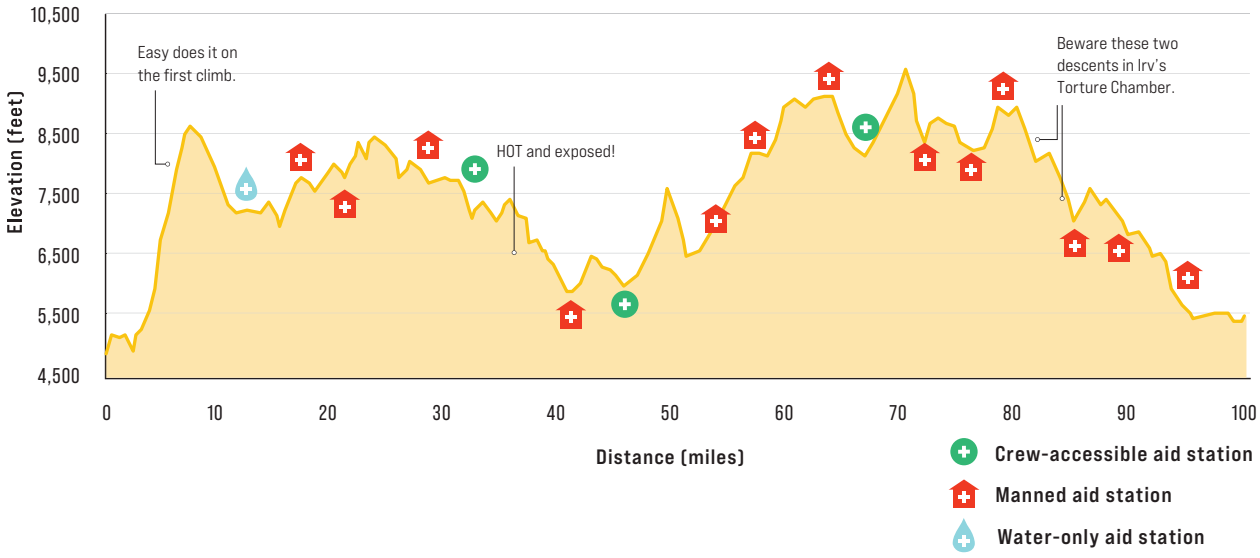



Crew-accessible aid station
Manned aid station
Drinks-only aid station
UTMB
Elevation (feet)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
0
10
20
30
40
50
60
70
80
90
100
Distance (miles)
CCC
Elevation (feet)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
0
5
10
15
20
25
30
35
40
45
50
55
60
Distance (miles)
TDS
Elevation (feet)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
0
10
20
30
40
50
60
70
80
90
100
Distance (miles)

VERMONT 100


Take these initial descents easy.
Take some time to alternate hiking and running the later climbs.
Alternate hiking and running.
Elevation (feet)
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
90
100
Distance (miles)
Crew-accessible aid station
Manned aid station
Unmanned aid station

WASATCH FRONT 100



WESTERN STATES 100