

Integrating perceived exertion and intensity data – a key to optimal training

BY CHARLES HOWE

Somewhat as psychologists do when interpreting behavior, so too can endurance workouts be evaluated using a stimulus-response model, or how hard an effort actually is, as quantified either by speed (for runners and skaters) or a power-measuring system (for cyclists), compared to how hard it feels, as described by the exercising subject according to the 10-point scale of perceived exertion (PE) developed by Gunnar Borg.

This relationship of imposed stress to the physiological strain it incurs can be used to guide training as it unfolds, evaluate it over time, and to plan it in the future.

Heart rate (HR) is frequently used as a proxy for the level of strain experienced by the body, and although HR associates well with both speed and power on a treadmill, ergometer, or most any stationary trainer, it increases, or “drifts” upward as exercise wears on, even under controlled conditions and with a constant load. Outdoors, the correlation is lower, even under the best conditions, and only gets worse as factors such as heat, hydration status, variability in pace and terrain, etc., take effect.

Table 1. 10 point perceived exertion scale.

LEVEL	SENSATION
0	Nothing at all
½	Extremely weak (just noticeable)
1	Very weak
2	Weak (light)
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	
10	Extremely strong
**	Maximal

PE, on the other hand, is the result of eons of human evolution, and reflects more physiological variables than HR, especially the most important among them, namely, blood lactate levels. Developing a sense of PE is therefore a valuable skill for optimizing exercise intensity during moderate-to-high high intensity training. This process is aided by a conscious effort to quantify PE throughout each workout, always in relation to speed or power output, recording it afterward, and then noting feelings of fatigue between workouts. To facilitate this, an expanded scale, referenced to responses in the latter stages of [tempo, lactate threshold, and VO₂max interval workouts](#) is proposed:

Table 2. Functional responses to perceived exertion levels during moderate to high-intensity training.

LEVEL	RESPONSE
4	Workout easily completed. Chosen intensity or duration were either too low (easy) or too short, respectively, such that average power rose (or could have been raised) substantially throughout workout, or else power/duration were intentionally set low due to training status, recent layoff, illness, etc.
6-7	Workout finished with some difficulty towards end of session; completion somewhat, but not seriously in doubt. Intensity/duration about right, as power/speed remained steady or gradually increased throughout, and could not have been sustained much or at all beyond end of workout.
8	Extreme difficulty and serious doubts about ability to finish encountered during middle and latter stages of session. Intensity/duration too high/long, or else recovery inadequate, since speed/power either faded during latter stages of workout, or workout was not quite completed.
10	Workout terminated well short of goal (early or middle of session) due to illness or accumulated fatigue, or intensity/ duration not being sustainable (unrealistically high/long).

The ultimate test of how well training intensity and (more importantly) load are chosen is whether workouts can be consistently completed, without undue fatigue, throughout a periodized training program, particularly the gradually progressive base (foundation) phase. Occasionally failing to finish a workout due to power and/or duration being too high is not a disaster; after all, in order to find your limits, it is sometimes necessary to exceed them.

Since overall perceptual awareness of effort is determined by numerous factors, differentiating the physical sensation(s) of several types of workout fatigue can aid in their identification and prevention:

Table 3. Recognition and management of acute fatigue.		
CAUSE of FATIGUE	SENSATION/SIGN	PREVENTION/REMEDY
Low muscle glycogen/blood glucose ("bonking") on longer rides/races.	Stress/fatigue localized in quadriceps area.	Knowledge/judgment of adequate quantity and correct timing of CHO intake; a feeding schedule and clear bottles can facilitate this.
High blood lactate ("blowing up") during intervals/repetitions, cycling time trials, breakaways, chases, and when "bridging up."	Discomfort ("burning") in legs and/or chest, plus increased breathing rate.	Knowledge/judgment of proper pacing, aided by feedback from speed (runners and skaters) or power (cyclists) information.
Environmental heat stress/elevated core temperature.	Overall perception of heat, as well as visual signs of excessive sweating.	<ol style="list-style-type: none"> 1. Knowledge/awareness of heat index. 2. Knowledge/judgment of adequate fluid replacement – the "drink before you're thirsty" rule; a feeding schedule and clear bottles can facilitate this. 3. External cooling, e.g., "drenching" as possible/available, use of a cooling vest, etc.

Knowledge of subjective feelings of exertion and fatigue, coupled with their close and continuous monitoring in relation to an objective measure of exercise intensity and remaining workout time, can serve to guide the rate of energy output and optimize the amount of work performed within a given period of time (a primary objective of training). This integration of speed or power information with PE forms a cycle wherein the former 'calibrates' PE, and allows the rate of work output to be closely monitored, while PE provides feedback which is used to modulate intensity, thereby allowing relatively even pacing of the overall effort.

'Steady-state' (i.e., primarily flat-terrain) threshold and tempo training runs/rides lasting 20-120 minutes are where management of the stress/strain relationship most often comes into play. Average power or speed after the first minute should be kept ~10% below the planned overall average, and ~5% under at the 4-5 minute mark, as aerobic metabolism comes 'on line' and PE is allowed to 'catch up' to effort. From there, PE essentially takes over, and power/speed should remain relatively steady or increase very gradually, always with a small reserve of energy maintained. Any increase in intensity should occur naturally, almost unconsciously, without any real attempt to "push" or force the pace, not as the result of a deliberate kick. As a gauge of how well the workout is paced, energy output for the respective workout halves should be in an approximate balance of 49%/51% of the total energy output. For runners, this can be represented by the reverse of halfway split times as a percentage of the final time, with a first-half value of >50% of the final time being termed 'negatively split.'

For a cyclist who plans on averaging 300 Watts for a 40-minute threshold interval workout, this would mean an average of 270 W after a minute, 285 W at the 5 minute mark, and 294 W halfway through, while a runner aiming for 10 km in 40 minutes (6:26 mile pace) would try to cover the first 200 meters in 53 seconds or so, the first 1 km in ~4:12, pass the halfway point in about 20:25, then come home in 19:35.

On training runs, where there is no warm-up and the early stages of the run are used to 'ease in' to the pace, a first/second half split more negative than 51%/49% usually indicates the first half was run a bit too easily and/or you pushed hard at the end, while an even or positive split means too fast of a start, or perhaps easing up considerably in the last kilometer(s). Within the framework of a first/second half split ratio of 50.5%/49.5%, some variation in pace, as PE may direct, does not appear to be detrimental to oxygen kinetics and performance, and may even be preferable to perfectly constant intensity.

Since the goal of racing is to reach the finish line ahead of as many other competitors as possible, tactics, pack psychology, and even random chance can affect energy distribution, as can pacesetters and pacing schedules during record attempts, but since the 1950s, the trend in Olympic and World championship competition, as well as world record progressions, has clearly been towards negative splitting:

Table 4. Pacing data summary for men’s Olympic, World Championship, and world record performances from 1 mile – 10,000 meters.

EVENT(S)	MEAN FIRST-HALF SPLIT as % of FINAL TIME	POSITIVELY SPLIT RACES (%)	MEAN 1st – 6th PLACE DIFFERENCE (%)
Mile WRs 1915-1966 (n = 19)	49.7% ±0.72%	16 (84%)	n/a
Mile WRs 1967-1998 (n = 10)	50.3% ±0.53%	3 (30%)	n/a
ALL MILE PERFORMANCES (n = 29)	49.9% ±0.73%	19 (66%)	n/a
OG 5,000 meters 1972-2004 (n = 9)	51.3% ±0.79%	0	0.79%
5,000 meter WRs 1912-1966 (n = 19)	49.9% ±0.34%	10 (53%)	n/a
5,000 meter WRs 1966-2004 (n = 13)	50.3% ±0.32%	1 (8%)	n/a
ALL 5,000 m PERFORMANCES (n = 41)	50.3% ±0.71%	11 (28%)	n/a
OG 10,000 meters 1912-1948 (n = 6)	49.5% ±0.54%	5 (83%)	5.03%
OG 10,000 meters 1952-2004 (n = 14)	50.4% ±0.77%	4 (31%)	1.62%
WC 10,000 meters 1987-2005 (n = 7)	51.1% ±0.40%	0	1.25%
10,000 meter WRs 1911-1973 (n = 23)	49.8% ±0.31%	18 (75%)	n/a
10,000 meter WRs 1977-2005 (n = 14)	50.2% ±0.22%	3 (21%)	n/a
ALL 10,000 m PERFORMANCES (n = 64)	50.1% ±0.64%	13 (33%)	n/a

Split times for the Olympic 5,000 meters from 1912-68, as well as the 1920 Olympic 10,000 meters, could not be obtained.
OG – Olympic Games WC – world championship performance WR – world record performance

A well-paced effort can sometimes overcome the early lead of a superior opponent who has gone out too hard. The discipline, patience, and judgment this requires are captured in a wonderful personal anecdote from the recently-published book *Bowerman and the Men of Oregon*. The author, Kenny Moore, then a sophomore on the University of Oregon track team, had overtrained himself by rigidly adhering to Arthur Lydiard’s 100-mile-a-week regimen, but after three weeks of reduced training load and easy days that were enforced with threats and a measure of physical intimidation by his “tyrannical” coach Bill Bowerman, Moore was ready for a two-mile race in a meet against Oregon State:

[Bowerman] said to begin no faster than 4:30 for the first mile and not chase after their animal, Dale Story, the NCAA cross-country champion, who ran barefoot and was 30 seconds better.

Stripping down, our filmy, Bowerman-designed racing shirts and shorts made me feel battle-naked. My sharpened steel spikes sank into the cinders with a gnash that evoked Jim Bailey years before. On the starting line, Story’s shirt looked heavy, almost like wool, and something hit me of the care with which Bowerman had prepared me. I gave myself completely to his plan. I hit 4:30 for the first mile. Story ran 4:19 and led by 70 yards. Bowerman, on the infield, said, “He won’t hold it. See what you can do.”

I began to gain, and the crowd, Bowerman’s crowd, ten thousand strong, saw me coming and got up and called. With half a mile to go, I had no real will left. All control had passed to that thunder that would not let me slow. Into the last turn, Story still had 10 yards. Then he looked back, his shoulders tightened, and I experienced for the first time the full savagery of my competitive heart.

I outkicked him by a second in 8:48.1, ripping 27 seconds from my best, finishing in bedlam, crowd and teammates pressing the air out of me, shouting that everything was possible now, the Olympics were possible now. Bowerman was there with wild blue eyes and a fiendish grin, and I knew what he would say. “See!,” he’d crow. “I told you! You just needed rest!” But he didn’t. He whispered in my ear as he had when he strangled me. “Even I didn’t think you could run that fast, Kenny,” he said. “Even I.”

Moore's status as a still-developing runner, along with a supercompensation resulting from overtraining, a timely intervention, and an appropriate reduction in training load all contributed to the 4.9% improvement he realized over his previous best, but pacing cannot be ignored: his halfway split of 51.1% was much better than Story's, who – as Moore himself confirms – would have won the race and run a PR of his own (rather than missing by just 4 seconds) had he paced more wisely, as opposed to running 4:19/4:30 – almost exactly the reverse of Moore.

Indeed, data for world championship (WC), Olympic (OG), and world record (WR) long-distance track events (Figure 1) indicates that near-even splitting produces the fastest time, relative to WR performance. Early Olympic 10,000 meter races are omitted from this illustration, since the smaller talent pool and wide range of abilities (the 1st – 6th place spread is >3% for all races from 1912-48) appears to have permitted sub-optimal pacing. Results from the 1968 Games are also excluded, since the altitude at which they were conducted (2250 meters) does not allow for comparison to sea-level performances.

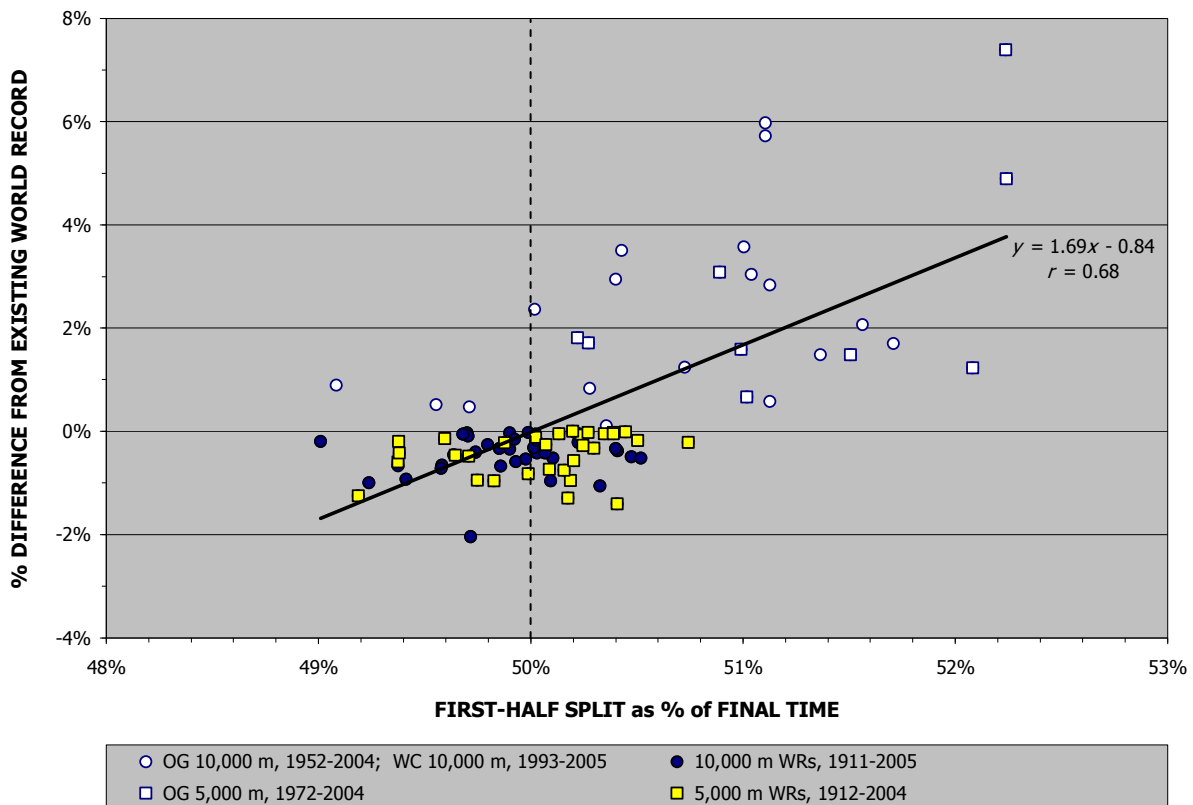


Figure 1. 5,000 and 10,000 meter run performance relative to world-record time, as a function of halfway split time.

By contrast, a survey of intermediate split times for all world mile records dating back to 1915 reveals that, although there is a similar trend toward negative splitting beginning in 1967 (Figure 2), this event has a much higher 'tolerance' for extremes of both positive and negative splitting (Figure 3), as reflects the influence of relatively larger contributions from anaerobic energy sources as compared to the 5,000 and 10,000 meters. That is, when the pace is very fast from the start, and the effort ends up being too positively split, the early onset of lactic acidosis inhibits aerobic energy production, which, along with excessively heavy utilization of anaerobic capacity early-on, causes a decline in velocity during the final stages of the race, while higher levels of stress hormones (which track with blood lactate levels) result in elevated PE towards the end of the race, as well as increased fatigue/stress afterward. On the other hand, when the effort is too negatively split, aerobic energy production may reach its maximum, but there is excess anaerobic capacity left over at the end, accompanied by a feeling of being too fresh post-race. Thus, the range of first/second-half energy distribution in record performances narrows as event duration increases, since energy output becomes more dependent on aerobic metabolism, which is maximized by more nearly equal halfway split times.

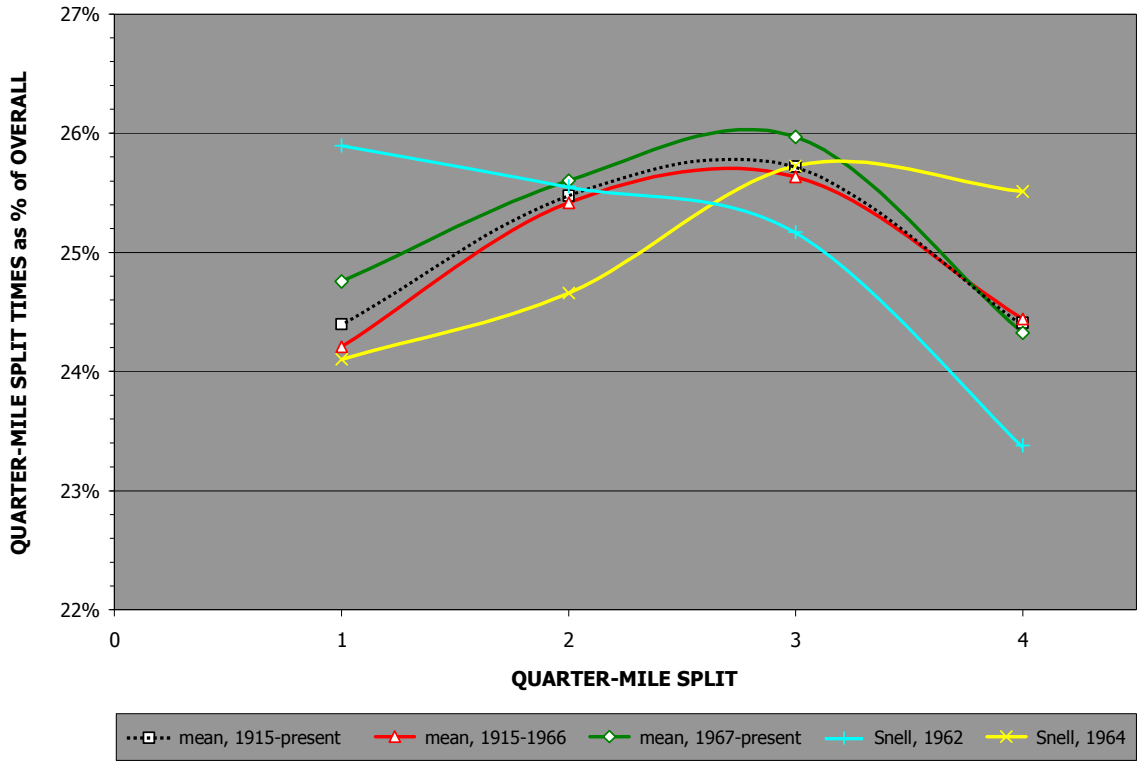


Figure 2. Quarter-mile split times as a per cent of final time from men's world mile records.

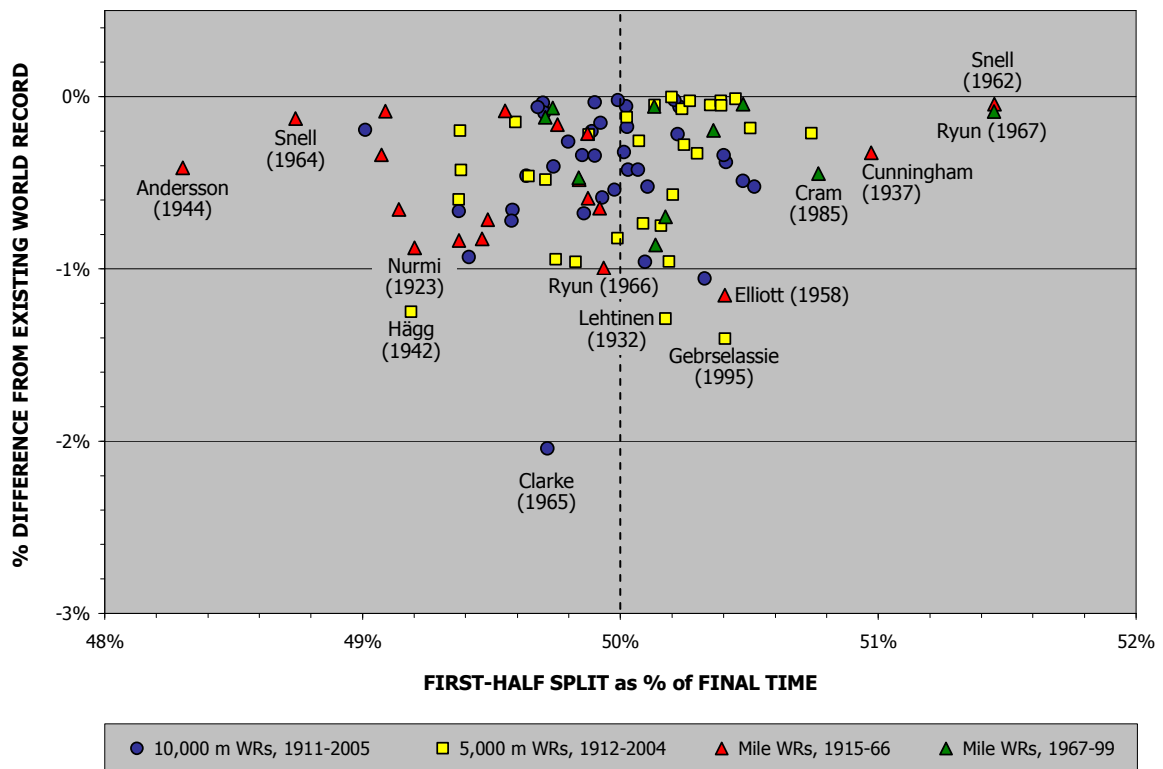


Figure 3. Margin of improvement for 10,000 meter, 5,000 meter, and mile world records in relation to first-half split.

Widely disparate splitting accentuates the varying level of perceived exertion and fatigue experienced for essentially equal performances. Peter Snell, in particular, is in a unique position to compare the two approaches, since his two world mile records represent extremes of pacing; his 1962 effort is the most negatively split record of all (51.5%), whereas his subsequent record two years later is the second-most positively split (48.5%). The latter was only 0.4 seconds faster, but exacted a much higher toll: “. ”

Similarly, Jim Ryun’s 1966 mile record of 3:51.3 had a slightly positive split (49.9%), while his record a year later, just 0.2 seconds faster, is the second-most negatively split ever (51.4%), and a [film of the race](#) shows him looking remarkably fresh just afterward, which he confirmed both in his 1984 autobiography and when contacted by the author:

“Bakersfield [the 1967 record] was perhaps the easiest mile I ever did. I ran hard, but when I crossed the line, I was hardly fatigued, and most atypically for me, I began to talk to the cluster of reporters almost immediately afterward; there was none of the usual post-race nausea (my first order of business after most races was to find a bathroom or other solitary spot where, in peace and quiet, I could lose my lunch.) It was a remarkably effortless run, and I felt so good, I thought I had run in the 3:54 to 3:56 range. I have always felt I could have turned around ten minutes later and run another sub-4 minute mile. I recovered quickly, which was evident when Jack Daniels did a VO₂max test the next day, and I recorded my highest levels ever.

On the other hand, Berkeley [the 1966 record] was without question the hardest race I ever ran. The level of stress was high going in, since there were high expectations (nationally, internationally, and personally). Afterward, I was exhausted and very slow to recover. A week later in Los Angeles I won an 800 meter race in 1:46, but in the mean time I was so flat, tired, and unmotivated that all I did was jog lightly 3-4 miles a day.”

Finally, Steve Cram’s comments nine years after his 1985 mile record, the fourth most negatively split (50.8%), perfectly capture the feeling after this type of effort and are remarkably consistent with Snell’s and Ryun’s, while adding a touch of sardonic, self-deprecating humor:

“I remember finishing the race and I kept saying to everyone, ‘It can’t be 3:46, I’m not tired.’ Then of course your big mouth starts going and you go before the press and say ‘Yes, I can run 3:44, no problem,’ but you never get anywhere near it again.”

SUMMARY

In contrast to competition, the purpose of tempo and threshold workouts is sustained aerobic development, and since negative splitting (or greater second-half energy output) facilitates this by minimizing fatigue, it is nearly always desirable for this kind of training. Developing and using your sense of perceived exertion with speed or power data is essential to optimal energy distribution and consistent, productive steady-state workouts, which, as part of a periodized, progressive training plan, allow aerobic development to continue almost indefinitely; as the late Arthur Lydiard often said, “*Train, don’t strain,*” or, put another way, *work, don’t suffer*. While this approach requires some discipline and restraint, especially in the initial stages of each flat-terrain training run or ride, with just a little conscious effort, it soon becomes so habituated that anything else feels wrong; indeed, in his first year of serious running (2006), the author’s personal experience, where intermediate times could be obtained, conforms to the guideline of a 50.5% halfway split:

Table 5. Energy distribution during the author’s recent flat-terrain training runs.		
PERIOD	MEAN FIRST HALF SPLIT as % of FINAL TIME \pm SD	POSITIVELY SPLIT RUNS
January 2006 (n = 12)	50.6% \pm 0.43%	1 (8%)
July-October 2006 (n = 25)	50.6% \pm 0.56%	3 (12%)
ALL RUNS (n = 37)	50.6% \pm0.53%	4 (11%)

Two of the positively split runs in the second period were likely due to slight fatigue from environmental heat/humidity in the late stages of each run.

On the other hand, even or near-even energy distribution produces the fastest time or highest power output possible, and for shorter events that are still determined by primarily by aerobic energy supply, such as the 1,500 and 2,000 meter runs, or the 3,000/4,000 meter individual pursuit in cycling, a slightly positive halfway split (greater first-half energy expenditure) may be optimal, to ensure that anaerobic capacity is fully spent, but not so positive as to inhibit aerobic energy output as the race wears on.

When duration is longer than ~5 minutes in both running races and road cycling time trials conducted on flat terrain, it is prudent to maintain a slight reserve of anaerobic energy that can be expended over the last ~2 minutes of the race, and a first-half energy output of 50% \pm 0.3% seems optimal. Pacing in cycling time trials conducted over hilly terrain is more complex and requires further analysis, since time is actually minimized by uneven pacing.

In footraces, tactical development affects energy distribution, such as when the pace is slow, and a lesser-known competitor in peak form escapes the pack, builds up a sufficient lead, then holds it off with a finely-judged effort (a la Murray Halberg and John Ngugi in the 1960 and 1988 Olympic 5,000 meters, respectively).

The same tactic is much less likely to succeed in cycling races, at least on theoretical grounds, since speeds are higher and aerodynamic drag is a much larger component of resistance, allowing riders in the pursuing pack to realize greater energy savings; more typically, such breakaway attempts are countered quickly or chased down, and the contending teams position their designated rider for the final sprint, putting the race “under pressure” and causing a greater second-half energy output. Even so, when there is a large enough disparity in the abilities present within a field, it is tactically advantageous for the aerobically stronger riders to play to their strength by escaping early, then work together (i.e., rotate the lead) smoothly to build up a margin adequate enough to be maintained until the end. The field might narrow the gap in the latter stages of the race, and end up with a more optimal energy distribution, but of course, the true object of the race is to get to the finish line in as little time as possible.

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Appendix A. Data for men's world mile record performances.

NAME, YEAR	TIME (min:sec)	HALFWAY SPLIT		QUARTER-MILE SPLITS								MARGIN of IMPROVEMENT (%)
		(min:sec)	% of overall	(seconds)				% of overall				
				1	2	3	4	1	2	3	4	
Taber, 1915	4:12.6	2:05.0	49.5%	58.0	67.0	68.0	59.6	23.0%	26.5%	26.9%	23.6%	0.71%
Nurmi, 1923	4:10.4	2:03.2	49.2%	60.3	62.9	63.5	63.7	24.1%	25.1%	25.4%	25.4%	0.88%
Ladoumeègue, 1931	4:09.2	2:04.2	49.8%	60.8	63.4	63.8	61.2	24.4%	25.4%	25.6%	24.6%	0.48%
Lovelock, 1933	4:07.6	2:03.6	49.9%	61.4	62.2	65.1	58.9	24.8%	25.1%	26.3%	23.8%	0.65%
Cunningham, 1934	4:06.8	2:05.8	51.0%	61.8	64.0	61.8	59.1	25.1%	25.9%	25.1%	24.0%	0.32%
Wooderson, 1937	4:06.4	2:02.6	49.8%	58.6	64.0	64.6	59.2	23.8%	26.0%	26.2%	24.0%	0.16%
Hägg, 1942	4:06.2	2:02.0	49.6%	60.0	62.0	63.8	60.3	24.4%	25.2%	25.9%	24.5%	0.08%
Hägg (2), 1942	4:04.6	2:00.2	49.1%	57.2	63.0	64.0	60.4	23.4%	25.8%	26.2%	24.7%	0.65%
Andersson, 1943	4:02.6	2:00.0	49.5%	58.5	61.5	63.5	59.1	24.1%	25.4%	26.2%	24.4%	0.82%
Andersson (2), 1944	4:01.6	1:56.7	48.3%	57.1	59.6	62.9	62.0	23.6%	24.7%	26.0%	25.7%	0.41%
Hägg (3), 1945	4:01.4	1:58.5	49.1%	56.6	61.9	61.2	61.6	23.5%	25.7%	25.4%	25.5%	0.08%
Bannister, 1954	3:59.4	1:58.2	49.4%	57.5	60.7	62.3	58.9	24.0%	25.4%	26.0%	24.6%	0.84%
Landy, 1954	3:58.0	1:58.7	49.9%	58.5	60.2	58.5	60.7	24.6%	25.3%	24.6%	25.5%	0.59%
Ibbotson, 1957	3:57.2	1:56.4	49.1%	56.0	60.4	63.9	56.9	23.6%	25.5%	26.9%	24.0%	0.34%
Elliott, 1958	3:54.5	1:58.2	50.4%	56.4	61.8	61.0	55.3	24.1%	26.4%	26.0%	23.6%	1.15%
Snell, 1962	3:54.4	2:00.6	51.5%	60.7	59.9	59.0	54.8	25.9%	25.6%	25.2%	23.4%	0.04%
Snell (2), 1964	3:54.1	1:54.1	48.8%	56.4	57.7	60.2	59.7	24.1%	24.7%	25.7%	25.5%	0.13%
Jazy, 1965	3:53.6	1:56.5	49.9%	57.5	59.0	60.9	56.2	24.6%	25.3%	26.1%	24.1%	0.21%
Ryun, 1966	3:51.3	1:55.5	49.9%	57.9	57.6	59.8	56.0	25.0%	24.9%	25.9%	24.2%	0.99%
1915-66		MEANS ±SD	49.7% ±0.72%					24.2% ±0.68%	25.5% ±0.50%	25.9% ±0.57%	24.4% ±0.82%	0.50% ±0.34%
Ryun (2), 1967	3:51.1	1:58.9	51.4%	59.0	59.9	59.7	52.5	25.5%	25.9%	25.8%	22.7%	0.09%
Bayi, 1975	3:51.0	1:56.6	50.5%	56.9	59.7	58.7	55.7	24.6%	25.8%	25.4%	24.1%	0.04%
Walker, 1975	3:49.4	1:55.1	50.2%	55.8	59.3	57.9	56.4	24.3%	25.9%	25.2%	24.6%	0.70%
Coe, 1979	3:49.0	1:55.3	50.3%	57.8	57.5	58.1	55.6	25.2%	25.1%	25.4%	24.3%	0.20%
Ovett, 1980	3:48.8	1:53.8	49.7%	55.7	58.1	57.2	57.8	24.3%	25.4%	25.0%	25.3%	0.07%
Coe (2), 1981	3:48.5	1:53.6	49.7%	56.2	57.4	58.1	56.8	24.6%	25.1%	25.4%	24.9%	0.12%
Ovett (2), 1981	3:48.4	1:54.5	50.1%	56.6	57.9	57.0	56.9	24.8%	25.4%	25.0%	24.9%	0.06%
Coe (3), 1981	3:47.3	1:53.3	49.8%	55.3	58.0	58.6	55.4	24.3%	25.5%	25.8%	24.4%	0.47%
Cram, 1985	3:46.3	1:54.9	50.8%	57.5	57.4	58.4	53.0	25.4%	25.4%	25.8%	23.4%	0.45%
Morceli, 1993	3:44.4	1:52.5	50.1%	54.7	57.8	57.3	54.6	24.4%	25.8%	25.5%	24.3%	0.86%
El Guerrouj, 1999	3:43.1											
1967-present		MEANS ±SD	50.3% ±0.53%					24.8% ±0.47%	25.5% ±0.30%	25.4% ±0.31%	24.3% ±0.75%	0.30% ±0.30%
ALL PERFORMANCES		MEANS ±SD	49.9% ±0.73%					24.4% ±0.67%	25.5% ±0.44%	25.7% ±0.55%	24.4% ±0.74%	0.43% ±0.33%

Appendix B. Data for men's Olympic and world record 5,000 meter running races.

EVENT	WINNER or RECORD-SETTER	FIRST-HALF SPLIT/FINAL TIME		DIFFERENCE vs. EXISTING WORLD RECORD (%)	1st – 6th PLACE DIFFERENCE (%)
1972 OG final	Lasse Viren	7:00.0/13:26.4	52.1%	+1.23%	0.77%
1976 OG "	Lasse Viren	6:54.5*/13:24.8	51.5%	+1.48%	0.28%
1980 OG "	Miruts Yifter	6:48.4/13:20.9	51.0%	+1.50%	0.29%
1984 OG "	Saïd Aouita	6:40.8/13:05.6	51.0%	+0.67%	1.63%
1988 OG "	John Ngugi	6:38.0/13:11.7	50.3%	+1.71%	1.53%
1992 OG "	Dieter Baumann	6:38.0/13:12.5	50.2%	+1.81%	1.39%
1996 OG "	Vénuste Niyongabo	6:41.0/13:08.0	50.9%	+3.08%	0.56%
2000 OG "	Million Wolde	7:06.0*/13:35.5	52.2%	+7.39%	0.21%
2004 OG "	Hicham El Guerrouj	6:55.0/13:14.4	52.2%	+4.89%	0.48%
		MEANS ±SD (n = 9)	51.3% ±0.79%	+2.65%	0.79%
1912 WR	Hannes Kolehmainen	7:17.0/14:36.6	49.9%	n/a	n/a
1922 WR	Paavo Nurmi	n/a /14:35.4	n/a	-0.14%	n/a
1924 WR	Paavo Nurmi	7:14.0/14:28.2	50.0%	-0.82%	n/a
1932 WR	Lauri Lehtinen	7:10.0/14:17.0	50.0%	-1.29%	n/a
1939 WR	Taisto Mäki	7:06.0/14:08.8	50.2%	-0.96%	n/a
1942 WR	Gunder Hägg	6:52.3/13:58.2	49.2%	-1.25%	n/a
1954 WR (1)	Emil Zátopek	6:58.8/13:57.2	50.0%	-0.12%	n/a
1954 WR (2)	Vladimir Kuts	7:00.3/13:56.6	50.2%	-0.07%	n/a
1954 WR (3)	Chris Chataway	6:50.6/13:51.6	49.4%	-0.60%	n/a
1954 WR (4)	Vladimir Kuts	6:56.7/13:51.2	50.1%	-0.05%	n/a
1955 WR (1)	Sándor Iharos	6:58.3/13:50.8	50.3%	-0.05%	n/a
1955 WR (2)	Vladimir Kuts	6:51.0/13:46.8	49.7%	-0.48%	n/a
1955 WR (3)	Sándor Iharos	6:51.6/13:40.6	50.2%	-0.75%	n/a
1956 WR	Gordon Pirie	6:45.5/13:36.8	49.6%	-0.46%	n/a
1957 WR	Vladimir Kuts	6:46.5/13:35.0	49.9%	-0.22%	n/a
1965 WR (1)	Ron Clarke	6:49.6/13:34.8	50.3%	-0.02%	n/a
1965 WR (2)	Ron Clarke	6:43.5/13:33.6	49.6%	-0.15%	n/a
1965 WR (3)	Ron Clarke	6:41.5/13:25.8	49.8%	-0.96%	n/a
1965 WR (4)	Kipchoge Keino	6:37.1/13:24.2	49.4%	-0.20%	n/a
1966 WR	Ron Clarke	6:36.3/13:16.6	49.7%	-0.95%	n/a
		MEANS ±SD (n = 19)	49.9% ±0.34%	-0.50%	
1972 WR (1)	Lasse Viren	6:41.3/13:16.4	50.4%	-0.03%	n/a
1972 WR (2)	Emiel Puttemans	6:31.6/13:13.0	49.4%	-0.43%	n/a
1977 WR	Dick Quax	6:40.0/13:12.9	50.4%	-0.01%	n/a
1978 WR	Henry Rono	6:35.8/13:08.4	50.2%	-0.57%	n/a
1981 WR	Henry Rono	n/a /13:06.2	n/a	-0.28%	n/a
1982 WR	David Moorcroft	6:30.9/13:00.4	50.1%	-0.74%	n/a
1985 WR	Saïd Aouita	6:31.8/13:00.4	50.2%	0.00%	n/a
1987 WR	Saïd Aouita	6:29.8/12:58.4	50.1%	-0.26%	n/a
1994 WR	Haile Gebrselassie	6:32.4/12:57.0	50.5%	-0.18%	n/a
1995 WR (1)	Moses Kiptanui	6:33.4/12:55.3	50.7%	-0.21%	n/a
1995 WR (2)	Haile Gebrselassie	6:25.3/12:44.4	50.4%	-1.41%	n/a
1997 WR (1)	Haile Gebrselassie	6:23.2/12:41.9	50.3%	-0.33%	n/a
1997 WR (2)	Daniel Komen	6:21.7/12:39.7	50.2%	-0.28%	n/a
1998 WR	Haile Gebrselassie	6:22.7/12:39.4	50.4%	-0.05%	n/a
2004 WR	Kenenisa Bekele	n/a /12:37.4	n/a	-0.26%	n/a
		MEANS ±SD (n = 13)	50.3% ±0.32%	-0.34%	
		MEANS ±SD, ALL 5,000 m PERFORMANCES (n = 41)	50.3% ±0.71%		

OG – Olympic Games WC – world championship performance WR – world record performance

*Halfway split time taken on lead runner. *Italics* indicate 2,500 meter split obtained by interpolating the preceding and following intermediate times.

Split times for the 1912-68 Olympics could not be obtained.

Appendix C. Data for men's Olympic and World Championship 10,000 meter running races.

EVENT	WINNER or RECORD-SETTER	FIRST-HALF SPLIT/FINAL TIME		DIFFERENCE vs. EXISTING WORLD RECORD (%)	1st – 6th PLACE DIFFERENCE (%)
1912 OG final	Hannes Kolehmainen	15:11.4/31:20.8	48.5%	+1.18%	6.93%
1924 OG "	Ville Ritola	15:00.2/30:23.8	49.4%	-0.66%	6.74%
1928 OG "	Paavo Nurmi	15:11.0/30:18.8	50.1%	+0.70%	4.31%
1932 OG "	Janusz Kusocinski	14:56.6/30:11.4	49.5%	+0.29%	4.73%
1936 OG "	Ilmari Salminen	15:01.0/30:15.4	49.6%	+0.51%	3.67%
1948 OG "	Emil Zátopek	14:54.0*/29:56.6	49.7%	+1.36%	3.79%
		MEANS ±SD (n = 6)	49.5% ±0.54%	+0.84%	5.03%
1952 OG "	Emil Zátopek	14:34.4/29:17.0	50.3%	+0.83%	2.15%
1956 OG "	Vladimir Kuts	14:07.0*/28:45.6	49.1%	+0.89%	2.67%
1960 OG "	Pyotr Bolotnikov	14:22.2*/28:32.2	50.4%	+0.11%	1.05%
1964 OG "	Billy Mills	14:04.6/28:24.4	49.6%	+0.52%	2.05%
1968 OG "	Naftali Temu	15:00.6*/29:27.4	51.0%	+6.51%	0.98%
1972 OG "	Lasse Viren	13:45.0/27:38.4	49.7%	-0.06%	1.63%
1976 OG "	Lasse Viren	14:08.9*/27:40.4	51.1%	+0.58%	1.20%
1980 OG "	Miruts Yifter	14:03.4*/27:42.7	50.7%	+1.24%	1.37%
1984 OG "	Alberto Cova	14:08.9/27:40.4	51.6%	+2.06%	1.29%
1988 OG "	Moulay Boutaib	13:36.0/27:21.5	49.7%	+0.47%	1.09%
1992 OG "	Khalid Skah	13:53.7/27:46.7	50.0%	+2.36%	2.01%
1996 OG "	Haile Gebrselassie	13:55.0/27:07.3	51.3%	+1.49%	1.71%
2000 OG "	Haile Gebrselassie	13:46.1/27:18.2	50.4%	+3.50%	1.20%
2004 OG "	Kenenisa Bekele	13:50.9/27:05.1	51.1%	+2.83%	2.26%
		MEANS ±SD (n = 14)	50.4% ±0.75%	+1.67%	1.62%
1987 WC "	Paul Kipkoech	14:13.1*/27:38.5	51.5%	2.06%	1.63%
1993 WC "	Haile Gebrselassie	13:59.7*/27:46.0	50.4%	2.94%	2.46%
1997 WC "	Haile Gebrselassie	13:58.8*/27:24.6	51.0%	3.57%	0.73%
1999 WC "	Haile Gebrselassie	14:17.2/27:57.3	51.1%	5.97%	0.69%
2001 WC "	Charles Kamathi	14:15.1*/27:53.2	51.1%	5.72%	0.26%
2003 WC "	Kenenisa Bekele	13:52.3/27:49.6	51.7%	1.70%	2.73%
2005 WC "	Kenenisa Bekele	13:51.1*/27:08.3	51.0%	3.04%	0.28%
		MEANS ±SD (n = 7)	51.1% ±0.40%	+3.57%	1.25%
OG – Olympic Games WC – world championship performance					
*Halfway split time taken on lead runner. Split times for the 1920 OG and 1983, 1985, and 1991 WC could not be obtained.					

Appendix D. Data for men's world record 10,000 meter running races.

EVENT	WINNER or RECORD-SETTER	FIRST-HALF SPLIT/FINAL TIME		DIFFERENCE vs. EXISTING WORLD RECORD (%)	1st – 6th PLACE DIFFERENCE (%)
1911 WR	Jean Bouin	15:11.0/30:58.8	49.0%	-0.19%	n/a
1921 WR	Paavo Nurmi	15:06.1/30:40.2	49.2%	-1.00%	n/a
1924 WR (1)	Ville Ritola	15:14.0/30:35.4	49.8%	-0.26%	n/a
1924 WR (2)	Ville Ritola	15:00.2/30:23.2	49.4%	-0.66%	n/a
1924 WR (3)	Paavo Nurmi	14:52.5/30:06.1	49.4%	-0.93%	n/a
1937 WR	Ilmari Salminen	15:01.0/30:05.5	49.9%	-0.03%	n/a
1938 WR	Taisto Mäki	14:59.0/30:02.0	49.9%	-0.20%	n/a
1939 WR	Taisto Mäki	14:58.2/29:52.6	50.1%	-0.52%	n/a
1944 WR	Viljo Heino	14:49.4/29:35.4	50.1%	-0.96%	n/a
1949 WR (1)	Emil Zátopek	14:39.5/29:28.2	49.7%	-0.41%	n/a
1949 WR (2)	Viljo Heino	14:44.0/29:27.3	50.0%	-0.06%	n/a
1949 WR (3)	Emil Zátopek	14:38.0/29:21.2	49.9%	-0.34%	n/a
1950 WR	Emil Zátopek	14:37.0/29:02.6	50.3%	-1.06%	n/a
1953 WR	Emil Zátopek	14:34.8/29:01.6	50.2%	-0.06%	n/a
1954 WR	Emil Zátopek	14:27.6/28:54.2	50.0%	-0.42%	n/a
1956 WR (1)	Sándor Iharos	14:14.2/28:42.8	49.6%	-0.66%	n/a
1956 WR (2)	Vladimir Kuts	14:08.0/28:30.4	49.6%	-0.72%	n/a
1960 WR	Pyotr Bolotnikov	14:07.0/28:18.8	49.9%	-0.68%	n/a
1962 WR	Pyotr Bolotnikov	14:04.0/28:18.2	49.7%	-0.04%	n/a
1963 WR	Ron Clarke	14:06.5/28:15.5	49.9%	-0.15%	n/a
1965 WR (1)	Ron Clarke	14:02.0/28:14.0	49.7%	-0.09%	n/a
1965 WR (2)	Ron Clarke	13:45.0/27:39.4	49.7%	-2.13%	n/a
1973 WR	David Bedford	13:39.4/27:30.8	49.6%	-0.46%	n/a
		MEANS ±SD (n = 23)	49.8% ±0.31%	-0.51%	
1977 WR	Samson Kimobwa	13:48.7/27:30.5	50.2%	-0.02%	n/a
1978 WR	Henry Rono	13:49.0/27:22.4	50.5%	-0.49%	n/a
1984 WR	Fernando Mamede	13:45.4/27:13.8	50.5%	-0.52%	n/a
1989 WR	Arturo Barrios	13:32.5/27:08.2	49.9%	-0.34%	n/a
1993 WR (1)	Richard Chelimo	13:33.8/27:07.9	50.0%	-0.02%	n/a
1993 WR (2)	Yobes Ondieki	13:28.0/26:58.4	49.9%	-0.59%	n/a
1994 WR	William Sigei	13:32.7/26:52.2	50.4%	-0.38%	n/a
1995 WR	Haile Gebrselassie	13:21.4/26:43.5	50.0%	-0.54%	n/a
1996 WR	Salah Hissou	13:25.5/26:38.1	50.4%	-0.34%	n/a
1997 WR (1)	Haile Gebrselassie	13:16.7/26:31.3	50.1%	-0.42%	n/a
1997 WR (2)	Paul Tergat	13:17.4*/26:27.9	50.2%	-0.32%	n/a
1998 WR	Haile Gebrselassie	13:11.6/26:22.7	50.0%	-0.32%	n/a
2004 WR	Kenenisa Bekele	n/a /26:20.0	n/a	-0.15%	n/a
2005 WR	Kenenisa Bekele	13:09.2/26:17.5	50.0%	-0.18%	n/a
		MEANS ±SD (n = 14)	50.2% ±0.22%	-0.32%	
MEANS ±SD, ALL OG, WC, & WR 10,000 m PERFORMANCES (n = 63)			50.1% ±0.64%		
OG – Olympic Games WC – world championship performance WR – world record performance					
*Halfway split time taken on lead runner.					