TRAINING FOR THE 400m

By William Black

A review of the physiological factors of performance in the 400. The author does an excellent job of relating the physiological factors to the all-important aspect of race distribution. Black was affiliated with Performance Fitness of Cincinnati, Ohio.

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Perhaps no other event is as perplexing to track coaches as the 400-meter dash. In contrast to a wealth of information about middle and long distance running and runners (Carter, et al., 1967; Wyndham, et al., 1969; Bosco, Komi, and Sinkkonen, 1980; Pollock, Jackson, and Pate, 1980; Taunton, et al., 1981; Boileau, et al., 1982; McKenzie, et al., 1982; Conley, et al., 1984; Svedenhag and Sjodin, 1985; Bale, Bradbury, and Colley, 1986), there is a lack of scientific information about: the immediate and long-term effects of competition and training and the characteristics of outstanding 400-meter performers. This makes it difficult to make a rational decision about the best methods for training for this event.

In order to answer the question of what is the best method for training 400-meter runners, it is necessary to analyze the nature and demands of the race by determining: 1. the responses to competition; and, 2. the characteristics of 400-meter competitors of varying levels of ability. The following information, derived from available literature, can be used as the basis for the rational planning of more effective training programs for the purpose of improving 400-meter racing performance.

During 400-meter racing, energy is derived from: 1. the breakdown of high-energy phosphate compounds (20.25%); and 2. the anaerobic productions of ATP by glycolysis (55-60%), and 3. aerobic production of ATP (15-25%). (GIadrow, 1983; Daley, 1978). Of the standard running events, the 400 probably requires the greatest energy production via anaerobic glycolysis, as evidenced by the observation that the most pronounced cases of lactate acidosis in athletic competition occurred after 400 and 800-meter racing.

Following a 400-meter dash of 45.5 seconds, an international-caliber runner had a lactate concentration of 24.97 mmol/liter with a pH of 6.923 and a base excess of 30.0 mval/liter. (Kindermann and Keul, 1977). Similar lactate concentration and pH values were reported following a run of 47.8 seconds (Osnes and Hermansen, 1972).

Research (Schnabel and Kindermann, 1983) indicates that the anaerobic capacity of runners is influenced by: 1. the energy derived from the lactacid anaerobic system; 2. energy derived from the alactate anaerobic system; and, 3. energy derived from aerobic metabolism. Those three factors were found to account for 57, 31, and 5% of the variability between groups of 400-meter, middle distance, long distance, and marathon runners in a short-duration run to exhaustion.

The most pronounced difference between 400-meter runners with a mean best time of 45.6 seconds, and those with a mean best of 48.0 seconds was that the better 400 runners apparently produced more energy via the alactate anaerobic energy system. Although the apparent difference did not reach statistical significance, this finding led the researchers to hypothesize that the superior 400-meter runners may be characterized by "an extraordinarily high capacity to increase their alactacid anaerobic capacity."

Lending support to this observation is the finding of Jolly and Crowder (1985) that trained sprinters were able to both accelerate and maintain maximum velocity for a greater distance than untrained sprinters with similar maximum velocity capabilities, leading to the hypothesis that the trained sprinters may have increased levels of PC in the working muscles which extends the time before energy is supplied by anaerobic glycolysis.

The research of VanCoppenolle (1980) found that:

1. 400-meter dashes run in 43.8-44.9 seconds were accomplished by running the first and second 200 meters in a mean time of 21.5 (20.7-22.4) and 23.0 (22.1-23.5) seconds, respectively. 400-meters run in 45.0-45.9 seconds were run with the first and second 200s covered in mean times of 21.7 (20.8-22.7) and 23.8 (22.5-25.0).

The top runners have a smaller time differential between the first and second 200 meters (1.5 vs. 2.1 seconds). The difference between the mean times for the second 200 meters for the two groups of runners is significant on the 1% level.

2. For the fastest (43.8-44.9) 400 runners, there is no distinct correlation between the second 200 meters and the final time. A favorable result can be run with a reactively fast or slow second 200 meters.

3. For 400 runners in the 45.0-45.9 second category, there is a distinct correlation between a better final time and a better second 200 time.

This information indicates that the difference between the best and the sub-best 400 runners is that the best were able to run a faster second 200. It is not known whether that ability was due to: 1. a greater alactate; 2. a greater lactacid anaerobic capacity; 3. to a combination of the two; or, if due to a combination of the two factors, 4. which of the two made the most significant contribution to the running performance.

Taking into account the research of Schnabel and Kindermann. (1983), it is possible that the ability of the top 400 runners to run a faster second 200, due to a smaller difference between the times for the first and second 200s, may be because the top runners derive more energy for running the first half of the race from alactate sources, thus reducing the detrimental effects of lactate acidosis on the running of the second 200.

The WorId Record of 43.86 for the 400 was run at an average velocity of 9.10 meters/second. The mean stride length was 2.20 meters and mean stride frequency was 4.13 strides/second. The corresponding velocity, stride length, and stride frequency for a 100-meter dash of 9.95 seconds was 10.1 m/sec., 2.25 meters, and 4.40 strides/sec., respectively. (Scholich, 1978). The first 200 was run in 20.7+ seconds and the second in 23.1+ seconds. (VanCoppenolle, 1980).

Ogorodnikov (1978) determined that 400 sprinters with best performances of 45.5 or better, 45.6-47.0, and 47.1-48.6 differed in their sprint speed abilities. The runners in these categories had mean best 100 times of 10.31, 10.52, and 10.78, respectively. It was concluded that “the sprinting ability of athletes was the single most important factor in the development of specific performance ability for the 400-meters... [and that] optimal training must be directed towards the development of speed.”

CrieIaard and Pirnay (1981) found that sprinters (including one 400-meter runner) developed much higher alactate anaerobic power values (1,030 W. or 14.16 W/kg) than 800-meter runner (761, 10.63), a long distance runner (551, 8.93), or student (710, 10.1) groups. Additionally, a strong negative correlation was found between maximum oxygen uptake and alactate anaerobic power in the athletic, but not the student, groups. The authors theorized that this relationship was due to: 1. the neural stimulation (fast-twitch vs. slow-twitch) and enzyme activities (glycolytic vs. oxidative) of muscle fiber; and, 2. the influence of different types of training.

Schnabel and Kindermann (1983) recorded mean maximal oxygen uptakes of 60.6 ml/kg/mm. and 59.5ml/kg/mm. for groups of sprinters with mean bests for the 400 of 45.6 and 48.0 seconds, respectively. A 400 runner with a best of 46.7 had a reported aerobic power of 55.2 ml/kg/min. (Withers, et al, 1977). This compares to a mean of 56.15 ml/kg/min. for world-class sprinters with a mean 100 time of 10.23 (10.16-10.31) (Barnes, 1981) and means of 63.6 and 69.8 ml/kg/min. for national-class (1:49.5-1:53.7) Canadian and Finnish 800 runners (McKenzie, et al., 1982; Rusko, et al., 1978). Long distance runners had reported mean maximal oxygen uptakes in the high-70s (BoiIeau, et al., 1982; CostilI, et al., 1973; Rusko, et al., 1978).

On the basis of the available information, it is possible to conclude that:

1. Success in the 400 is highly dependent upon a very high ability to produce energy via anaerobic glycolysis, with the accompanying lactate acidosis. When comparing heterogeneous groups of runners, the anaerobic capacity of the athlete is the main determinant of superior ability to run the 400.

2. More successful 400 runners are characterized by superior sprint speed. When comparing homogeneous groups of runners characterized by a very high anaerobic capacity, those who are faster over shorter distances tend to also be faster in the 400.

3. More successful 400 runners may be characterized by superior alactate anaerobic capacity. It may be that those runners who are able to produce more energy in the early stages of the race, via the splitting of high energy phosphates, are more successful.

4. Successful 400 runners are characterized by an anaerobic power similar to that of other athletes who participate in sports requiring a combination of speed and aerobic endurance (for example, soccer and basketball). A very high maximum oxygen uptake is not advantageous, and may even be detrimental, to high-level performance.

Consequently, those training methods that most effectively increase the athlete’s alactate anaerobic power and capacity and the capacity of the lactacid anaerobic energy system will produce the fastest times. The challenge to the coach and the sports scientist is to discover those methods.

REFERENCES

1. Bale, P., D. Bradbury and E. Colley, “Anthropometric and Training Variables Related To 10km Running Performance,” *Brit. J. Sports Med.*, December, 1986; 20(4), 170173.
2. Barnes, W., “Selected physiological characteristics of elite male sprint athletes”; *Jour. of Sports Med. and Physical Fitness,* 1981,21,49-54.

3. Boileau, R., J. Mayhew, W. Riner and L. Lussier; "Physiological Characteristics of Elite Middle and Long Distance Runners", *Canadian Jour. of Appl. Sport. Sci.,* 1982,7(3), 167-72.
4. Bosco, C., P. Komi and K. Sinkkonen, "Mechanical power, net efficiency and muscle structure in male and female middle distance runners", *Scand. J. Sports Sc.,* 1980, 2(2), 47-51.
5. Carter, J., F. Kasch, J. Boyer, W. Phillips, W. Ross and A. Sucec; "Structural and functional assessments on a champion runner—Peter Snell", *Research Quarterly,* 1967, 38(3), 355-65.
6. Conley, D., G. Krahenbuhl, L. Burkett and A. Millar, "Following Steve Scott: Physiological Changes Accompanying Training", *The Physician and Sportsmedicine,* Jan., 1984, 12(1).
7. Crielaard, J. and F. Pirnay, 'Anaerobic and Aerobic Power of Top Athletes", *Eur. Jour. of Appl. Physiol.,* 1981, 47, 295-300.
8. Jolly, S. and V. Crowder, "The Energy Continuum and the Stages of Velocity in Sprinting", *Track Technique,* Winter, 1985, 91, 2909-11.
9. Kindermann, W. and J. Keul, 'Lactate acidosis with different forms of sports activities", *Canadian Jour. of Applied Sport Sc.,* 1977, 2, 177-82.
10. McKenzie, D., W. Parkhouse and W. Hearst, "Anaerobic Performance Characteristics of Elite Canadian 800 Meter Runners", *Canadian Jour. of Appl. Sprt. Sci.* 1982, 7(3), 158-60.
11. Ogorodnikov, A., "Only A Lap-400-meters" in Sprints and Relays.
12. Osnes, J. and L. Hermansen, "Acid-base balance after maximal exercise of short duration", *Jour. of Appl. Physiology,* Jan., 1972, 12(1),59-62.
13. Pollick, M., A. Jackson and R. Pate, "Discriminant Analysis of Physiological Differences Between Good and Elite Distance Runners", *Res. Qtrly. for Exerc. and Sprt.,* 1980, 51(3), 521-32.
14. Rusko, H., M. Havu,and E. Karvinen,"Aerobic Performance Capacity in Athletes," Eur. *Jour, of Appl. Physiol.,* 1978, 38, 151-59.
15. Scholich, M., "East German Study Of The Distance Stride", Track Technique, Winter, 1978, 74, 2355-59.
16. Schnabel, A. and W. Kindermann, "Assessment of Anaerobic Capacity in Runners", *Eur. Jour, of Appl. Physiol.,* 1983, 52, 42-46.
17. Svedenhag, J. and B. Sjoclin, "Physiological Characteristics of Elite Male Runners In and Off-Season", *Can. J. AppI. Spt. Sci.,* 1985, 10(3), 127-33.
18. Taunton, J., H. Maron and J. Wilkinson, "Anaerobic Performance in Middle and Long Distance Runners", *Can. J. Appl. Spt. Sc.,* 1981, 6(3), 109-13.
19. VanCoppenolle, H., "Analysis of 200 meters Intermediate Times for 400-Meters World-Class Runners", *Track & Field Quarterly Rev,* Summer, 1980, 80(2), 37-39.
20. Withers, R., R. Roberts and G. Davies, "The maximum aerobic power, anaerobic power and body composition of South Australian male representatives in athletics, basketball, field hockey and soccer", *Jour. of Sprts. Med. and Phys. Fitness,* 1977, 391-400.
21. Wyndham, C., N. Strydom, A. Van Rensburg and A. Benade, "Physiological Requirements For World-Class Performances In Endurance Running", *S. African Med. Journ.,* Aug., 1969, 19, 996-1002.