Thirty-Eight Years of Training Distribution in Olympic Speed Skaters

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During the last decade discussion about training-intensity distribution has been an important issue in sports science. Training-intensity distribution has not been adequately investigated in speed skating, a unique activity requiring both high power and high endurance. **Purpose:** To quantify the training-intensity distribution and training hours of successful Olympic speed skaters over 10 Olympiads. **Methods:** Olympic-medal-winning trainers/coaches and speed skaters were interviewed and their training programs were analyzed. Each program was qualified and quantified: workout type (specific and nonspecific) and training zones (zone 1 \( \leq 2\) mMol/L lactate, zone 2 2–4 mMol/L lactate, zone 3 lactate >4 mMol/L). Net training times were calculated. **Results:** The relation between total training hours and time (successive Olympiads) was not progressive \((r = .51, P > .5)\). A strong positive linear relation \((r = .96, P < .01)\) was found between training distribution in zone 1 and time. Zones 2 and 3 both showed a strong negative linear relation to time \((r = -1.94, P < .01; r = -0.97, P < .01)\). No significant relation was found between speed skating hours and time \((r = -0.11, P > .05)\). This was also the case for inline skating and time \((r = -0.86, P > .05)\). **Conclusions:** These data indicate that in speed skating there was a shift toward polarized training over the last 38 y. This shift seems to be the most important factor in the development of Olympic speed skaters. Surprisingly there was no relation found between training hours, skating hours, and time.

**Keywords:** polarized training, threshold training, progression

During the last half-century the quality of speed skating performance during international competitions such as the Olympic Games and various world championships has continued to improve. The simple fact that world records continue to improve is evidence that sports performance is progressing. Almost 50% of this improvement can be explained by technological improvements (indoor ovals, klapskates, high altitude, aerodynamic suits, excellent ice preparation), and the other 50%, by athletic improvement.1

With the introduction of refrigerated and covered skating rinks, athletic improvement was expected because there are more training facilities, training locations, and training times available, so athletes are training more hours under better conditions. During the last 25 years, the availability of indoor rinks has allowed skaters to do specific practice virtually year-round, whereas before 1987, the possibility of on-ice training was limited to ~4 mo/y. Furthermore, during the last 20 years the emergence of professional speed skating teams has allowed athletes to have longer careers and potentially enhanced performance development.

If the possibility for increased specific training hours is improved, another question is, has better access to specific training resulted in a change in training pattern and practice? One major element of the training pattern is the training-intensity distribution. Training-intensity distribution is generally recognized as a major component of the development of elite athletes.2–6 Studies have shown that athletes have 2 primary patterns of training-intensity distribution. The 2 main training models are the threshold and polarized training patterns.3 During the last decade, the polarized-training model has appeared to become more common in endurance athletes. However, the threshold-training model is still an accepted type of training. A number of studies have been published suggesting the benefit of polarized training on endurance performance.2–6 Despite the fact that during competition the intensity distribution is dominantly at higher intensities,4–6 endurance athletes appear to train surprisingly little in the intensity range between the lactate threshold and the intensity of the maximal lactate steady state. One reason for this could be the demand on glycogen as an energetic substrate during this type of training and the restricted training time associated with the limited glycogen stores.7 Speed skating is a unique sport, in that competition is dominantly at high power but also requires significant endurance.8,9 Furthermore, the inherent physiologic response during on-ice skating is very often above the maximal lactate steady state.
Training-intensity-distribution studies have not been widely done in ice speed skating. Speed skating is different from other endurance sports. In particular, the small angles in knee and hip in combination with a static body position and a long duty cycle of the skating stroke (~55% vs ~33% during cycling and ~10% during running) results in intermittent blood-flow restriction during parts of the skating movement. Consequently, speed skating has the tendency to a more anaerobic character, as demonstrated in several studies based on blood lactate measurements and muscle O₂ saturation. The question arises as to if and how speed skating training has evolved, given the physiological constraints that are inherent to speed skating.

To qualify and quantify the training programs used during the last 10 Olympiads we needed an intensity-quantifying distribution method to evaluate these programs. Published studies reporting the training characteristics of endurance athletes have employed several methods of quantifying intensity distribution. We choose to follow the method used by Seiler and Kjerland, because this method makes it possible to quantify the training programs (and lactate tests) we retrieved based on interviews with trainers, athletes, and coaches and their stored documentation. Accordingly, the aim of this study was to investigate the total training hours and pattern of training-intensity distribution in elite speed skaters. Our hypotheses were to find an increase in training hours over the last 38 years, with a more polarized training-intensity distribution, and given the increased possibility of on-ice training during the last 25 years, to find increases in on-ice training hours.

### Materials and Methods

We interviewed trainers and coaches of Dutch Olympic medal winners in speed skating, as well as the Olympic medal winners, in long-track middle- and long-distance events (1500-m, 5000-m, and 10,000-m, approximate competitive duration 2–15 min). Our analysis was limited to male athletes. We retrieved complete training programs of 4 Olympic Seasons (1988, 1998, 2006, and 2010) and 2 almost complete training programs (1972, missing maximally 2 wk in total, not more than 1 wk in a row, and 1992, missing maximally 4 wk in total, not more than 2 wk in a row). The missing weeks were discussed with the trainers/coaches and athletes, who suggested that the missing weeks were almost equal to the former and later training weeks, because they were in the same period of the training year. The athletes who trained on the analyzed training programs were members of the National Dutch team or of one of the commercial speed skating teams. In total, 19 of these athletes qualified for the Olympics (1971, 4; 1988, 3; 1992, 4; 1998, 4; 2006, 1; and 2010, 3) and won 8 gold, 5 silver, and 4 bronze Olympic medals.

The information from the interviews allowed us to quantify the workout intensity of each training session. There were also testing data available from several training forms in each year. We discussed the test result for each type of workout with the trainers/coaches to have a better understanding of the intensity. If there were doubts about the training intensity of a specific workout, the workout was mimicked in a contemporary group (6 men and 5 women) of compatibly elite speed skaters. Halfway through these workouts and 3 minutes afterward, completion lactate concentration was obtained to allow assignment of the workout to a certain zone. Measurements were made under field conditions (~8°C to 20°C) using the Lactate Pro LT-1710 (ArkRay Inc, Kyoto, Japan). The simulated workouts consisted of circuit training, extensive and intensive endurance training, and extensive and intensive interval training.

For each year we qualified and/or quantified each training session on the basis of

- Training workout types: speed skating, inline skating, running, cycling, jumps, weight training, slide board.
- Training-intensity zones: zone 1, lactate ≤ 2 mMol/L; zone 2, lactate 2–4 mMol/L; zone 3, lactate > 4 mMol/L. It is difficult to distribute weight training over these 3 training zones, so weight training was excluded from the training distribution, but it counted for the total training time.
- Net training minutes: To calculate net training minutes we counted warm-up (5 min) + cooldown (5 min) + active training minutes (rest times within the training were excluded). See example in Table 1.

Races were qualified as zone 3 activity, while race preparation was rated in the zones described. For each year, the analysis of the training program started with the first available training week (generally early May) and ended on the day of the Olympic race (mid-February). The yearly total hours were divided by the number of weeks of the training season (40–43) to obtain training hours per week.

### Table 1  Example of the Calculation of Gross and Net Training Time of 4 Different Workouts

<table>
<thead>
<tr>
<th>Workout</th>
<th>Gross</th>
<th>Net (gross – rest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 h cycling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm-up 5'; interval 6 × (3′—3′ rest); 5′ cooldown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm-up 5'; rest 3'; interval 5 × (6′–3′ rest);</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm-up 10'; interval 4 × (15″–2′ rest);</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rest 10″; interval 6 × (10″–2′ rest)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

42′   12′
Results

Relationship Between Training Hours per Week and Time

There was not a progressive increase in total training hours (expressed as net training hours per week) across the period of analysis (Figure 1). By comparison, during this period the world records for the men’s 1500-, 5000-, and 10,000-m improved on average by 18%. Probably this does not look dramatic, but expressed in power needed to skate at these higher speeds the increase averages an impressive 57%. Half of this improvement can be explained by technological improvements, and the other half, by athletic improvement. The relationship between total training hours and time (successive Olympiads) was not significant ($r = .51, P > .5$).

Relationship Between Training Distribution and Time

Figure 2 shows the distribution of the training hours over the 3 zones. It is clearly visible that the contribution of zone 1 has increased at the expense of zones 2 and 3. The figure shows a significant linear increase for the contribution of zone 1 and a significant linear increase for the contribution of zone 3.
decreasing contribution for zones 2 and 3 (r of, respectively, .96, \( P < .01 \); –.94, \( P < .01 \); and –.97, \( P < .01 \)). The training-intensity distribution in 1972 was essentially representative of a classic threshold pattern, whereas the training-intensity-distribution pattern after that has become increasingly polarized in character.

**Relationship Between Total Hours Skating per Season and Time**

Further analysis of specific components of training shows that there is no systematic trend in the total hours of on-ice speed skating across time (\( r = -.11, P > .05 \); Figure 3). Specific summer training for speed skating is inline skating. The hours of inline skating show a decreasing trend over the years (\( r = -.86, P < .05 \) (Figure 4).

**Discussion**

In the current study, we analyzed the training of 6 Olympic seasons over the last 38 years. For a proper comparison of the different training years we calculated the net training minutes, excluding the significant recovery time between repetitions during training sessions that are often strongly interval in character. This was done because in the first decades of our analysis it was precisely recorded which activities were done during
the training sessions, but no precise information was retrievable about recovery times in training (example in Table 1). For the later years we were able to retrieve this information, and, for instance, the training logs of 2010 showed that net (actual) training time was about 60% of gross (total) training time. We are aware of the fact that training adaptation depends partly on proper recovery time during a workout. However, it was not possible to trace all the recovery times of the older training programs. These limitations are inherent to retrospective data such as these, so we chose to report only the actual time of effective training (net training). For comparison of our calculated net training times with the literature, this fraction (gross training time = ~1.67 × net training time) needs to be taken into account. Still, the average amount of training hours was small compared with other endurance sports such as cycling, cross-country skiing, swimming, and distance running. There is a strong variation in training hours within a speed skating season. In the winter, the speed skaters’ traveling program is extensive. World Cup competitions and European and World championships are organized around the world, which is partly the reason for the low total seasonal training volume. Traveling, acclimatization to time zones and altitude, and tapering are associated with a strong decline in average training hours, which is partly the reason for the low total training hours.

To explain the performance development over the years, we first hypothesized that the total amount of training hours would have been increased over the years. Our analyses showed that this was not the case, although it is well known that training volume is an important parameter for a training effect. One reason for the lack of a significant progression of training hours across time could be the fact that specific speed skating workouts, in crouched position as used during races, restrict blood flow in the legs. Combined with the minimal speed necessary for maintaining a proper technique, this could be of such high intrinsic intensity that only a limited volume can be tolerated, both in terms of momentary metabolite burden and in terms of availability of glycogen as an energetic substrate. In favor of specific adaptation, workouts involving movements with small knee- and hip-joint angles are important. There is evidence that muscle load during weight-bearing activities with these small joint angles causes blood-flow restriction. This restricted blood flow causes an oxygen deficit in the working muscle fibers, which results in a more anaerobic energy contribution. This anaerobic character may explain why many specific training hours are qualified in moderate or high intensities (zones 2 and 3). Too much anaerobic training might hinder endurance-capacity development. This is in line with our current finding, namely, a lack of increase in speed skating hours, a declining tendency of inline training hours, and no increase in total training hours. According to trainers and coaches, on-ice speed skating training is an important factor in enhancing speed skating efficiency. However, there was no increase in speed skating hours, although there was a distinct change in terms of spreading of the skating hours over the season. Since the existence of covered speed skating ovals, speed skating is possible during part of the summer. In the past, speed skating was more concentrated during the winter months. The spreading over the training season of the specific training hours, which tend to be inherently high intensity, might be an important factor in terms of allowing the training distribution to evolve to a more polarized character. Given the change in performance, this wider distribution of skating hours appears to be beneficial for the development of athletes. Additional research is needed to explore this process.

A remarkable result of our analysis was the observation of a dramatically changed distribution of training hours over the different zones. There was an obvious increase in the percentage of training hours spent in zone 1 (lactate ≤2 mMol/L) and a decrease in the percentage of training hours in zones 2 and 3 over the years. The observed increase in the percentage of low-intensity training is also demonstrated in other studies of endurance athletes in a variety of sports. In contrast to our study, the study of Fiskerstrand and Seiler used a 2-intensity-zones model (low or high intensity). Furthermore, Seiler and Kjerland, Seiler, and Esteve-Lanaro et al (3-zone quantification model) and Yu et al showed, as well, that a larger amount of low-intensity training is effective in stimulating physiological adaptations. Although different experimental research designs were used (cross-sectional in Seiler and Kjerland and Esteve-Lanaro et al, quasi-experimental in Yu et al), their results demonstrate that a larger percentage of training in zone 1 was beneficial. Geijser reported in 1979 that marathon skaters who had formerly done a lot of skating simulations (high intensity) became better as they added more cycling (lower intensity) to their training program. In addition, Seiler and Kjerland and Yu et al reported that training at low intensities in combination with a much smaller amount of training hours at moderate intensity (zone 2) compared with high intensity (Zone 3) is even more effective. This combination of low and high intensities is called polarized training. Our data showed that both moderate and high training zones declined over time but the percentage of moderate training intensities is still higher than the percentage at high training intensities. This is reasonably attributable to the inherently high intensity of skating training, such that even the so-called endurance sets cannot be accomplished in zone 1 and became zone 2 activities.

A potential limitation of the 3-intensity-zone quantification model used in the current study is the resolution of the intensity zones. The division of the high-intensity zone in only 1 zone with lactate >4 mMol/L is especially open to discussion. In this relatively large zone many different training intensities specific for the different competitive race distances can be used. Stepto et al identified 5 intensity zones at 80%, 85%, 90%, 100%, and 175% of the subjects’ maximal power output within our zone 3. They showed a U-shaped relation between physiological adaptation and training intensity. Because
of this U-shaped relation, the conclusion can be made that zone 3 is polarized by itself. In that case it could be more appropriate to speak about a 3-wave model. To avoid the early mentioned limitation and to get a better understanding of training-intensity distribution, in future investigations a method with a better differentiation in this zone could be beneficial.

**Conclusion**

Our data indicate that for successful middle- and long-distance speed skaters there was a shift toward polarized training over the last 38 years. Surprisingly, there was no increase in net training hours and hours of on-ice skating over these years, while performance increased considerably. The current findings clearly show the importance of training-intensity distribution.

**Practical Application**

Our findings could be an important guide for trainers/coaches to balance their training programs and to transfer results from research in other sports to speed skating. On the basis of the presented findings it can be concluded that changes in training-intensity distribution were an important factor in the development of speed skating over the last 38 years.

**Acknowledgments**

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**References**
