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Introducing a Method to Quantify the Specificity of Training for Races in Speed Skating

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Abstract

Roete, AJ, Stoter, IK, Lamberts, RP, Elferink-Gemser, MT, and Otter, RTA. Introducing a method to quantify the specificity of training for races in speed skating. *J Strength Cond Res* XX(X): 000–000, 2022—The specificity of training for races is believed to be important for performance development. However, measuring specificity is challenging. This study aimed to develop a method to quantify the specificity of speed skating training for sprint races (i.e., 500 and 1,000 m), and explore the amount of training specificity with a pilot study. On-ice training and races of 10 subelite-to-elite speed skaters were analyzed during 1 season (i.e., 26 weeks). Intensity was mapped using 5 equal zones, between 4 m·s^{-1} to peak velocity and 50% to peak heart rate. Training specificity was defined as skating in the intensity zone most representative for the race for a similar period as during the race. During the season, eight 500 m races, seven 1,000 m races, and 509 training sessions were analyzed, of which 414 contained heart rate and 375 sessions contained velocity measures. Within-subject analyses were performed. During races, most time was spent in the highest intensity zone (Vz5 and HRz5). In training, the highest velocity zone Vz5 was reached 107 ± 28 times, with 9 ± 3 efforts (0.3 ± 0.1% training) long enough to be considered 500 m specific, 6 ± 5 efforts (0.3 ± 0.3% training) were considered 1,000 m specific. For heart rate, HRz5 was reached 151 ± 89 times in training, 43 ± 33 efforts (1.3 ± 0.9% training) were considered 500 m specific, and 36 ± 23 efforts (3.2 ± 1.7% training) were considered 1,000 m specific. This newly developed method enables the examination of training specificity so that coaches can control whether their intended specificity was reached. It also opens doors to further explore the impact of training specificity on performance development.

Key Words: athletic performance, heart rate, velocity, athletes, long-track speed skating, physiology

Introduction

In sports, training is considered an important way to improve performance. Training can be described as a dose-response relationship in which the stress of training on an individual athlete (referred to as load or dose) yields subsequent changes in performance (generally referred to as a training response) (1). Training at the specific load of individual events, thus duplicating the sport-specific intensity and duration, may elicit specific adaptations that could enhance performance (12,19). However, understanding of the precise load underlying performance development in athletes is limited (16), and studies examining the similarities between competition and training demands are scarce in the field of endurance sports. Those comparisons have been made in a variety of team sports (10,11,13) that, for example, focused on the time spent in different sport-specific velocity or heart rate zones. Training intensities were often unable to replicate the high-intensity demands of competitive events (10,11,13). Long-track ice speed skating, from here on referred to as "speed skating," is an individual endurance sport and holds various events: sprint (500 and 1,000 m), middle (1,500 m), and long-distance events (3,000, 5,000, 10,000 m). Each race distance calls for a specific energy distribution and therefore may require a unique type of training (14). Still, knowledge is lacking about how race-specific the training is and how it could be quantified for each speed skating distance.

Previous research has studied speed skating pacing patterns using lap times (400 m laps) and showed that sprint races in general are characterized by a rapid acceleration at the start of the race, followed by a phase of relatively constant velocity, whereas a deterioration of speed (velocity) is generally observed toward the end of a race (4,17). In line with this pattern, heart rate tends to rapidly increase from the start of a race, with most speed skaters reaching their maximal heart rate midway through the race (7). From a physiologic perspective, a training program must target those energy systems engaged in performing a particular activity to achieve specific training adaptations (2,19). A challenge in speed skating, however, is that the amount of race-specific stimuli that can be executed may be limited because of a skater's crouched positions and static gliding phases because of which there seems to be a blood flow restriction (8). This position is needed for a proper skating technique with which a skater can produce a powerful extension of the legs to produce high velocities. However, this crouched position also results in higher blood lactate and heart rates at a given $\dot{V}O_2$ than in other sports such as running or cycling (8,9,18). These physiologic reactions intrinsic to the speed skating movements may be of such intensity that only a limited volume can be tolerated (18). Currently, knowledge is limited on how to quantify the distribution of training time at high intensity and time at middle- or low-intensity in training of speed skaters based on physiologic measures. An exception is the study of Yu et al. (24). This study showed

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Journal of Strength and Conditioning Research 00(00)/1–7

that the performance of elite Chinese sprint speed skaters improved when their training was adapted from a threshold to a polarized intensity distribution, resulting in more training time at high and low intensities (24). However, this study did not further investigate whether the high intensities in training were related to the intensity levels in competition.

To the best of our knowledge, a method to examine the specificity of training for sprint races in speed skating does not exist. Therefore, it is unknown how much speed skaters train on race-intensity. The aim of this study was to develop a method to quantify the specificity of speed skating training for sprint races and explore the amount of training specificity for sprint races during an entire season with a pilot study.

Methods

Experimental Approach to the Problem

To develop a method to quantify the specificity of speed skating training for sprint races, 17 speed skaters of 1 team were monitored. Data were collected during the 26 weeks of a competitive speed skating season. The speed skaters trained daily and competed in races on a weekly basis. Training and competition data (velocity, heart rate, and performance) were recorded at the teams' home track. Official race results were obtained from an online database (www.speedskatingresults.com).

Subjects

To be included in the pilot study, the speed skaters needed to keep the teams' home track as their base training track throughout the season, as only on that particular track velocity could be measured as performed in this study. Speed skaters were excluded from the study if they were not able to train regularly on their home track because of, for example, transfer to another team, regular international competitions or injuries. Finally, in line with the aim of this study, criterion sampling (21) was purposefully applied to select those speed skaters of the monitored speed skating team who would compete in at least 1 sprint race on the teams' home track during the season. Of the 17 speed skaters, 4 men (age: 19 ± 1 year, bodyweight: 68 ± 11 kg, height: 179 ± 6 cm) and 6 women (age: 19 ± 2 years, bodyweight: 67 ± 3 kg, height: 174 ± 3 cm; mean and *SD*) met the criteria. The speed skaters trained on a daily basis and competed on a weekly basis. The speed skaters were performing at elite- or subelite-level following the classification of Stoter et al. (23), meaning that the seasonal best times (SBTs) of the speed skaters were within 115% of the prevailing world records (WR at the end of the monitored season) ($SBT_{500\ m}$ = 109.43 ± 3.80% WR, $SBT_{1,000\ m}$ = 108.85 ± 1.51% WR). The study was approved by the ethics committee of the Local Ethical Committee of the Department Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands and, all speed skaters were informed on the benefits and possible risks associated with participation in this study before signing a written informed consent form. All speed skaters were aged 18 years or older upon signing the informed consent. In addition, the study was conducted in accordance with principles set out in the Helsinki Declaration (2013).

Velocity

The velocity of races and training was determined by 12 MyLaps measurement loops (MyLaps bv, Haarlem, the Netherlands), which is embedded into the 400 m ice-track in Heerenveen, The Netherlands. As part of measuring velocity, speed skaters were asked to wear a transponder (MyLaps Prochip Classic), which was strapped to an ankle of the speed skater. The MyLaps system in combination with the transponder, was able to sample velocity data at the ice-track with a timing resolution of 0.003 in a value up to 4 decimals when going over the measurement loops. Velocity was calculated as the mean velocity in meters per second by the division of the distance between the loops and the time between the loops. The distances between the loops ranged from 55.2 to 11.6 m gaps, see also Figure 1 for the placement of the loops.

In competitions, speed skaters start in the inner-lane or outer-lane of the track and then switch lanes in each round (see also Figure 1). This strategy corrects for that the outer lane is slightly longer in distance and makes sure that both speed skaters have completed the same distance at the end of a race. The effect of the starting lane on the distance between loops was taken into account for the velocity determinations of competition data. In training, the organization was done in such a way that skating bouts were mainly performed in the inner lane. Consequently, the distances between the loops belonging to the inner lane were used to determine training velocities.

Heart Rate

Heart rate was measured continuously with a Polar Team2 chest strap (Polar Electro Oy, Kemple, Finland) that was sampled at 1,000 Hz. Using the Polar Team2 software, heart rate data were manually marked and then sliced to retrieve heart rate values belonging only to the race or on-ice training.

Quantifying Intensity

Velocity and heart rate were analyzed for each subject by the time spent in 5 intensity zones. Velocity zones were not used previously in speed skating and therefore a new method for intensity zones was defined in this study. To only include active moments of training, the velocity zones started at 4 $m \cdot s^{-1}$, because this velocity corresponds with riding in an upright position for our group. When they ride faster, they assume the crouched position. The 5 active velocity zones (Vz1–5) ranged from 4 $m \cdot s^{-1}$ to the speed skaters' peak velocity (V_{peak}) and were equally spaced, meaning: Vz1: 0–19%, Vz2: 20–39%, Vz3: 40–59%, Vz4: 60–79%, Vz5: 80–100% of active velocity range. Five zones have been chosen to match the 5 heart rate zones described below. V_{peak} was individually determined over the entire season and included all races and training sessions. Exit from the velocity zones was calculated as the moment when more than 1 value was continuously situated outside the velocity zone. The 5 heart rate zones (HRz1–5) were based on the zones originally presented by Edwards (6). The time spent in predefined heart rate zones was calculated as: HRz1: 50–59%, HRz2: 60–69%, HRz3: 70–79%, HRz4: 80–89%, HRz5: 90–100% of HR_{peak}. HR_{peak} is the highest measured heart rate of a speed skater during the entire speed skating season, all races and training sessions included. So, all zones were calibrated to each individual's peak velocity and heart rate. To check whether the calculated intensity zones captured the total time on ice, the time spent below Vz1 and HRz1 were calculated as well ($Vz0 = V < 4\ m \cdot s^{-1}$; HRz0 = 0–49% of HR_{peak}).

Specificity

The first step was to determine the characteristics of the sprint races in velocity and heart rate. Second, the same methodology was applied to characterize training throughout the season. The

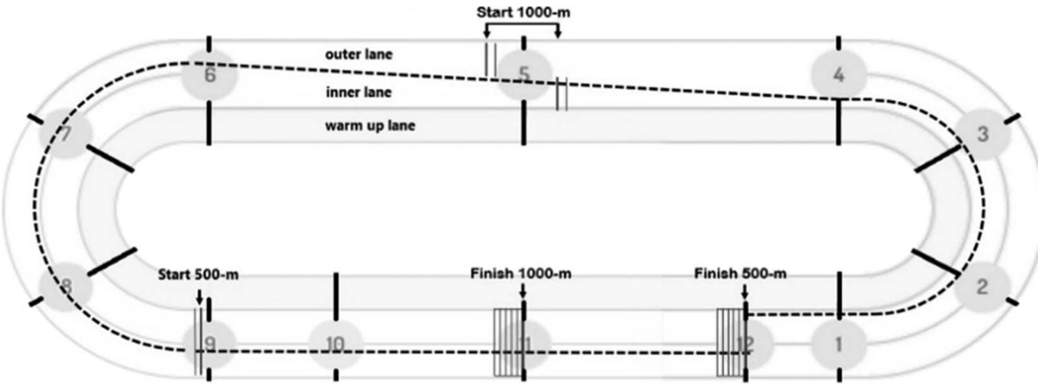

Figure 1. Overview of the speed skating track. Black lines interspersed by a number (1–12) indicate the placement of a measurement loop under the ice. The black dotted line represents the 400 m lap, containing 1 outer lane corner, 1 inner lane corner, skated 0.5 m of the inner edge of the skating lane. Text and the corresponding arrows indicate the start and finish position of the sprint races.

third step was to determine when a speed skater had trained specifically for a race distance. Foster et al. (9) noted that skating velocity is largely muscle-specific and that training becomes more specific when a speed skater is able to tolerate longer intervals at the target pace of the race. Reilly et al. (19) defined specificity as a combination of intensity, duration, and mode of sport. Based on that definition, training specificity in this study was defined as: skating in the intensity zone most representative for the race for a similar period as during a race performance. A similar duration was achieved during training when a speed skater spent at least the mean minus 1 *SD* in the race-specific intensity zone as performed by the speed skaters during the race. The specificity of training for the sprint races was mapped as the absolute number of times a speed skater trained specifically for the intensity and duration of sprint races during the season (i.e., absolute training specificity) and, by the percentage of the total training time it represented (i.e., relative training specificity).

Statistical Analyses

For this pilot study, descriptive data were presented as mean ± *SD*. Before statistical testing, normality was verified by the Shapiro–Wilk *W* test and by visual inspection of Q-Q plots. In case of normality, paired samples t-tests were conducted. Otherwise, nonparametric testing was applied using paired samples Wilcoxon tests. Tests were computed to determine whether differences existed in absolute or relative training specificity of velocity between the 500 and 1,000 m. A similar analysis was executed for heart rate. In addition, tests were executed to determine whether differences existed in absolute or relative training specificity for the 500 m between velocity and heart rate. A similar analysis was executed for the 1,000 m. 95% confidence intervals (CIs) and effect sizes reported as Cohen's *d* were determined for data interpretation. Qualitative interpretation of *d* was based on the benchmarks suggested by Cohen (3): 0–0.2, small; >0.2–0.5, medium; >0.5, large. The significance level was set at $p < 0.05$. All data analyses were done with MATLAB (R2018b; Mathworks, Natick, MA).

Results

Velocity and Heart Rate Intensity Zones

Overall, the skaters reached a V_{peak} of 15.50 ± 0.46 $m{\cdot}s^{-1}$. Of the 10 speed skaters, 8 reached a higher V_{peak} during training than during races. Four meters per second, the estimated velocity at which speed skaters transition to the crouched position, occurred at 25.8 ± 0.77% of the speed skaters' V_{peak}. The mean range of each velocity zone was 2.30 ± <0.01 $m{\cdot}s^{-1}$, which represented ranges of 14.8% V_{peak}, meaning that the 5 velocity zones (Vz1–5) ranged from: Vz1: 25.8–40.6%, Vz2: 40.7–55.4%, Vz3: 55.5–70.3%, Vz4: 70.3–85.1%, Vz5: 85.2–100% V_{peak}. Overall, the HR_{peak} of the skaters was 198 ± 5 bpm. Of the 10 speed skaters, 4 reached a higher HR_{peak} during training than during races. The range of each heart rate zone, accounting for 10% of HR_{peak}, was 20 ± 1 bpm.

Sprint Races

Of the 10 speed skaters, 8 performed a 500 m race while being monitored, with 1 of these races yielding velocity data without heart rate data. Seven speed skaters performed a 1,000-m race while being monitored. The mean finishing times of the eight 500 m races was 39.31 ± 1.86 seconds and of the seven 1,000 m it was 75.15 ± 2.96 seconds. The monitored races were 101 ± 1% of the speed skaters' SBTs.

The velocity profile of the races is presented in Figure 2A, B. The peak race velocities were a mean of 14.68 ± 0.73 $m{\cdot}s^{-1}$ for the 500 m and 15.15 ± 0.62 $m{\cdot}s^{-1}$ for the 1,000 m. These peaks were reached around the second corner for the 500 and the 1,000 m, namely at 405.31 ± 57.32 m (32.59 ± 3.54 seconds) during the 500 m race and at 274.55 ± 30.10 m (22.90 ± 1.64 seconds) during the 1,000 m race. Mean velocity was 12.67 ± 0.58 and 13.31 ± 0.52 $m{\cdot}s^{-1}$ for the 500 and 1,000 m, respectively. Most time was spent in Vz5 during the 500 m and the 1,000 m. During the 500 m, it was 24.16 ± 1.07 seconds (61 ± 3% total race time) and, during the 1,000 m, it was 52.78 ± 11.60 seconds (70 ± 15% total race time). After entering Vz5, all speed skaters were able to remain in Vz5 throughout the 500 m race, whereas 4 of the 7 speed skaters were not able to remain in Vz5 during the last lap of the 1,000 m.

Heart rate profiles are shown in Figure 2C, D. At the start of the race, the speed skaters were in HRz3 or HRz4, because the mean heart rate at race onset was 163 ± 6 bpm (83 ± 2% HR_{peak}) for the 500 m and 159 ± 7 bpm (80 ± 4% HR_{peak}) for the 1,000 m. Heart rate increased from the start of the race and did not decline during the race. HR_{peak} of the 500 m was 195 ± 6 bpm, and for the 1,000 m it was 196 ± 6 bpm. The peaks were reached at an average of 440.26 ± 44.55 m during the 500 m, which was for all riders in the last straight part before the finish except for 1 rider who reached the peak near the end of the last corner. During the 1,000 m, the peaks were reached at an average of 606.18 ±

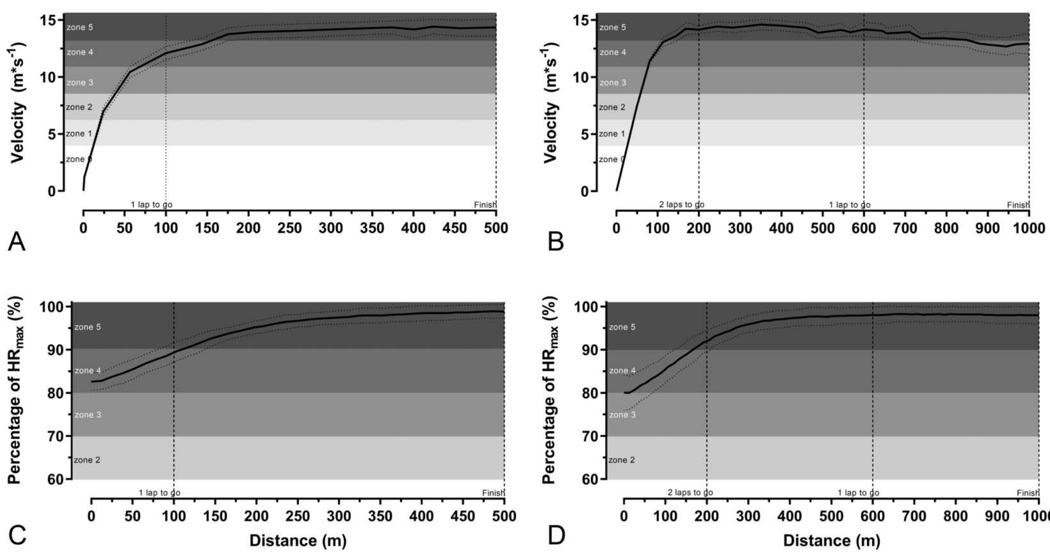

Figure 2. Mean velocity of the 500 m (A) and the 1,000 m (B), mean heart rate (HR) of the 500 m (C) and the 1,000 m (D).

83.75 m, which was before the third corner, after the third corner, before the fourth corner or in the fourth corner of the race. Mean heart rate was 186 ± 6 bpm for the 500 m and 189 ± 5 bpm for the 1,000 m. During the race most time was spent in HRz5. The time spent in HRz5 was 30.86 ± 2.54 seconds (79 ± 6% total race time) during the 500 m race and 63.14 ± 4.26 seconds (84 ± 6% total race time) during the 1,000 m race.

Training Sessions over the Entire Season

A total of 509 training sessions were monitored on the speed skaters' home-track during the season. Velocity data were collected during 375 sessions, with 38 ± 8 sessions per speed skater, containing 34 ± 10 hours of training per speed skater. 414 sessions yielded heart rate data, with 41 ± 9 sessions per speed skater, containing 36 ± 7 hours of training per speed skater. The speed skaters trained 88 ± 8% of the season on their home-track, velocity data were obtained for 81 ± 9% of the training time and heart rate data was obtained for 73 ± 9% of the training time.

The highest measured velocity during training was a mean of 15.49 ± 0.45 $m{\cdot}s^{-1}$. The velocity zones Vz1–5 and Vz0 captured approximately 85% of the total training time, so approximately 15% of training time was not mapped. More than half of the total training time was spent in Vz0, indicating that the speed skaters spent more than half of their training time in active recovery. Over the course of the entire season, the shortest time was spent in Vz5 (which corresponds to specific race intensity), namely 1.2 ± 0.4% total training time.

The highest measured HR during training was 196 ± 5 bpm. Most of the training time (~97%) resorted to heart rate zones HRz1–5. During the season, the least amount of training time was spent in the lowest and the highest HR zones (HRz1 and HRz5), whereas most of the time was spent in the middle HR zones (HRz2–4). Figure 3 shows the relative time spent in Vz0–Vz5 and HRz0–HRz5 during training and during sprint races.

Specificity of Training for the Sprint Races

The race-specific intensity zone regarding velocity (Vz5) was reached 107 ± 28 times. For this group of speed skaters, all efforts in Vz5 from 23.1 till 41.2 seconds were considered as 500 m specific. Efforts of 41.2 seconds and longer were considered as 1,000 m specific. See Table 1 for the absolute and relative training specificity for the 500 and 1,000 m. Paired samples t-tests showed that the absolute training specificity was higher for the 500 m than for the 1,000 m ($p = 0.05$, CI: 0.26–6.74, $d = 0.77$, large), whereas the relative training specificity did not differ ($p = 0.74$, CI: −0.26 to 0.19, $d = 0.13$, small). Most often, when the skaters did intervals in Vz5, the duration of the interval was too short to be sprint-race-specific (<23.1 seconds), which occurred for a mean of 92 ± 25 efforts (0.7 ± 0.2% of total training time).

Regarding heart rate, the race-specific intensity zone (HRz5) was reached 150 ± 89 times. All efforts in HRz5 from 28.3 until 58.9 seconds were considered as 500-m-specific and efforts of 58.9 seconds and longer were considered as 1,000-m-specific. See Table 1 for the absolute and relative training specificity. Paired samples t-tests showed no differences between the 500 and 1,000 m regarding absolute training specificity ($p = 0.66$, CI: −21.48 to 32.88, $d = 0.28$, medium), whereas the relative training specificity was higher for the 1,000 m than for the 500 m ($p = 0.01$, CI: −3.14 to 0.50, $d = 1.16$, large). Most often, when the riders were in HRz5, the duration was too short to be sprint-races-specific (<28.3 seconds), those intervals occurred for a mean of 73 ± 44 efforts (0.7 ± 0.3% of the total training time).

Paired samples Wilcoxon tests showed that the training specificity of heart rate, when expressed as an absolute or relative value, was higher than specificity of velocity for the 500 m (500 m absolute training specificity: $p < 0.01$, CI: 9.00–64.00, $d = 0.95$, large; 500 m relative training specificity: $p < 0.01$, CI: −1.90 to −0.40, $d = 1.11$, large). Paired samples t-tests showed this also for the 1,000 m (1,000 m absolute training specificity: $p < 0.01$, CI: −47.0 to −14.00, $d = 1.24$, large; 1,000 m relative training specificity: $p < 0.001$, CI: −4.08 to −1.61, $d = 1.58$, large).

Discussion

The aim of this study was to develop a method to quantify the specificity of speed skating training for sprint races and explore the amount of training specificity for sprint races during a season with a pilot study. The application of this method on the races and on-ice

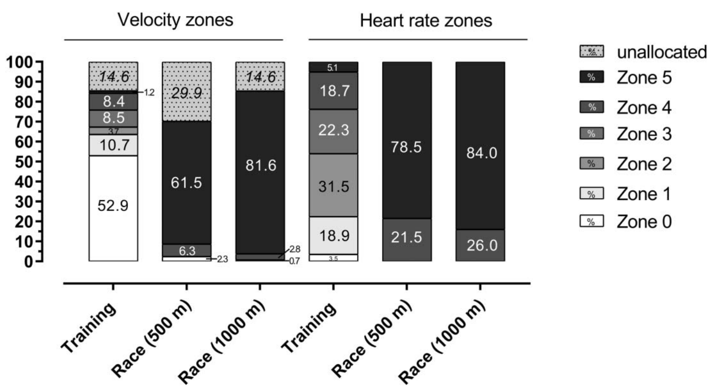

Figure 3. Relative time spent in the velocity and heart rate zones during training, 500 and 1,000 m.

training of subelite and elite speed skaters during an entire season yielded multiple findings. The first finding of this study is that velocity in sprint races can be mainly defined by the time spent in the highest velocity and heart rate zones. Second, this study showed that in an entire season of training, the highest intensity zone was reached for a mean of 107 ± 28 times for velocity and a mean of 151 ± 89 times for heart rate. Third, of those efforts, 9 ± 3 efforts (0.3 ± 0.1% training time) for velocity and 43 ± 33 efforts (1.3 ± 0.9% training time) for heart rate were 500-m-specific. In addition, 6 ± 5 efforts (0.3 ± 0.3% training time) for velocity and 36 ± 23 efforts (3.2 ± 1.7% training time) for heart rate were 1,000-m-specific. For both distances, there was a higher training specificity for heart rate than for velocity ($p < 0.01$).

In an effort to test the method, this study set out to map the sprint races. Speed skaters increased their velocity and heart rate from the very beginning of the race and postacceleration, most riders remained at high velocities and heart rates until the end of the race. Remarkably, the peak velocities were reached earlier in the 1,000 m than in the 500 m. So even though in both distances, the skaters reached their peak velocity around the second corner, because of the starting position of the distances, the skaters need to cover less distance before reaching the second corner in the 1,000 m compared with the 500 m. Based on personal observations in this current study, it seems that speed skaters accelerate more in the corners than during the straight parts of the ice-track. This is probably because of a continuous push-off in the corners, whereas on the straight parts of the ice-track there is often a gliding phase before the push-off. This also implies that coaches could implement differences in accelerations into practice to make the training more specific to different race distances.

The second step in this study was to analyze on-ice training. In speed skating, a high aerobic and anaerobic power is required (7). Endurance athletes' training is commonly monitored in heart rate. Stöggl and Sperlich (22) noted that elite and well-trained endurances athletes' performances occur at >90% of maximal heart rate for 20% of the total training time. In this study, speed skaters' performances were with 5.1% of total training time well-below these noted outputs, which is probably because of the aerobic and anaerobic nature of speed skating. Therefore, we have introduced velocity zones, which could add an indication of anaerobic power which serves to further highlight the novelty of this method.

Previous studies have reported on the benefits and current applications of polarized training distributions in speed skating

Table 1
Training specificity over the entire season.*

	Velocity		Heart rate		Velocity		Heart rate	
Skater	Absolute training specificity 500 m (efforts)	Relative training specificity 500 m (% training time)	Absolute training specificity 500 m (efforts)	Relative training specificity 500 m (% training time)	Absolute training specificity 1,000 m (efforts)	Relative training specificity 1,000 m (% training time)	Absolute training specificity 1,000 m (efforts)	Relative training specificity 1,000 m (% training time)
1	11	0.4	20	1.0	0	0	19	2.1
2	6	0.2	58	1.9	1	<0.1	37	3.3
3	12	0.4	29	0.9	14	0.8	13	1.1
4	10	0.3	56	2.1	1	<0.1	36	3.2
5	7	0.2	43	1.1	3	0.1	44	3.1
6	15	0.5	24	0.8	10	0.6	50	5.8
7	4	0.2	11	0.4	8	0.7	15	1.7
8	7	0.1	126	3.4	4	0.1	84	5.2
9	12	0.3	19	0.8	9	0.3	11	1.0
10	7	0.1	32	0.9	6	0.3	52	5.0
Mean ± *SD*	9 ± 3	0.3 ± 0.1	42 ± 33	1.3 ± 0.9	6 ± 5	0.3 ± 0.3	36 ± 23	3.2 ± 1.7

*Training was considered 500 m specific when the time spend in the race specific intensity zone by a speed skater was between 23.1 and 42.2 seconds for velocity and between 28.3 and 58.9 seconds for heart rate in the race specific intensity zone. Training was considered 1,000 m specific when the time spent in the race specific intensity by a speed skater was 41.2 seconds or longer for velocity and, 58.9 seconds or longer for heart rate.

for sprinters (24), male middle- and long-distance speed skating (18). It is difficult to make comparisons with these studies because they examined training distribution in 3 intensity zones, whereas we worked with 5 zones. The 3 zones are not meant to measure race specificity, because these ranges are too broad. However, a comparison with studies that used 3 zones may indicate that training at higher intensities (closer to race intensities) can be beneficial. Based on results obtained by Seiler and Kjerland (20) (in a study of 17- to 18-year-old cross-country skiers) and values reported by Yu et al. (24), we may estimate that heart rate zone 5 represented the time spent above the second ventilatory threshold (i.e., high) and that heart rate zone 4 represented the intensity between the first and second ventilatory threshold (i.e., moderate) (20,24). Yu et al. (24) reported a training distribution where most of the time was recorded at low intensity, and the least amount of time at moderate intensity. In the study by Orie et al. (18) it was noted that most time was spent at low intensity, followed by moderate intensity. However, comparisons with those studies are also difficult because the studies of Orie et al. (18) and Yu et al. (24) included other sport modes in the presented training distributions as well (e.g., cycling, running, strength). These alternative types of training are often included in the skaters' training programs because ice may not be available during the entire season. In addition, they are added to the program to be able to train at lower intensities as the crouched position during skating result in exercise bouts mainly of anaerobic character (8,18). We have not taken other training types into account in our study, as following our definition, those are not specific. Even though this study focused on the specificity of training for races, we acknowledge that high intensities for shorter durations than our definition of specificity and low-intensity activities may also play a role in the performance development of speed skaters. The anaerobic and aerobic energy systems have to be developed in speed skating (7,15).

Based on the exploration of the specificity of speed skating training for races, it was noticed that speed skaters trained more specific on heart rate than on velocity. This may be because of the use of interval training at which there is a short rest between repeated exercise bouts. Incomplete recovery can lead to a rise of heart rate during later exercise bouts (5) of which velocities may have been lower than race-specific. In addition, heart rate inertia at the end of an exercise bout (often referred to as heart rate recovery) can create an overestimation of the actual work done (2) whereas velocity may drop quickly and needs time to get up again to the highest velocity zone. Finally, heart rate is not able to inform on the intensity of physical work done above the velocities associated with $\dot{V}O_2max$ (2), so whereas heart rate may be near maximal values, velocity may not be near the race specific intensities. Because this was a pilot study on only 1 group of speed skaters, more research needs to be done with more training groups to see whether this is the case in more groups and at all ages.

This study has more limitations that should be considered when interpreting these results. Most notably is the usage of intensity zones to determine what intensity was race-specific. This study used the intensity zone that was most representative for the sprint races as race-specific. As such this method does not take into account the demands of the acceleration at race onset. The advantage of using the intensity zones was that it could be determined during races and during training. In addition, the advantage of velocity and heart rate for speed skating is that subjects were not required to use additional equipment and it did not interfere with the speed skaters' movement or performance. This makes the method highly sport-specific and individualized as the peak velocity and peak heart rate were determined during speed skating. Another consideration of this study's method is that velocity was derived from loop data, which were recorded noncontinuously. Actual time spent in the intensity zones may thus have been underestimated, and the determined velocities may slightly differ with the actual continuous velocity. However, many loops (i.e., 12 over a course of 400 m) were used to determine velocity, which makes it unlikely that large fluctuations in measures of velocity would occur. And even though the velocity data was noncontinuous, our method provides a lot more details than the lap times used by previous studies with 1 data point per lap. For example, a study by Muehlbauer et al. (17) examined the 1,000 m event by the time needed to complete the three-race segments (0–200, 200–600, and 600–1,000 m) and observed a decline in velocity during the 600–1,000 m segment. In addition to these findings, our measurement method shows that this deceleration starts earlier in our group of speed skaters.

To the best of our knowledge, this study is the first to develop a method to examine the training specificity in speed skating based upon data of a speed skating team throughout an entire season using heart rate zones and novel velocity zones. This methodology enables a sport-specific individualized examination of races and training throughout the season, thus facilitating a feasible comparison between the 2 entities in time-trial sports. This process will enable researchers and coaches to further explore the impact of training specificity on performance development. Future research can use this valuable data as a reference to determine the effect of training specificity, thereby shedding light on physiologic factors underlying performance development.

Practical Applications

The tested method can be used to examine and visualize the effort of races and on-ice training. In doing so, training specificity for races using heart rate zones and the novel velocity zones can be established. This process will enable researchers and coaches to further explore the impact of training specificity on performance development. The application of this new method showed that sprint races are executed at the highest intensities whereas training mostly occurs at lower intensities and if high intensities were performed in training, it was mostly done shorter than during races. In addition, this pilot study noticed that training is more specific based on heart rate than based on velocity. Coaches could reflect whether this is the case in their own training group as well and seek for training drills at which velocity can be maintained for a longer period of time which is more race-specific.

Using this method as a starting point, future longitudinal studies could add to the knowledge store regarding the dose-response relationship in speed skating as well as in other sports. In addition, coaches can use this method to visualize the heart rate and velocity data of their athletes to control if the intended training specificity has been reached by each individual.

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