Wingate test as a strong predictor of 1500-m performance in elite speed skaters
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Evaluation of anaerobic energy production is important to athletes involved in speed-endurance sports. The Wingate test is one of the most popular laboratory tests designed to evaluate anaerobic power. This 30-second cycle ergometer test has been shown to be effective at distinguishing successful from nonsuccessful speed skaters. However, van Ingen Schenau et al concluded that measures of anaerobic power did not appear to be of use in evaluating seasonal (eg, longitudinal) progression in performance or cross-sectional identification of performance-influencing factors in homogeneous groups of highly-trained, all-round speed skaters. Speed skating is a seasonal sport, which means that racing and specific training takes place during the winter months, while most physical conditioning takes place in summer, with long periods without ice or competition. Thus, summer training does not inherently provide good references for winter race performance, although for proper guidance of the training process in elite athletes regular testing to provide a performance reference would potentially be useful. This holds not only for speed skating, but also for many other seasonal sports (eg, skiing, hockey). This raises the question of how well markers of general fitness, such as measures from the Wingate test, translate into on-ice performance in the subsequent winter within homogeneous groups of athletes. As identified by Foster et al and van Ingen Schenau et al, tests to monitor the effects of training programs should provide measures that have both a significant correlation with performance, and reflect competitive progression with the progression of training. Therefore in this study we search for a tool to be used during the summer training period that provides measures that correlate with performance in winter and which are also sensitive to changes in exercise capacity due to training.

With the introduction of the klapskate around the turn of the century, the 1500 m, which had always been the “index event” for speed skating, became more the domain of sprint-oriented athletes. The 1500-m speed skating World Record is currently 1:41.04 for men and 1:50.85 for women, so final times and use of energy systems are comparable with events like 800-m running or 200-m swimming. The 1500-m is skated at speeds that should require a power output well above VO2max, with the overall energy contribution approximating 55% aerobic and 45% anaerobic. Foster et al found, in a 1500-m cycling simulation study, that the distribution of the energy systems ranged from 16% aerobic and 84% anaerobic in the first part to 72% aerobic and 28% anaerobic in the last part of the time trial, so all energy systems are heavily stressed during a 1500-m effort. Similar findings are found in 800-m running. Because the anaerobic energy system is highly stressed during 1500-m speed skating, the Wingate test is an obvious candidate to consider as a tool to predict success at the 1500 m in winter competitions.

Therefore our research question is: Are outcomes of Wingate tests performed during the summer training period predictive of 1500-m speed skating performance in the subsequent winter in elite speed skaters?

Methods

The subjects for this study were 13 elite speed skaters (8 male, 25.3 [SD 3.5] y; 5 female, 27.3 [SD 3.5] y). Their elite status was evidenced by results at the Olympic Winter Games (4 gold and
1 silver medals), World Championships (19 gold, 6 silver, and 17 bronze medals), World Cups (68 gold, 56 silver, and 45 bronze medals) and Dutch national championships (54 gold, 49 silver, and 43 bronze medals).

Cycling Wingate test results from the summer training period, during which each subject had to perform 3 or 4 Wingate tests, and 1500-m performances at the first important winter competition following that summer (Dutch single distance championships in November), were analyzed over a 3-year period. The number of year-by-year observations varied per subject due to uncontrollable team selection strategies, injuries, and the ending of speed skating careers. In the males, there were 3 years of data for 2 athletes, 2 years of data for 4 athletes, and 1 year of data for 2 athletes. In the females, there were 2 years of data for 3 athletes and 1 year of data for 2 athletes.

Outcome Variables

The outcome variable was the official 1500-m time (Anatec electronic timing, The Netherlands) at the Dutch single distance championships in November, as assessed by official race protocols. The split times (cumulative time at 300, 700, and 1100 m) and 400-m lap times were retrieved from the official race protocols and used as an index of the pacing strategy during each race.

Predictor Variables

Wingate tests were performed on an electrically braked bicycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands) in laboratory conditions. A standardized warm-up was performed prior to each test, and all tests were conducted after a normal regeneration period. Resistance for male and female subjects was applied as 10% and 8% of body weight, respectively. The athletes had a 10-minute warm-up at 100 Watts, including 2 accelerations of 5 to 10 seconds, before the Wingate test was performed. After the warm-up, the subjects rested for 2 minutes.

All subjects remained seated and started from a complete standstill. We chose starting from a complete standstill as in the experiments of de Koning et al and as recommended by MacIntosh et al, rather than the more commonly used “flying start” on both theoretical grounds (a flying start is power output generated before the test) and on the applicability to the real-world setting of speed skating, where early power generation is important to success. After a 5-second countdown the test was started and subjects pedaled as fast as possible for 30 seconds. Verbal feedback as to the time remaining was provided at 15, 10, 5, 4, 3, 2, and 1 second remaining. Power output was measured at 1 Hz and digitally stored for later analysis. Peak power (PP) was taken as the highest power value during the test and mean power (MP) the average value over the test duration. Each subject had to perform 3 to 4 Wingate tests throughout the summer training period, starting in April with intervals of 6 to 8 weeks between the tests. The average value across the summer test sessions for each year was used in the statistical analyses.

Statistical Analysis

To determine whether Wingate test performance in the summer period was predictive of the 1500-m performance during the subsequent winter period, regression analyses were performed using generalized estimating equations (GEE). This approach to regression analyses considers the measurements within subjects of subsequent years as repeated measurements, and accounts for this dependency. An exchangeable working correlation structure was used. In separate regression analyses PP and MP were used to predict 1500-m final times, split times, and lap times, respectively. Regression coefficients for the predictor variables and their 95% confidence intervals (CI) were determined using IBM SPSS Statistics 22.0 (Armonk, NY, USA) and P < .05 was accepted as being significant.

Results

Descriptive Variables

The average race times on the 1500 m during the Dutch single distance championships for the participants in this study were 1:51.57 (SD 2.52 s) for males and 2:04.30 (3.38 s) for females. These times were on average 102.3% (SD 1.5) and 100.8% (SD 0.6) of the winning time during the championships for males and females, respectively, indicating that our subjects were highly competitive at this time of year within the context of Dutch speed skating.

The average PP and MP of all tests in this study were 24.4 (SD 1.5) and 13.3 (SD 0.5) W/kg, respectively, for the males and 18.3 (SD 1.5) and 10.3 (SD 0.5) W/kg, respectively, for the females.

Wingate Test Performance in Relation to 1500-m Performance

The results of the regression analyses are presented in Equations 1–4 and in Table 1; 1500-m times for women can be predicted with the use of PP and MP (in W/kg) from the Wingate tests with, respectively:

1500 m time(s) = 137.8 [CI 136.3; 139.4] + −0.75 [CI −0.83; −0.67] PP (1)

and

1500 m time(s) = 145.4 [CI 136.7; 154.2] + −2.05 [CI −2.94; −1.16] MP (2)

The significant regression coefficient of −0.75 for PP in relation to the 1500-m final time in the women (Equation 1) indicates that an increase in PP of 1 W/kg results in a faster 1500-m final time of 0.75 seconds. One has to bear in mind that this is the result of both between-subject, as well as within-subject, relations (ie, the resulting regression coefficient is a combination of both more powerful women skating faster [in the following winter] than less powerful women) and of longitudinal changes in which women that become more powerful over time also skated faster. In the same way, a 1 W/kg higher value of MP results an average 2.05-second faster 1500-m final time in the next winter (Equation 2). For the men, also, significant regression coefficients were observed for PP and MP scores in relation to 1500-m final times with −0.92 seconds and −2.32 seconds per W/kg, respectively, resulting in the predictive equations:

1500 m time(s) = 133.9 [CI 124.3; 143.4] + −0.92 [CI −1.32; −0.52] PP (3)

1500 m time(s) = 142.2 [CI 127.5; 154.2] + −2.32 [CI −3.44; −1.20] MP (4)
Besides final times, relationships between Wingate test performance and 1500-m performance were also determined for the 3 full laps times (300–700 m, 700–1100 m, and 1100–1500 m) in the 1500-m speed skating race. Generally, the PP and MP for both women and men, as assessed during the summer period, were significantly related to the lap times during the 1500 m in the subsequent winter, except for the final lap (Table 1). Regression coefficients for the first 2 full laps vary between −0.08 and −0.91, which indicates that skaters that show higher PP and MP values in the summer, or increase in PP and MP in the subsequent years, also show faster lap times varying between 0.08 seconds and 0.91 seconds per W/kg. However, for the final lap, PP and MP were positively related to lap time with regression coefficients varying between 0.01 and 0.22, which was only significant for the MP in women. This indicates that women with higher mean power scores, or women who show an increase in mean power over the years, need more time to complete the final lap.

**Discussion**

In this study we show, for the first time, that in truly elite athletes, PP and MP from Wingate tests during summer are good predictors of 1500-m performance. This result justifies the use of Wingate tests to monitor the effect of the summer training program on 1500-m speed skating performance during the winter season and use of Wingate results for goal setting during the off-ice training season. With the regression Equations 1–4 it is possible to calculate the effect of an acquired gain in PP or MP on 1500-m performance. On the other hand, these equations make it possible to estimate how the smallest worthwhile improvement in 1500-m performance. The smallest worthwhile improvement is 0.23% and 0.25%, respectively. Given the results of the current study, these performance improvements translate to necessary improvements in PP or MP of 0.14% for males and 2.1% and 1.4% (0.38 and 0.14 W/kg) for females, respectively. The analysis of Noordhof et al further revealed that for top-10 male 1500-m skaters, the smallest worthwhile improvement is even smaller at 0.14%. This means that a 0.14% improvement in performance reflects a 10% increase in the chance of winning the event by an athlete who is already winning medals on a regular basis. Given the fact that our subjects are exceptionally high-performing athletes and belong among the top-10 category, an improvement of 0.17 W/kg in PP or an improvement of 0.07 W/kg in MP, as can be calculated with Equations 3 and 4, is relevant for improving the chances for winning gold.

The regression analysis shows a considerable gain in performance for improvement in PP as well as in MP. The larger regression coefficients for the first full lap (Table 1) relative to the second and last lap indicate that the effect of extra PP and MP during the Wingate test on the first full lap seems the largest. PP and MP is not predictive for the final lap. The reason for this finding could have different origins. The first explanation could be the anaerobic nature of the Wingate test and the large contribution of the anaerobic system in the first part of the 1500 m compared to the last part. According to Granier et al., the anaerobic contribution to the work done during the Wingate test is approximately 75%, while during the duration of the 1500 m, the contribution of the anaerobic system is rapidly declining from ~70% during the first part to ~30% during the last lap. This is supported by the cycling time trial simulations reported by Foster et al.

The second explanation could be found in the pacing strategy usually employed by speed skaters at the 1500-m event. Skaters tend to start fast, but not all-out, try to achieve peak power during the first full lap, and skate the remaining 2 laps on their anaerobic reserve and maximal aerobic power, resulting in a declining speed during the second and third full lap. A unique characteristic of the pacing in speed skating is that speed at the end of the race is essentially wasted kinetic energy. Therefore, gains in speed during the first full lap are much more important to improving final time than speed during the last lap.

The third explanation could be found in the longitudinal nature of our analysis. From studies on concurrent training it has become more evident that training programs meant to improve peak power could have negative consequences for the aerobic contribution to performance. Because our analysis spans 3 years of training and 1500-m performances, gains in peak and mean Wingate power as a result of training on that quality could have led to reductions in the ability to liberate aerobic energy during the last lap of the 1500 m. In this case it could be explained that in the female skaters the improvement in mean Wingate scores resulted in a slower last lap during the 1500 m. More research on this aspect is warranted.

The limitation of this study lies in the relatively small number of subjects and the variable length of the follow-up between
subjects. However, the subjects are amongst the most elite in the world. These data show, for the first time, that laboratory testing can be valuable in guiding and evaluating training in homogenous groups of the most elite athletes. The elitism of these subjects can be illustrated by the fact that the Wingate scores for PP and MP of these athletes was 85% and 35% higher than the references values for the highest category of National Collegiate Athletic Association (NCAA) Division IA male power athletes,27 despite that in our testing we did not allow the athletes to ‘spin in’ at high RPM before the load was applied. Even the females in our study showed higher Wingate scores (35% and 5% for PP and MP) than the male NCAA Division IA athletes. In the interpretation of these numbers it needs to be taken into account that PP and MP can be influenced by the type of ergometer used in the reported studies in the literature. There could be differences up to 10% between mechanically-braked and electromagnetically-braked Wingate tests.28 Another characteristic of this specific pool of subjects is their superior ability to skate, illustrated by the reported median count. One of the technical difficulties in speed skating is the transfer of power to the ice to create velocity. Without this ability, improvements in PP and MP will not translate in speed, so results from this analysis have limited value for athletes that have still to learn to skate properly.

Conclusion and Practical Application

For elite speed skaters, peak power (PP) and mean power (MP) from Wingate tests performed during summer are good predictors of winter 1500-m performance. For the smallest worthwhile improvement in 1500-m performance, a gain in PP or MP of 2.1% and 1.4% (0.38 and 0.14 W/kg) for females and 1.2% and 0.9% (0.29 and 0.12 W/kg) for males is needed. These findings could be an important guide for trainers/coaches to use the Wingate test in off-season to prepare the athletes for the subsequent winter. The results of the Wingate test can be used as goal setting or to evaluate progress made in training.

References


