EVALUATION OF ROLLER SKATING TRAINING LOADS USING HEART RATE MONITORING. A REPORT OF 4 YEARS DATA COLLECTION

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This paper reports the experience in using the heart rate (HR) monitor for roller skating in a period of 4 years. The relationship between HR and mechanical power is shown. A method for calculating the total load of the training sessions is also shown. The experience shows that HR alone can be easily used in an effective way to measure the training load for roller skating.

KEY WORDS: Rollerskating, heart rate, training load

INTRODUCTION: Several methods are available to evaluate the training load of each exercise for many sports. For roller skating, however, there is lack of information in this field. Fedel et al. (1995) and Wallick et al. (1995) show that there are strong analogies between running and skating, both in HR and VO_2 Max. However, all of the studies were of very low speeds, typically around 21 Km/h, which is almost one half than true speed for marathon (42 km in less than one hour). For this reason further investigation is required in the actual competition and training speed range. Martinez et al. (1992), used an ergometer to measure the mechanical power. Such an instrument, however, can be easily applied within a laboratory, but cannot be used daily during training. For a coach it is really useful to get an overall evaluation of the training session, adding-up all kinds of exercise in a unique figure. The simple heart rate monitor is an easy and wide-spread scale device for training. Very often it is used only as a rough index of the current situation. The purpose of this paper is to describe the experience of 4 years with a small group of high level skaters and to suggest an easy method to estimate the total training load using the HR monitor.

METHODS: A group of 6 skaters, 3 males and 3 females, trained for a period of 4 years. At the beginning, their age was in the range 14-16. Their level went from National level to International level. All of them were experienced skaters, with 5 to 12 years of practicing. All of them practiced speed skating, ranging from 300 m to 1500 m competitions (lasting from 30 s to 3 min), and substantially followed the same training program. They did 4 to 7 training units of 90-150 min per week, depending on the season. Throughout the year a single-period training pattern was used, with the main competition period between June and September, the main goals of training being anaerobic power and strength.
The heart rate monitor was a Polar Electro PE3000 with data recording. During all training sessions the recording interval was set to 1 minute. All training sessions were recorded, with the exceptions of competitions and stages, and later processed. Because the tests were made almost daily, it would have been impossible to do lactate measurements or other tests. For the same reason, any psychological effect on the heart rate was supposed to be either negligible or constant.
The evaluation of the HR vs Power relationship was made using the ***step test,*** with the following procedure: After measuring the weight, the athlete had to go up and down 3 steps of different height (0.138 m, 0.250 m, 0.401 m) for 3 min at a constant rate (suggested value: 30 steps/min). At the end of each minute the actual number of steps and the HR were recorded to check the true climbing rate and the increase of HR. A rest period of 5 minutes was used between the sessions. The final values of HR, the actual number of steps and the actual height of each session were used to set a point in the HR/Power space. Data from each test were fied using a linear regression. Each athlete usually had a step test every month. The characteristics of this test are similar those suggested by Francis and Cuipepper (1988). A time-series analysis of HR/Power relationship during the training period was not performed, due to lack of a sufficient number of data. For this reason only a qualitative description was made.

The relationship **HR/Power** was used to calculate the overall mechanical work (U) of each training session. Such a figure is strictly related to the individual subject under test. To apply this information to other athletes, further assumptions are required. To do this, let's define the equivalent height (H), the height that an athlete weighing mass times acceleration due to gravity (mg) must climb to get the work U. With this assumption, the overall training load can be expressed in terms of a vertical measure, regardless of the kind of exercise. The total equivalent height of each week was calculated by simply adding the values of each day of the week. The comparison with the desired training load was also made.

RESULTS AND DISCUSSION: The step test was chosen for three reasons: 1. It is really easy to do. 2. It is quite easy to evaluate the mechanical external power required. 3. The motion is close enough to roller skating. Equation (1) gives the mechanical power:

$$P = m\, g\, n\, h / t \qquad (1)$$

The assumptions for this equation are the following: 1. The mechanical work to move back and forth is negligible. 2. Work made by gravity during descending is lost (the athlete must stop between each step). 3. The athlete must mount the step completely, therefore reaching the same standing posture as before starting to climb it.

It is well known that the HR/P relationship is linear for aerobic exercises. Our work confirmed this because all the tests always gave us a correlation well over 0.9. In general, the overall result of the step test can be fitted by linear regression, as in the following equation:

$$HR = HR_0 + k\,P \qquad (2)$$

Figure 1 shows a typical drawing of actual data. HR_0 should be the heart rate at 0 power, i.e. the HR at rest. Actually, its values were close enough to the true HR at rest of the athletes, but the latter values were not used within the correlation because an information at no load was not relevant. The coefficient k means the 'heart' required to get an extra Watt. Please note that this fitting relates to one individual subject on a given date.

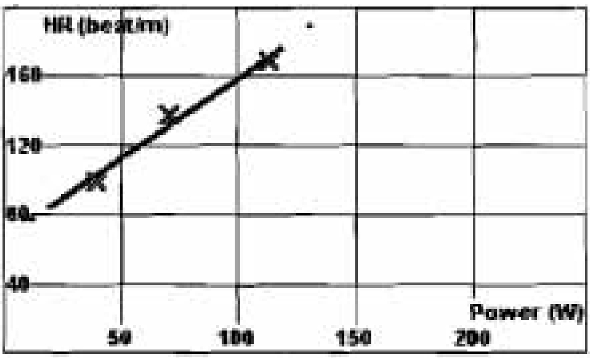

Figure 1- Actual step test results for a top-level female
Mass = 50 Kg.
Low step : n=105, HR = 99.
Middle step : n=102, HR = 137.
High step : n=102, HR = 168.
Fitting equation :
HR = 65 + 0.927 W: r = 0.988

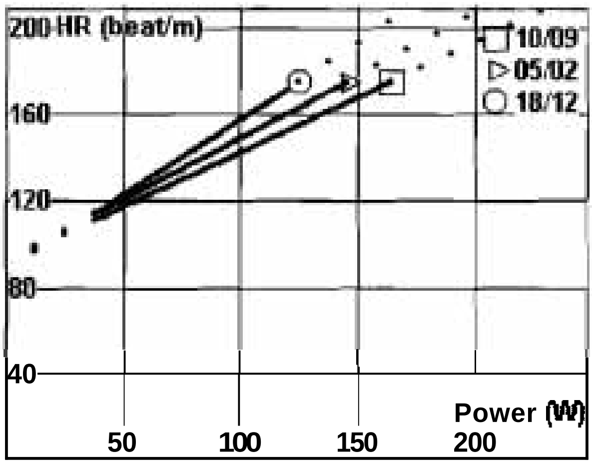

Figure 2 - Example of trend of the **HR/Power** during the year. The first set of data shown was recorded on December; the second on February; the last on September.

At the very beginning of the experience, one of the questions was how should the equation (2) change during a whole year of training. For sure, it was expected that the HR should decrease. Figure 2 shows a typical evolution during a year for a single subject. Please remember that all the athletes were specialized in speed skating, so that the amount of aerobic exercises was kept high only during the first period of each year. In the picture we can appreciate that there is a significant decrease in the value of k and a very little increase

of HR_0 (the straight lines seem to rotate around a point close to the $0,HR_0$ point). This behavior was recorded for all athletes every year.
Through the equation (2) we have a mathematical model of the athlete; now the goal is to calculate the total work U and H of a training session through the equations (3) to (6):

$$HR_{avg} = \Sigma_i Hr_i / N ; \quad i = 1,2,...,N \tag{3}$$

$$P_{avg} = (HR_{avg} - HR_0) / k \tag{4}$$

$$U = 60 P_{avg} N \tag{5}$$

$$H = U / (m g) \tag{6}$$

HR_{avg} is the average heart rate value for the whole set of data of one day. P_{avg} is the average power, obtained by solving equation (2). HR_0 and k are the most recent data available from the step test for the athlete wearing the heart rate monitor. U is the total work of the day. The number 60 is needed to convert minutes to seconds. H is the equivalent height.

Table 1 Symbols and Units

g	acceleration of gravity	=9.8 m/s^2	m	mass of the athlete	Kg
H	equivalent height	m	N	number of data available for each training session	-
HR	heart-rate	beat/min	n	number of steps	
HR_0	HR at rest (calculated)	beat/min	P	Power	W
h	height of each step	m	t	time of each test	= 180 s
k	Power factor	beat/min/W	U	work	J, kJ

The equation (2) has four limits: 1. It applies only to the subject who performed the test; thus, the value of U is correct only for himlher. 2. It can be used for a limited period of time. One month has proved to be short enough not to yield dramatic changes in HR_0 and k coefficients. 3. The equation (2) states the relationship HR/P only for aerobic exercises. We should not use the equation (2) when the HR goes above the aerobic threshold. From now on, however, we are no longer interested in power itself, as we are dealing with work, which is the integral of power over the time. That's why we can assume that the underestimation of power during anaerobic exercises can be compensated by the overestimation of power during rest phases. Considering that for long-lasting exercises the overall work is largely due to oxygen transport, this should be quite a good approximation. 4. The fourth limit of the equation (2) is that it applies only to the step test. We should have a different test for each kind of training load we are going to use. For skating we can use an independent estimation of mechanical work, like Giorgi's (1998), to compare some HRIP points with the equation (2). The HRIP points for skating are always on the right side of the line, with a range of 0 to 30 Watt to the right. Typically, the athletes with the highest shifl to the right are the more skilled, which means that they do have a more efficient engine for skating than for climbing stairs. Anyway, this kind of correction was not taken into account
Figure 3 shows the curve of a typical training session. The total amount of load, calculated as above, was 618.000 J. The equivalent height of that day, calculated through equation (6), was 900 m. In our experience, the climbing height of each training session ranged between 500 and 1600 m.
The last thing we can do is to consider a whole year. Figure 4 shows in detail the comparison between the-expected load, expressed as %, and the actual equivalent height, expressed in m/week. The picture shows the main part of the training and the competition period (January to October). The main targets are also shown. The more the '+', the most important the competition. The schedule was based on a 2 (load) - 1 (rest) pattern. In the first months very often we experienced delays due to rainfall that forced to change the schedule. Between April and May three main load cycles (70. 100 and 100 %) were applied. All of them used time, exercises, intensity and rest in a quite similar way. The subjects actually almost doubled their capability of producing mechanical work, rising from about 4000 mlweek to 7000.

In June it was scheduled a lower load (80-70%) followed by an extra rest. However, even during easy sessions, the athletes experienced a continuous increase of load, due to their high capacity of producing work. We had to almost completely stop in order to force resting. Please notice that, even if the training program should have allowed them a low load, the athletes were actually still forcing on.

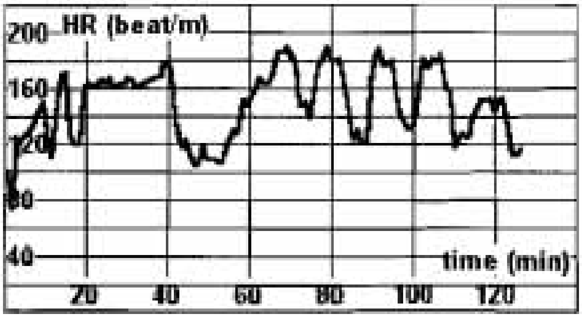

Figure 3 - Actual curve of a training session. The first peaks represent the step test. 20-40 min: fast jogging. 40-60 min: gym exercises. 60-130 min: skating. The three peaks between 80 and 110 min were 3 series of 4 repetitions (15" at top speed + 45" rest) with 5 min rest between series. The total load of this training session was 618 **kJ;** the equivalent height was 900 m.

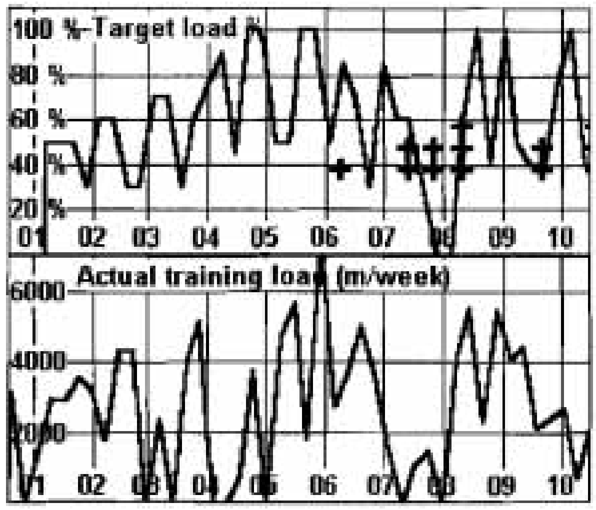

Figure 4 - Comparison between target load (%) and actual load (equiv. mlweek) vs. season (month of the year). The '+' marks the main competitions

CONCLUSIONS: The HR alone **can** be used to have a general estimation of training loads for roller skating. The suggested method can be used to help coaches in verifying the actual effect of the training process. Using it, further investigations could be made for different specialization (endurance instead of speed) and for other sports.

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