Journal of Human Kinetics volume 12, 2004, 109-116

"Anaerobic Endurance" and its Assessment*

by

Romuald Stupnicki[1], E. Sienkiewicz-Dianzenza

Generally, endurance is understood as the ability to perform prolonged, continuous aerobic work. The presented concept of "anaerobic endurance" relates to intermittent, discontinuous work, consisting of anaerobic bouts of exercise. Anaerobic endurance is associated with the entire exercise task of the above mentioned nature. The consequence of this concept is, that laboratory or field tests based on single, maximal, anaerobic exercises, cannot serve as a measure of athlete's performance in team sports. Two measures are proposed in order to assess an athlete's performance task-wise: maximum performance (maximum value of given variable attained in intermittent task or a corresponding test) and task endurance (the capacity to perform well throughout the task). This requires designing exercise tests consisting of series of exercise bouts, resembling (in the number and spacing of bouts) competitive conditions. The following steps need to follow: selection of variables, determination of maximum performance and determination of task endurance.

Maximum performance is the best result in the series, and task endurance, or performance index (PI), is the ratio of the mean performance to the maximum one. These two variables (max and PI) enable the assessment of subjects with respect to a given task since, as a rule, they are not correlated with one another.

***Keywords**: task structure, performance, intermittent work, endurance*

[1] Academy of Physical Education, 00-968 Warsaw, Marymoncka 34, PO Box 55.

Introduction

Endurance has been associated with a prolonged, continuous aerobic work, combining the terms "anaerobic work" and "endurance" may thus sound contradictory. Let us, however, look at it from a different point of view, which shall require re-defining some terms and concepts.

First, let us consider the concept of task structure. Work tasks are performed at diverse and varying intensities, and a constant intensity may take place at intervals only, unless the intensity is low and strictly controlled. For example, a football player and a long-distance runner perform quite differently. Their performances may be expressed in terms of work output, energy expenditure, heart rate, etc. (fig. 1).

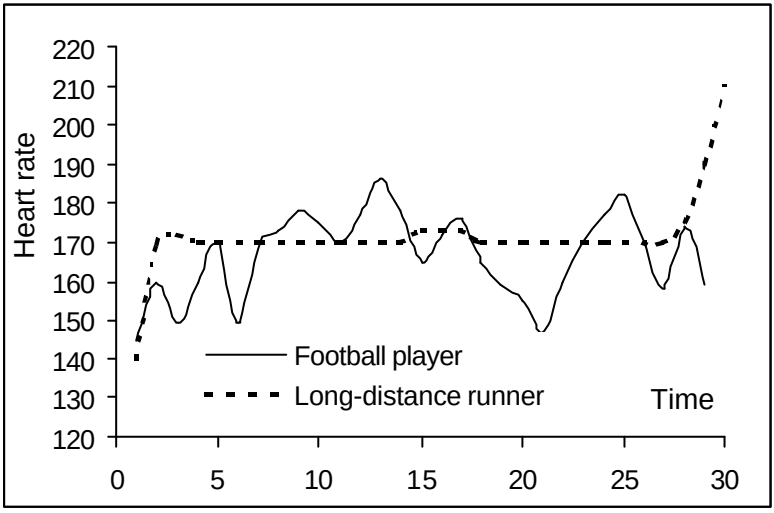

Fig. 1

Schematic presentation of the performance of two athletes expressed by heart rate

A running task may be continuous or intermittent. In as much the competitive running exertion may be considered maximal that of a football player may be maximal at intervals, as called for by specific actions. Nonetheless, both a sprinter and football player have to exhibit two features: the capacity to perform at their *maximum*, even if for a very short period only, and endurance (the capacity to maintain the intensity until the end of the task), irrespectively of the task structure. Athletes can thus be characterised by these two variables – *maximum performance* (MP) and *task endurance* – both with respect to a given task.

Continuous tasks are relatively easy to assess, and designing specific tests resembling competitive task structure, may pose no difficulties. In contrast, intermittent tasks are very hard to evaluate with appropriate tests, due to great variability. Modern science makes use of attributing the performed work to various energy sources: anaerobic alactic, anaerobic lactic, mixed, aerobic glycolytic, and lipolytic aerobic. Continuous tasks may be easily analysed with respect to the contribution of various energy sources, but intermittent ones usually escape such categorising. This is because intermittent work consists of various anaerobic bouts of exercise, which result in an accumulation of lactate and the intermissions consisting of rest or low-intensity work bring about only partial restoration of phosphagens. Therefore, it seems that the above mentioned categorisation would be of little practical value due to unpredictability of the course of exercise. The procedures used to assess athletes engaged in sports of intermittent structure (team sports, combat sports, etc.), consist of applying laboratory tests, which measure anaerobic threshold or aerobic endurance. Such tests do not, however, reflect the athlete's task endurance.

Assessment of repeated exercises

When individual records, like those presented in figure 1 can be collected, typical maximal values, bout and spacing durations may help to design tests consisting of several bouts of maximal exercise, separated by rest intervals lasting 10 – 30 s. The exercise should resemble competition and consist of runs (straight or shuttle), weight lifts, etc. Figure 2 shows running times of two athletes performing such a test. Both athletes exhibit accumulating fatigue, as reflected by slower running times. However, fatigue is associated with a decreased performance, so when converting running times to velocities such a tendency is apparent. Subject A attained highest velocity in Bout 1, while subject B – in Bout 2. These represent the performance maximum for every subject in a given series of bouts. Subject A performed the running task more uniformly, but attained a lower maximum speed than Subject B, and the objective is, to express the difference between the two subjects.

In general, the problem is similar to that with the Wingate test, in which maximum and mean power outputs and power decline rate (PDR) are the basic characteristics recorded. Various approaches were used: fitting linear regression (Platonov, 1984), end-to-initial values ratio (EIR), etc. However, in as much the slope in linear regression may be regarded as an equivalent of PDR, no such meaning can be attributed to the regression constant. The issue becomes

particularly complicated when the data cannot be approximated by linear regression, but by a polynomial one (in the example above, data of Subject A follow a quadratic regression). Then, no coefficient has a rational meaning. On the other hand, the end-to-initial values ratio depends too much on the incidentality of both values: both subjects, clearly differing in performance, attained identical EIR values (Table 1).

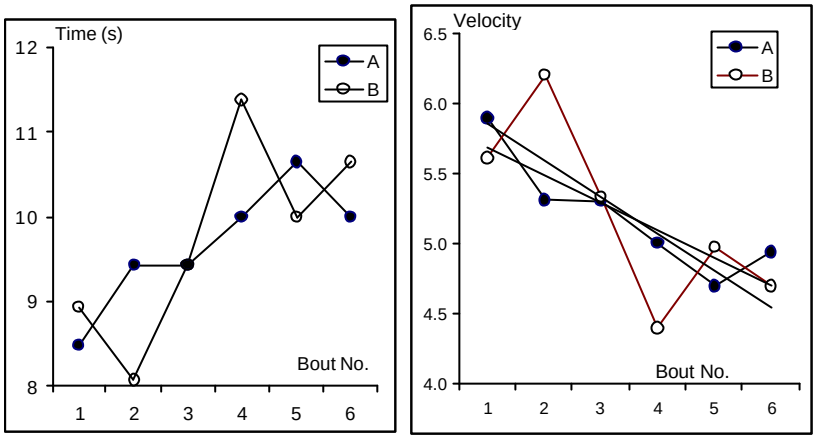

Fig. 2

Running times (left) and velocities (right) of two subjects (A and B) performing 6 shuttle runs (2 ´ 25 m) spaced by 15-s rest intervals

Table 1

Individual and mean velocities attained by two subjects (A and B) performing 6 shuttle runs (2 ´ 25 m) spaced by 15-s rest intervals, and fatigue-related indices

Subject	1	2	3	4	5	6	Mean	b_{regr}	EIR	PI
A	**5.89**	5.31	5.30	5.01	4.70	4.94	5.24	–0.20	0.838	0.881
B	5,61	**6,20**	5,33	4,39	4,97	4,70	5,20	-0,26	0,838	0,839

Maximum value recorded for each subject is bolded. Explanation of symbols: b_{regr} – slope of linear regression; EIR – end-to-initial values ratio; PI – performance index

"Performance Index" – a measure of "anaerobic endurance"

The proposed method of assessing anaerobic endurance, as a measure of task endurance, is based on the following assumption. If a subject performed the task consisting of 6 bouts without becoming fatigued, the work and power

outputs would be the same in all 6 bouts as represented by the rectangle in figure 3. Since, however, fatigue is involved, his performance decreases and the total work or power output is represented by the area under the curve. The ratio of both areas – the actual to the maximum one – is the performance index (PI). This is, of course, equal to the ratio of mean performance from all bouts to the maximum one as shown in Table 1, provided all bouts are equally spaced.

In as much the area under the curve is easy to measure, the maximum performance may not be easy to define, when the task consists of many repetitions and its performance is erratic, like in multiple (40 – 60) push-offs on an inclined plane (Urbanik, 1995). In such cases, the maximum may be defined as the mean value from records not lower than 95% of the peak value.

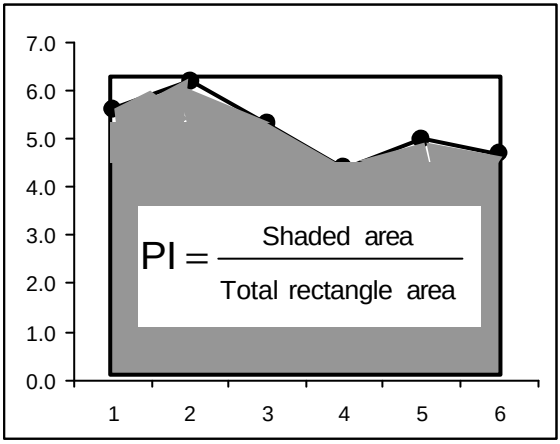

Fig. 3

Schematic presentation of the Performance Index (PI). Data of subject B from table 1 and figure 2.

The concept of PI (Sienkiewicz et al., 2002; Stupnicki and Norkowski, 2001) is quite general and may be applied to all processes in which the variable reaches a maximum and then declines, irrespectively of whether the task is continuous or an intermittent, as mentioned above for the example of the Wingate test. The index may thus serve as a measure of overall performance, provided the exercise is a maximum one, otherwise the assessment could be overestimated due to an incomplete workout. In order to reduce the risk of overestimation, the index should not be used alone but in combination with the maximum value achieved in a given task. Interestingly, although it might be expected that the higher the maximum performance the lower the PI, both

variables proved not correlated with one another or the negative correlation was negligible. Data recorded in 45 physical education students are presented in Fig. 4 as an example.

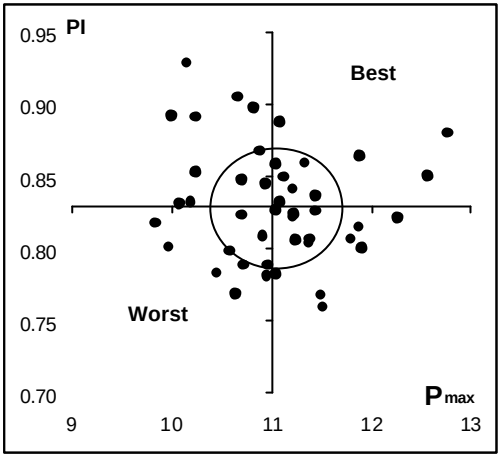

Fig. 4

Relationship between maximum power output (P_{max}) and performance index (PI) recorded in 45 physical education male students subjected to 6 maximal cycle ergometer exercise bouts lasting about 10 s each, separated by 15-s rest intervals.

In the simplest version, the area may be divided into 4 zones, the dividing lines being means of both variables – maximum performance and PI. The athletes exhibiting highest MP and maximum PI simultaneously would be the best ones, those with lowest values - the worst, the remaining ones being deficient in either MP or PI. That deficiency might, of course, be the result of inadequate engagement. The dividing lines may be established arbitrarily so as to represent a performance minimum required for selecting athletes. Moreover, a fifth zone may be added – the central one – representing medium level. Again, the size of that zone may be arbitrarily selected so as to meet training requirements. Implementing such a procedure is of particular importance in team sports and in other intermittent tasks, since no tests are known to measure maximum performance and task endurance at the same time.

It seems that whenever a subject has been well motivated to perform the task at his/her best, the assessment will reflect the subject's abilities and predispositions for that type of work.

In summary, the presented performance index, very simple in structure, seems to adequately reflect the subject's performance, whether continuous or intermittent. When combined with the maximum value recorded in a given

task, it may serve as a powerful tool in classification and selection, as well as in monitoring training effects.

Acknowledgments

Lecture delivered at the Conference "Assessment of Anaerobic Endurance", Warsaw, 12 Sept. 2003. The study was supported by grant No. DS-40

References

Platonov VN (1984). Teorya i metodika sportivnoy trenirovky. GIIO "Vysha Shkola", Kyiv, Ukraine, p. 331

Sienkiewicz E, Milde K, Norkowski H, Stupnicki R (2002). Assessment of repeated, high-intensity leg exercises. Wych. Fiz. i Sport, 46: 437-438.

Stupnicki R, Norkowski H(2001). Index of anaerobic endurance in repeated maximal exercise bouts. Papers Anthropol, 10: 280-287.

Urbanik C (1995). Ocena spadku mocy w funkcji czasu u dziewczat w wieku szkolnym. Materialy Ogólnopolskiej Konferencji Biomechanika'95. AWF Kraków. pp.270-273.