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The Influence of Specific Training on Explosive Power in Top Athletes

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Abstract

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Explosive power is an important aspect in sports events such jumping and throwing as well as in other sports like tennis, boxing, wrestling and most sports games. To clarify whether explosive muscle power depends only on the macroergic phosphate compounds or other factors, which can be influenced through specific training, are also involved, this study used a Wingate testing protocol to follow the evolution of anaerobic performance parameters in 450 top athletes trained for aerobic (70 athletes), anaerobic (224 athletes) and mixed events (156 athletes). Parameters studied were the Peak Power (PP), Time at Peak Power (TPP), correlations between them and Average Powers recorded on each 5-second interval of maximal effort. The results showed that TPP was shorter than 5 sec only for the alactacid anaerobic groups (3.630 sec for men and 3.960 sec for women), the other athletes reaching maximum power after 5 sec. Most athletes registered the highest average power in the second 5-second interval (5-10 sec) and not in the first one (0-5 sec), as expected, except for the alactacid anaerobic group. The anaerobic alactacid and mixed energogenesis groups achieved a significant negative correlation between PP and TPP ($p < 0.05$), these groups being composed of athletes whose specific training aimed to improve their neuro-motor skills and movement pattern. The results of this research show that explosive power depends on the muscle composition, but also confirms the importance of motor skills in improving the recruitment velocity of fast muscle fibres and muscle power generation.

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1. Introduction

Muscular power is an important aspect in most sports events. Power is the product of force and velocity, and this relationship suggests that the factors that influence muscular force (muscle cross-sectional area, proportion of fast-twitch fibres, initial fibre lengths) also affect the muscle capacity to generate power (McArdle, Katch, & Katch, 2004). Muscle power is the explosive aspect of force



(Brukner & Kahn, 2012), but it is important to notice that it also has, in its turn, three aspects: the peak power (maximal amplitude of power), explosive power (rate of maximal power development) and power endurance (the period of time in which maximal power can be maintained). A running event, for instance, is not won by the athlete who develops the greatest power at one time (maximal power aspect), but by the athlete who is able to develop and *maintain* as much power as possible over the whole period of running (power endurance aspect). However, during those athletic events similar to jumping and throwing, when the athlete's body or various objects are propelled like a projectile, the ability to generate maximal power over a very short period of time (explosive power aspect) is significant for performance.

The Monark cycloergometer software, used in the Wingate testing (Inbar, Bar-Or, & Skinner, 1996), displays graphically the curve of powers developed by the athletes over a 30-second period, but also average values of this parameter over 5 sec intervals. The Peak Power parameter is represented by the greatest value of the average power recorded in any 5 sec interval. Theoretically, the greatest muscular power should be recorded in the first 5 sec interval, since it relies upon high-energy phosphate compounds, but it is important to verify this aspect in order to emphasize the involvement of other factors upon the rate of maximal power development. For some events like throwing and jumping, not only the value of maximal power is important, but also the moment when it is generated.

2. Materials and methods

In order to clarify whether the explosive aspect of muscular power mainly depends on energogenic capacity of high-energy phosphate compounds or some other factors, such as neuromuscular factors, are also involved, this study followed the results obtained in testing the anaerobic exercise capacity of 450 top athletes, specifically trained for aerobic, anaerobic and mixed events, through a slightly modified Wingate protocol. The parameters specific to Wingate testing, such as the Peak Power (PP), Fatigue Index (FI), Average Power (AP), but also other parameters that are included in the Monark cycloergometer software used in the testing process, but are not incorporated in the classical Wingate protocol, have been followed: the Average Powers on each 5 sec testing interval, Average Power on a 45 sec interval (AP45") and Time at Peak Power (TPP).

The subjects were represented by a total of 450 top athletes, components of Romania's National and Olympic Teams, men and women, aged between 18-28 years.

- *Aerobic groups*: 70 athletes participating in aerobic events (great endurance events: marathon and race walking) out of whom 35 women (aerobic women's group) and 35 men (aerobic men's group).
- *Alactacid anaerobic groups*: 162 athletes participating in *alactacid anaerobic events* (very short-lived events: throwing, jumping, 100 m dash). The women's group was made up of 85 female athletes (alactacid anaerobic women's group), while the men's group of 77 male athletes (alactacid anaerobic men's group).
- *Lactacid anaerobic groups*: 62 athletes also participating in *anaerobic events*, but with an important *lactacid* component (400 m dash and 400 m hurdles runners). The women's group included

31 female athletes (lactacid anaerobic women's group), while the men's group included 31 male athletes (lactacid anaerobic men's group).

- *Mixed energogenic group*: 156 athletes participating in *mixed energogenic events*, aerobic and anaerobic (800 m and 1500 m runs, football and handball). The women's group included 64 female athletes (mixed energogenic women's group), while the men's group, 92 (mixed energogenic men's group).

Anaerobic exercise capacity testing protocol: The athletes were tested using a modified Wingate protocol, in which duration of maximal effort was extended to 45 seconds in order to observe more aspects of tolerance to acidosis. The athletes trained for very short sport events (anaerobic alactacid groups, male and female) were tested only for 10 seconds of maximal effort. The cycloergometer we used to test maximal effort, a Monark 894-E from Sweden, was connected to a computer that runs software supplied by the producer - (Sports Medicine Industries, Inc. (SMI) (St. Cloud, MN) (Power software). Resistance applied to cycloergometer was calculated in terms of each subject weight (kg x 7.5%).

Data analysis: For each subject, the absolute values of Peak Power (PP), Average Power (AP), Fatigue Index (FI), Time at Peak Power (TPP) were recorded. The statistical analysis was performed using the statistical analysis mode of the Microsoft Excel software and included average values, standard deviations and value intervals for the collected parameters. The comparison between the levels of these parameters for each individual group was carried out by using the Student test. Correlations between parameters were assessed using the Pearson correlation method, while the level of significance was considered $p < 0.05$.

3. Results

Expressed as a relative value, that is W/kg, *Peak Power* had the following values for the studied groups: aerobic events (women) 7.21 ± 0.94 , aerobic events (men) 7.93 ± 1.69 , mixed energogenic events (women) 7.75 ± 1.21 , mixed energogenic events (men) 9.61 ± 1.57 , lactacid anaerobic events (women) 8 ± 1 and 10.13 ± 1.68 (men), alactacid anaerobic events (women) 8.93 ± 1.48 and 11.57 ± 1.96 (men). The results show that the athletes trained for alactacid anaerobic events have the best values, followed by the athletes trained for lactacid anaerobic and mixed energogenic events, and then by those participating in aerobic events, who had the lowest values of this parameter.

The Average Power over 30 sec, a parameter recommended by the Wingate testing protocol, also displays the same trend as the Peak Power - it increases as a particular event requires a greater anaerobic metabolism and a lower aerobic metabolism: lactacid anaerobic groups 7.96 ± 0.94 w/kg for men and 6.58 ± 0.85 w/kg for women, mixed energogenic groups 7.55 ± 0.86 w/kg for men and 6.2 ± 0.88 w/kg for women, aerobic groups 7.23 ± 0.69 w/kg for men and 5.71 ± 0.79 for women. The Average Power was also calculated over the whole 45 sec period of maximal effort and presented the same increasing profile as the Average Power over the 30 sec, paralleling the involvement of the anaerobic mechanisms in the energy production of the studied athletic events, although the recorded values were lower, as it was expected: lactacid anaerobic groups 7.59 ± 0.79 w/kg for men and $6.37 \pm$

0.77 for women, mixed energogenic groups 7.2 ± 0.71 w/kg for men and 5.92 ± 0.77 w/kg for women, aerobic groups 6.71 ± 0.68 w/kg for men and 5.71 ± 0.79 w/kg for women. The Average Powers over 30 sec and respectively 45 sec were not determined for alactacid anaerobic groups of athletes, since they performed a maximal testing for a period of only 10 sec.

The Monark cycloergometer software displays both a graphical representation of power during testing as well as the numerical values for the *average powers recorded for each 5 sec interval* from the beginning up to the end of testing. From the cumulative analysis of all testing performed in this study, it followed that it was the second 5 sec interval in which the greatest value of power was recorded and not the first one, as it was expected, with the exception of the alactacid anaerobic men's group, which was characterized by higher values of average power in the first 5-second interval when compared to the next 5-second interval (Fig. 1).

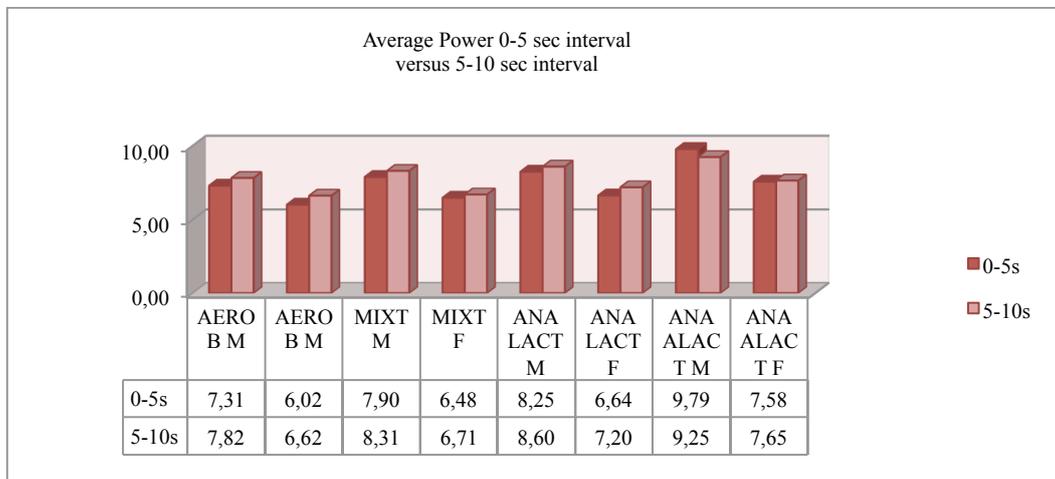


Fig. 1. Comparisons between Average Powers for the first 5 sec interval and Average Power for the second 5 sec interval

The *Time at Peak Power (TPP)* was also, on the average, over 5 seconds in all tested groups, (lactacid anaerobic groups 5.92 sec for men and 8.59 sec for women, mixed energogenic groups 6.96 sec for men and 6.41 sec for women, aerobic groups 5.35 sec for men and 6.94 sec for women), with the exception of alactacid anaerobic men's and women's groups (3.63 sec for men and 3.96 sec for women), which supports the idea that in most cases the peak power is not achieved in the first 5 sec of the maximal effort. We mention that this parameter measures in milliseconds the time elapsed from the beginning of the effort and the moment when the muscle power curve generated by athlete reaches the highest point.

The *correlation between the value of the Peak Power and Time at Peak Power* showed that, for the groups with mixed and alactacid anaerobic energogenesis, the great values of the Peak Power (PP) correlated with a smaller duration of the time necessary to develop the Peak Power (the correlation coefficients were -0.36 cu $p = 0$ in men and -0.34 cu $p = 0$ in women) in mixed energogenesis events and respectively (-0.25 cu $p = 0.03$ in men and -0.27 cu $p = 0.04$ in women) in alactacid anaerobic events. For the other groups, correlations were not significant.

The *Fatigue Index (FI) or Power Decline (PD)* is considered an indicator of muscle fatigue. The values attained by this parameter (expressed as percentage of the peak power) were: lactacid anaerobic groups 53.46 ± 15.46 % for men and 48.05 ± 10.56 for women, mixed energogenesis groups 53.25 ± 14.26 % for men and 50.35 ± 11.37 for women, aerobic groups 53.53 ± 13.8 % for men and 44.6 ± 12.56 for women. The Power Decline was calculated only for 10 seconds in those subjects who participated in alactacid anaerobic events (male and female) and had values of 31.28 and 33.68%.

4. Discussions and conclusions

Skeletal muscle is a heterogeneous tissue composed of a large variety of fibre types. The classification of fibres provides information about functional characteristics as strength, power and fatigue resistance (Bottinelli, 2001; Malisoux, Francaux, & Theisen, 2007). Training produces adaptive responsiveness and even a fibre-type transition (Armstrong, Welsman, & Chia, 2001; Brandon & Boileau, 1987; Brodal, Ingjer, & Hermansen, 1977; Brooke & Engel, 1969; Brooks, Fahey, & Baldwin, 2005; Hakkinen et al., 1998; Pette & Staron, 1997). The strictly glycolytic fibres (FG) contract faster than the mixed (FOG – glycolytic and oxidative fast fibres) or slow oxidative ones (SO – slow oxidative fibres), and the generated power is greater (MacIntosh, Gardiner, & McComas, 2006; Buchthal & Schmalbruch, 1970). The individuals with fatigue in high-intensity exercise are characterized by a shift in the EMG power spectrum of the muscle involved, indicating selective fatigue of fast-twitch fibres (Kupa et al., 1995; Billaut et al., 2006; Bogdanis, 2012).

The results of this study show that the athletes trained for alactacid anaerobic events have the best values for Peak Power, followed by the athletes trained for lactacid anaerobic and mixed energogenic events, and then by those participating in aerobic events, who had the lowest values of this parameter. The Peak Power, Average Power and Fatigue Index parameters obtained in this study are similar to other authors' results (Maud & Shultz, 1989; Zupan et al., 2009). But the comparative analysis of the average power values on each 5 sec interval of the maximal effort in all athlete groups showed that the alactacid anaerobic men's groups were the only groups in which the average power developed in the first 5 sec of effort, exceeding the one developed in the next 5 sec interval. This result supports the idea that the specific training has produced in these athletes a proportion of fast-twitch fibres (probably the strict glycolytic fast fibres – FG) (Pette & Staron, 2000; Staron & Johnson, 1993) superior to all the other athletes, including those trained for lactacid anaerobic efforts. However, for the other groups, the peak of anaerobic power was recorded in the second 5 sec interval. This observation suggests the fact that in the athletes trained for aerobic and mixed efforts, but also for longer anaerobic efforts, with an important lactacid component, the fibres that have an important contribution to generating anaerobic muscle power are also the fibres that have glycolytic content, but are slower and more resistant to fatigue (probably FOG) than those exclusively developed through alactacid anaerobic training (FG).

If the development of the anaerobic peak power depended only on the high-energy phosphate compounds availability and the proportion of fast glycolytic fibres, we should find a significant negative correlation between the Peak Power (PP) and the Time at Peak Power (TPP) in the groups of athletes whose performance implies an increased percentage of fast glycolytic fibres (alactacid anaerobic groups). In this study, we found significantly negative correlations between the Time at Peak

Power and the Peak Power in the alactacid anaerobic groups, but also in those with mixed energogenesis. The common factor that characterizes the process of training for both the alactacid anaerobic events (the studied group being mostly made up of athletes participating in throwing and jumping events) and the sports games and 400 m hurdles event (the mixed energogenic group including mostly this type of athletes) is represented by exercises similar to jumping and throwing, which facilitate the recruitment velocity of muscle fibres by the neuronal factors. Many authors claim that the explosive power is influenced in a more than significant proportion by the degree and modality in which muscle fibres are recruited by the neuronal factors (Clamann, 1993; McArdle, Katch, & Katch, 2007). In this study, the groups that obtained a significant negative correlation between PP and TPP were made up of athletes for whom the neuromotor skills and pattern of movement are especially important for performance, and their improvement by specific training can be an explanation for the results obtained. It is obvious that the elapsed time from the beginning of effort up to the attainment of the peak power depends on how fast the power-generating fibres contract, that is on the fibre type, but also the neuromuscular factors like the recruitment velocity of muscle fibres by motoneurons and the recruitment pattern that exert an important influence over the moment when the peak power is generated.

We recommend that for the sports events similar to jumping, throwing, etc., that is when the explosive aspect of the anaerobic muscle power matters significantly for performance, the preferred testing parameter should be the Peak Power. However, it is indicated that its values should be corroborated with the Time at Peak Power, because the information regarding the moment when musculature generates the peak power may constitute a feedback for the training of neuromuscular factors.

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