ORIGINAL ARTICLE

# Relationship of the results of the modified special endurance test in fencing with the indicators of training experience, aerobic capacity and motor skills of top female fencing athletes

**Authors' Contribution:**
**A** Study Design
**B** Data Collection
**C** Statistical Analysis
**D** Manuscript Preparation
**E** Funds Collection

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## Abstract

**Background and Study Aim:** Success at the highest level of competition in any sport is determined by special skills, endurance and motor skills, and talent (and this factor is generally the most difficult to quantify). Maintaining the ability to achieve high achievement sports (in every competition and in long-term cycles) is related to the development, and over time, maintaining these predispositions at an optimal level. Therefore, the basic method of forecasting the results of sports rivalry with high probability is to systematically control the most important indicators of training using appropriate research tools. The cognitive aim of this study is to knowledge about the correlation between the results of the modified test of special endurance in fencing and the indicators of training experience, aerobic capacity and motor skills previously considered important. Two hypotheses are verified: H1, there is a significant relationship between training experience and the result of the test of special endurance in fencing; H2, the higher result of the special endurance test is significantly related to the motor structure of top female fencing athletes.

**Material and Methods:** The competitors of the Polish National Team in fencing (n = 34) were tested during the preparatory training camp. Special endurance for fencing was measured with the modified Weichenberger et al. test. Aerobic capacity was estimated using OwnIndex. Motor skills were measured: 5m running; minimum ground contact time; maximum flight time; maximum jump height; the maximum power of the legs; average power over 4 jumps; the maximum stroke frequency and the reactive force index (derivative of the stroke frequency). These measurements were made using the Optagait System.

**Results:** A significant relationship (r = 0.538, p = 0.001) was demonstrated between training experience and the result of the special endurance test in fencing. Competitors with higher scores on the special endurance test in fencing have a better motor structure in some respects.

**Conclusions:** The modified special endurance test in fencing has been shown to be useful as the result is significantly related to training experience, aerobic capacity and some motor skills indices. It is justified to recommend the test as a tool for current control of special performance in the training process of top fencing athletes.

**Key words:** combat sports • lateralisation • perception • special training • training load



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**Achievement sport** – *noun* a sport in which the aim is to achieve some independent goal that does not depend purely on beating an opponent, e.g. archery [56].

**Perception** – *noun* the process of using the senses to acquire information about the surrounding environment or situation [56].

**Lateral** – *adjective* **1.** further away from the midline of the body **2.** referring to one side of the body [56].

**Extreme form of physical activity (EFPA)** – 'extreme sports, often classified according to the environment in which they are performed (water, land, air), extreme form of physical recreation as well as gainful activity or voluntary service, and all varieties of physical activity that meet at least one classification criterion of the feature associated either with extreme risk of injury or death, or extreme body burden with high level of effort, or extreme coordination difficulty' [54, p. 19].

## INTRODUCTION

In athletes who compete at fencing, special endurance must be monitored using dedicated tools. Fencing is a combat sport modality where two fencers compete using weapons (sabre, épée or foil). More-advanced fencers must be able to coordinate sequences of hand and leg movements [1]. During a single bout, contestants travel 250 to 1,000 metres with asymmetric footwork [2]. Irrespectively of the level of the competition, a single bout consists of three 3-minute rounds [3], and an entire fencing tournament at an international level takes 9 to 11 hours to complete [4].

In direct fencing combat, most of the energy (90%) comes from the phosphagen system, and balance comes from the glycolitic system [5]. Considering the length of a tournament and each bout, as well as the complexity of special moves at the competitive level, athletes must have a high level of endurance.

Endurance is the body's ability to maintain the required intensity of physical work over a long period, without any significant impairment to performance and with high resistance to fatigue [6]. Hence, endurance is a key aspect in developing other motor skills [7]. Furthermore, when searching for an endurance testing tool suitable for combat sports, attention must be paid to the biological considerations of this particular quality. Those considerations are strongly related to one's physical capacity [8] and ability to manage one's own body during physical effort [9].

So far, research has shown that fencers who wish to advance a level must accept the greater intensity of training routines and tournaments. Thus, it is important to understand the physiological burden associated with practice and competition [10, 11]. The cardiorespiratory and metabolic requirements during fencing tournaments have been analysed [12, 11], and it has been shown that the heart rate during a bout is close to one's maximum capability, and it tends to go up with each round. Also, the specialist gear worn by fencers has an adverse effect on the performance of the cardiorespiratory system [13]. Therefore, aerobic capacity, often analysed in the context of its motor effect, should be a key focus in fencing practice [14, 15]. Significant relationships also have been found between perception and both lateralisation [16] and experience [17].

Based on these considerations, the authors have analysed competitive experience (as one factor that determines one's ability to manage physical effort), aerobic capacity (as a biological factor) and motor structure reflecting fencers' footwork. We have assumed that these components play a role in an athlete's competitive success. Thus, it is essential to use a special tool to monitor endurance that is adequate for fencing, in terms of testing both the methods and expectations of fencing practitioners.

The cognitive aim of this study is to determine whether there is a correlation between the results of the modified test of special endurance in fencing and the indicators of training experience, aerobic capacity and motor skills, which have already been considered important. Two hypotheses are verified: H1: there is a significant relationship between training experience and the result of the test of special endurance in fencing; H2: the higher result of the special endurance test is significantly related to the motor structure of top female fencing athletes.

## MATERIAL AND METHODS

### Participants

The study group included female athletes from Poland's national fencing team (n = 34; age groups: youth to senior) who attended a training camp in the preparatory period (summer 2021). The mean age of the study group was 19.1 years (12 to 31).

### Study design

#### *Dependent variable*

*Special endurance* in fencing was measured with a special endurance test for fencers. The test was developed by modifying the test proposed by Weichenberger et al. [18]. The tested fencer

moves forward and back 3.5 metres, maintaining the typical fencing position and footwork. The change of direction takes place outside the lines marking the beginning and end of the 3.5-metre section. The pace of movements is controlled by sound signals. For the first 2 minutes, the testee moves at 3 km/h, and every two minutes the speed increases by 1 km/h. The test stops after 15 minutes or when the testee no longer wishes to continue, whichever is earlier.

Two indicators were monitored during the test: heart rate and speed of movement on the strip. Both were monitored by the Polar Team Pro athlete tracking system.

### *Independent variables*

The test described above was immediately followed by the Polar Fitness Test to determine the *aerobic capacity* of the athletes. Its results are presented in the form of a score known as OwnIndex.

In addition, the authors looked at motor performance, including 5-metre sprints (s), the minimum ground contact time in bouncing (s), maximum flight time (s), maximum jumping height (cm), maximum leg power (W/kg), mean power of 4 jumps (W/kg) and maximum jumping frequency (jumps/s). Furthermore, the reactive force index (m/s) was derived from the tested variables.

Motor performance was tested with the Optogait System, which has two bars fitted with optical sensors spaced at 1-cm intervals and two Full HD cameras. The system captures spatial and quantitative data.

*Competitive experience* was determined on the basis of the years of professional training, as declared by the testees.

### Ethical considerations

The study was authorised as part of a project entitled 'Supporting Research Projects in Competitive Sports 2021'. The project is implemented by the Polish Fencing Association. It was accepted and co-financed by the Ministry of Culture, National Heritage and Sport, and consent is expressed in an agreement dated 25 June 2021.

### Statistical analysis

The estimation of the results is based on the following indicators: frequency (n), mean (*M*), standard deviation (*SD* or ±), minimum (Min), maximum (Max), significance level and probability (*p*).

Pearson correlation coefficients (r) were used to determine the strength of relationships between the variables. Differences of at least $p < 0.05$ was considered statistically significant.

## RESULTS

The mean special endurance rest result was 11.868 minutes (8.56 to 14.15), and the mean experience of the fencers was 11.235 years (6 to 25). This is in line with the represented age categories (youth to senior) (Table 1).

The study identified five significant relationships between the special endurance test and the tested dependent variables: training experience (0.538; p = 0.001), aerobic capacity (0.530; p = 0,001), reactive force index (0.409; p = 0.016), maximum jump height (0.392; p = 0.022), maximum jump flight (0.388; p = 0.024) (Table 2).

## DISCUSSION

The study showed that both hypotheses are true. Training experience (H1) and aerobic capacity (understood as the physiological component of motor performance), maximum flight time, and reactive force index (H2) are correlated with the special endurance test results. In other words, the study showed that the better the motor structure of female fencing athletes, the higher their special endurance score.

Research has shown that the ability to manage one's own body while preparing for a competition (even at the most advanced levels) grows in line with one's training experience [19]. Similar conclusions have been drawn from the comparison of fencing professionals and novices, which has been supported by observing fencers' muscle work during special movements. After a training cycle, efficiency gains were greater in the group of more experienced professionals than among novices [17].

The findings of other authors, as well as the results of this study, confirm H1. Hence, it is reasonable to recommend the modified special endurance test as a useful tool for monitoring regular training practice, especially for top fencing athletes.

It is far from surprising that fencers with greater aerobic capacity performed better in the special endurance test. This relationship is in line with

**Table 1.** Results of fencing special endurance, training experience, aerobic capacity and indicators of the motor skills of the female Polish Fencing National Team (n = 34).

| Variable | M | SD | Min | Max |
|---|---|---|---|---|
| Fencing special endurance [min] | 11.868 | 1.432 | 8.560 | 14.150 |
| Training experience [years] | 11.235 | 4.473 | 6.000 | 25.000 |
| Age [years] | 19.105 | 4.508 | 12.000 | 31.333 |
| $Vo_2$max [ml/kg/min] | 43.235 | 3.085 | 35.000 | 49.000 |
| HR max [bpm] | 193.206 | 7.491 | 176.000 | 204.000 |
| Body height [cm] | 169.765 | 6.434 | 153.000 | 181.000 |
| 5m run [sec] | 1.183 | 0.070 | 1.050 | 1.340 |
| Maximum contact time [s] | 0.475 | 0.109 | 0.303 | 0.748 |
| Maximum flight time [s] | 0.492 | 0.045 | 0.399 | 0.598 |
| Maximum jump height [cm] | 29.971 | 5.506 | 19.500 | 43.800 |
| Maximum leg power [W/kg] | 24.589 | 5.318 | 16.090 | 40.910 |
| Average power of four jumps [W/kg] | 23.129 | 4.953 | 15.720 | 38.320 |
| Maximum stroke frequency [jumps/s] | 1.064 | 0.106 | 0.810 | 1.250 |
| Reactive force index [m/s] | 0.653 | 0.226 | 0.320 | 1.350 |

**Table 2.** Results of fencing special endurance vs training experience, aerobic capacity, and indicators of the motor structure of the female Polish Fencing National Team (with Pearson's r correlation).

| Variable | Statistic indicator | |
|---|---|---|
| | r | P |
| Training experience [years] | **0.538** | **0.001** |
| $Vo_2$max [ml/kg/min] | **0.530** | **0.001** |
| HR max [bpm] | 0.112 | 0.527 |
| Body height [cm] | 0.253 | 0.149 |
| 5m run [sec] | −0.188 | 0.286 |
| Maximum contact time [sec] | −0.105 | 0.554 |
| Maximum flight time [sec] | **0.388** | **0.024** |
| Maximum jump height [cm] | **0.392** | **0.022** |
| Maximum leg power [W/kg] | 0.315 | 0.070 |
| Average power of four jumps [W/kg] | 0.287 | 0.100 |
| Maximum stroke frequency [jump/sec] | −0.049 | 0.785 |
| Reactive force index [m/s] | **0.409** | **0.016** |

the findings of Milia et al. [20], who showed that the training process of professional fencers (both male and female) must include endurance training. The need to combine lengthy training effort with special practice is confirmed by studies that show that fatigue leads to the loss of accuracy in fencing movements. It is clear that fencing, not unlike many other sports or military/police field operations [21-25], requires optimum accuracy under prolonged physical (and mental) strain. Therefore, it requires a high level of special endurance that is commensurate with the nature of the activity [15]. Other studies confirm that effort-induced fatigue may have an adverse effect on the speed and accuracy of responses to sensory stimuli, and they can lead to loss of concentration, and this eventually affects one's motor performance [26, 27].

A similar relationship was identified in studies of reaction time to physical effort at 70% and 100% of the maximum. At 100% effort, the reaction time was significantly longer [28]. Furthermore, Ando et al. [29] analysed the timing of reactions to peripheral visual stimuli during a cycloergometer routine with a gradually increasing load. The researchers found that, above the ventilatory threshold, reaction times tended to be longer.

In addition, intensive physical effort combined with sleep deprivation significantly reduces the ability of law enforcement officers and soldiers to tolerate disturbance in body balance. This not only impairs their motor performance, but it also increases the risk of loss of balance and injury in case of a fall or collision with stationary or moving objects [30-35]. Therefore, fencing practice may be an important addition to training rescue, military and law enforcement professionals.

Bouting fencers perform a variety of footwork techniques (lunges, slides and throws). They must also respond quickly to everything that happens during a bout. On the piste, they make sequences of high-intensity movements followed by low-intensity periods and breaks, when fencers can rest for a while [36]. These arguments, related to one's motor performance and physiology, alongside the relationships identified between empirical variables on the one hand and special endurance scores on the other, speak in favour of recommending this simple tool. The theoretical and empirical evidence presented above confirms that the rationale and assumptions followed in modifying the test proposed by Weichenberger et al. [18] are both based on firm methodological foundations.

However, empirical data from the authors' original studies can do little in the way of designing methods and indicators for identifying fencing talent. The most fundamental measurements should be done when young athletes are recruited (when special endurance in fencing cannot be reasonably taken into account) and then continued for years thereafter. Inspiration can still be drawn from Wężowski's pioneering research [37]. From the perspective of innovative research methodology largely dedicated to combat sports and self-defence, equally inspiring are the papers by Kalina et al. [38, 39] and Niedomagała [40]. It is also necessary to understand the effects of many years of fencing practice, which accumulate also in the somatic sphere of fencing athletes [41]. During the COVID-19 pandemic, researchers increasingly look at the adaptive outcomes caused by reduced training activity over long periods [42] and at possible creative ways to modify training programs [43, 44].

In the context of broadly understood promotion of health, survival competencies and prevention of diseases [45-50], fencing can be classified as one of the 'martial arts of long distance in ontogenesis', although this view deserves some criticism. On the one hand, hardly any sport stimulates motor and cognitive skills as creatively as fencing. Also, as in other combat sports and martial arts, offensive techniques (as well as some defensive ones, such as counterattacks) directly target the opponent's body. However, the protective gear and fencing weapons guarantee a high level of safety (the number of fatalities because of equipment failure is immeasurably lower than in other martial arts [51-53]). Under the definition of extreme human physical activity [54], fencing qualifies as the sport of extreme coordination and extreme burden on the body, with a high level of effort and a relatively low risk of death.

On the other hand, fencing is an asymmetric sport, which understandably makes it of little use for older people and those with spinal conditions. Therefore, with health concerns in mind, any combat sports and martial arts recommendations should be carefully balanced. A fine example is a paper by Błach et al. [55], who explored the limited potential of judo in preventing fall-induced injuries among farmers.

## CONCLUSIONS

It has been shown that the modified special fencing endurance test is useful because its results are strongly correlated with training experience, aerobic capacity and selected motor skills. It is reasonable to recommend the test as a tool for regular monitoring of special endurance in the training of top fencing athletes.

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