The fencing endurance test is associated with a ranking position in the national classification and body composition analysis in elite female fencers

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C Statistical Analysis
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Bartosz Hekiert [1ABCDE], **Adam Prokopczyk** [2ACD], **Marek Sokołowski** [2ADE], **Jarosław Klimczak** [3ADE], **Przemysław Guzik** [4CD]

[1] Department of Physical Education and Sport, Adam Mickiewicz University, Poznań, Poland
[2] Department of Sports and Defence Education, Poznan University of Physical Education, Poznań, Poland
[3] Department of Tourism and Recreation, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland
[4] Department of Cardiology-Intensive Therapy, Poznan University of Medical Sciences, Poznań, Poland

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Abstract

Background and Study Aim: Fencing Endurance Test (FET) examines physical activities like aerobic capacity, motor skills, speed-agility, interval backward and forward movement, and endurance in fencers. Competitive experience is reflected by the ranking position in the national classification. Such experience depends on various features of physical activities and usually impacts body composition. This study aimed is the answer to the question: whether FET results are correlated with ranking position in the Polish National Fencing Team and body composition in elite Polish female fencers.

Material and Methods: Thirty-four youth to senior female athletes from Poland's National Fencing Team were studied in the preparatory period. The average age of studied female fencers was 18.59 ±4.57 years. Their body weight was 59.55 ±7.70 kg, muscle mass 44.87 ±5.61 kg, water mass 31.49 ±2.39 kg, and fat content 20.53 ±2.91%. During FET, each fencer moved forward and back on a section of 3.5-metre length, maintaining the typical fencing position and footwork at speed increasing between 3 km/h and 7 km/h. FET was stopped if the teste was exhausted or after 15 minutes. Total body impedance analysis measured body composition (Tanita MC-580 S MA, Tanita, Japan), and heart rate for the maximal intensity of the physical effort was monitored by the Polar Team Pro (Polar, Finland) system. Depending on the data distribution, parametric Pearson or nnonparametric Spearman correlation was used in statistical analysis.

Results: The mean FET duration was 11.87 ±1.43 min, during which they achieved 95.99 ±4.38% of the age-predicted maximal heart rate. FET negatively and significantly correlated with the ranking position ($r = -0.76$; $p<0.001$) and positively with body weight ($r = 0.38$; $p = 0.028$), muscle mass ($r = 0.47$; $p = 0.005$), water mass ($r = 0.37$; $p = 0.031$), and the relative to age-predicted maximal heart rate ($r = 0.39$; $p = 0.023$). No correlation was found between FET and fat content.

Conclusions: FET correlates with competitive experience, body composition, and the intensity of physical effort in top national female fencers. Whether FET should be routinely used for fencers monitoring of the specific endurance requires further investigation.

Key words: combat sports • division of the combat sports • motor simulation • Polish National Fencing Team

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Author's address: Bartosz Hekiert, Department of Physical Education and Sport, Adam Mickiewicz University, 9 Zagajnikowa Street, 60-995 Poznan, Poland; e-mail: barhek@amu.edu.pl

Endurance – *noun* the ability or power to bear prolonged exertion, pain or hardship endurance athlete [33].

Flexibility – *noun* **1.** the amount or extent to which something can be bent **2.** the extent to which something can change or respond to a variety of conditions or situations [33].

Aerobic capacity – *noun* same as **VO2Max** [33].

Motor skills – *plural noun* the ability of a person to make movements to achieve a goal, with stages including processing the information in the brain, transmitting neural signals and coordinating the relevant muscles to achieve the desired effect [33].

Épée – is the heaviest of the three modern fencing weapons (foil, épée, and sabre), each a separate event, épée is the only one in which the entire body is the valid target area.

Division of the combat sports under forms of the direct confrontation – workings of weapons; hits (strokes); throws and grips of immobilisation of opponent's body [34].

INRODUCTION

Fencing is a combat sport where two contenders duel using the same weapon, i.e., a sabre, sword, or épée (belongs to the workings of weapons group – see glossary). At eexerciach level of competition, one match consists of 3 bouts of 3 minutes each [1]. The duration of an entire international fencing tournament is between 9 to 11 hours [2]. Fencing involves a mixture of physical activities-related to strength-power, flexibility, explosive movements,speed-agility, interval, and endurance exercise.

Top-level athletes must be able to coordinate consistent sequences of arm and leg movements [3]. Fencing footwork is highly asymmetrical. During a bout, fencers travel a distance of 250 to 1,000 metres [4]. Fencing is an aerobic exercise as energy for working muscles mainly comes from the phosphocreatine and adenosine triphosphate. It may also depend on anaerobic metabolism and cytoplasmic glycolysis in more prolonged and intensive bouts, training, and tournaments [5].

Special fitness in competitive fencers must be regularly monitored and analysed. The training must consider the athletes' body composition components,given a fencing bout's motor and energy characteristics. In combat sports, these components are critical todeveloping an athlete's career [6] and determining the achievement of training goals [7, 8].

Building and preserving proper body composition is crucial in the training process for athletes of any age [9, 10]. Body composition translates into better performance in specialised tests in combat sports [11, 12]. Several studies looked at fencers' anthropometric [13, 14] and morphological profile [15], body composition, and somatotypes [16-18].

The competitive experience, aerobic capacity, and motor skills of competitive-level female fencers are correlated with their performance in the special fitnesstest – Fencing Endurance Test (FET) [19].Their position in the national ranking best reflects the competitive experience of fencers. The aerobic capacity and motor skills can be estimated using FET.

This study aimed is the answer to the question: whether FET results are correlated with ranking position in the Polish National Fencing Team and body composition in elite Polish female fencers.

MATERIAL AND METHODS

Participants

The study group included 34 female athletes from Poland's national fencing team in youth to senior age categories. The average age of studied female fencers was 18.59 ±4.57 years. All attended a training camp during the preparatory period in the Summer of 2021.

Fencing Endurance Test – FET

FET was performed according to Hekiert et al. [19] (based on the work of Lorenzo and Andreoli [20] and Weichenberger et al. [21]). It is a modified test developed by Weichenberger et al. [21] and accounts for a specific fencer's footwork. During the FET, a fencer moves 3.5 metres forward and back along the playing area, maintaining the typical fencing footwork. The movement direction changes outside the lines marking the beginning and end of the 3.5-metre section. Sound signals control the pace of movements. For the first 3 minutes, the testee moves at 3 km/h, and then the speed increases by 1 km/h every three minutes. The maximal designed speed up is 7 km/h for the last three-minute, and then the test stops after 15 minutes. If the testeeis exhausted earlier and no longer wishes to continue, the test ends earlier [19]. The total FET duration reflects the current endurance of the fencer.

Ranking position

All the athletes from the study group compete at the senior level. Thus their *ranking positions* were determined based on the current ranking of senior female athletes of the Polish Fencing Association.Additionally, heart rate (HR) was monitored in all participants during the test with the chest strap transmitter (Polar Team Pro, Polar, Finland) and recorded by a dedicated system (Polar Team Pro,Polar, Finland) recording physical activity and HR. We measured maximal HR achieved at the end of FET and the relative HR as a ratio of the maximal achieved HR to the estimated HR using the formula "220 – age". The relative HR reflects the intensity of the physical effort during the exercise test.

Anthropometric and body composition analysis

Body height, weight, and composition were measured in the morning before the first meal. Body composition was analysed using the total body bioelectrical impedance analysis with octapolar-electrodes and dual-frequency (6.25&50 kHz) current(Tanita MC-580 S MA, Tanita, Japan).The following indicators were measured [21, 22]: total body fat weight [kg] and its relative content [%]; muscle mass [kg]; lean muscle mass [kg]; total body water mass [kg] and its relative content [%].

Ethical considerations

The study was a part of the "Supporting Research Projects in Competitive Sports 2021" project by the Polish Fencing Association from Warsaw, Poland, and co-funded by the Polish Ministry of Culture, National Heritage and Sport in Warsaw. After accepting all protocols (25th June 2021), the Polish Fencing Association permitted to perform the project. All athletes participated in the project voluntarily and gave their informed, written consent for participation. Additionally, parents or legal guardians of underage athletes gave their written permission.

Statistical analysis

Data distribution was analysed using the D'Agostino-Pearson test. Except for the ranking position in the National Polish Fencing Team, all indicators had normal distribution and were presented as mean (M), standard deviation (SD or ±), minimum (Min) and maximum (Max). The ranking position was summarised as median and the 25^{th}-75^{th} percentiles. Parametric Pearson correlation (with r coefficient) was used to determine the relationships between the FET duration and indicators with normal distribution. Nonparametric Spearman correlation (with rho coefficient) measured the association between the duration of the endurance test and the current ranking in the Polish National Fencing Team. Results were considered statistically significant for p-values <0.05.

RESULTS

The median ranking position in the Polish National Team of studied athletes was 24.412 ±15.412. The duration of the special endurance test ranged from 8.56 to 14.15 minutes. The average intensity of the effort during the test was maximal as the relative HR was nearly 100% of the predicted by age HR The remaining data are summarised in Table 1.

Table 1. Results of special fencing endurance (FET), body height, body weight, and body composition of the female fencers (n = 34) from Polish National Fencing Team.

Variable	M	SD	Min	Max
Fencing special endurance [min]	11.868	1.432	8.560	14.150
Ranking position	24.412	15.412	51	1
Body height [cm]	169.765	6.434	153.000	181.00
Body weight [kg]	59.547	7.699	43.800	73.700
Fat tissue [%]	20.529	2.905	14.200	26.100
Fat tissue [kg]	12.285	2.616	6.800	17.500
Muscle mass [kg]	44.871	5.607	33.700	55.000
Lean mucle mass [kg]	47.268	5.905	35.500	58.000
Body water [kg]	31.488	2.393	26.000	35.700
Body water [%]	53.286	3.592	47.238	60.960

There were 5 significant correlations between the special endurance test in fencing and the examined dependent variables: ranking position (−0.759; p = 0.000), body weight (0.376; p = 0.028), muscle mass (0.470; p = 0.005), and water content [kg] in the body (0.372; p = 0.031) (Table 2).

DISCUSSION

We have found that FET results are significantly correlated with the ranking position of female fencers from the Polish National Team and their body composition. Athletes who ran longer during the test, i.e., had better exercise performance and capacity, and were ranked higher. Such fencers usually had a higher body, muscle, lean mass and body water content. Of interest, no correlation was found between the FET results and the achieved maximal HR, although a positive correlation was noted with the relative maximal HR.

We demonstrate that superior athletes, i.e., those with a higher ranking position and competitive experience, perform better in the FET. Similarly to the beep-test, FET results reflect exercise capacity and are correlated with muscle oxygen consumption (VO2) [19]. However, unlike the beep test, FET requires specific skills from an athlete who moves forward and backward using typical fencing footwork. FET results are closely correlated with the ranking position of fencers, but similar data for the beep-test are unavailable. Altogether, FET provides more information than the standard beep test for fencers.

Endurance is one of the predictors of performance in competitive fencing at the international level [23]. Hence, athletes' endurance should be regularly monitored, considering the specific fencing nature. Fencers competing at the international level achieved better FET results than those competing domestically [23].

Furthermore, the movement accuracy of female fencers at various levels of sporting excellence and preparing for the Olympic Games was better during longer efforts than those competing domestically. The most considerable movement accuracy differences were near the FET's end when the highest endurance level occurred [24].

The athlete's ability to maintain movement accuracy despite increasing physical effort and fatigue is vital for the top fencers. So far, various studies have shown that movement accuracy and speed decrease faster in athletes with less adequately trained motor skills [25-28] (we emphasize the importance of not only motor simulations, but also the non-apparatus and quasi-apparatus test [29] in the practice of combat sports training, especially as self-defence art). Reaching the tournament's final round is a crucial goal for competing fencers. Whereas the fencers' fatigue increases, their ability to maintain movement accuracy declines. Athletes with higher sporting excellence achieved better FET results.

Our study also demonstrates that female fencers with a higher body, muscle, lean mass, and body water content have better exercise

Table 2. Correlation between the special fencing endurance indicator and other empirical variables (all relationships are Pearson's correlation results, except for the ranking position, for which the rho coefficient from the nonparametric Spearman correlation is shown).

Variable	Corelation with FET results	
	R	p
Ranking position	**−0.756**	**0.000**
Body height [cm]	0.253	0.149
Body weight [kg]	**0.376**	**0.028**
Fat tissue [%]	−0.267	0.127
Fat tissue [kg]	0.053	0.767
Muscle mass [kg]	**0.470**	**0.005**
Lean muscle mass [kg]	**0.469**	**0.005**
Body water [kg]	**0.372**	**0.031**
Body water [%]	−0.319	0.066

performance and capacity. Such women have a more masculine body build as they are better muscled [30, 8]. Our findings are consistent with the body composition analysis of competitive fencing athletes reported in earlier studies – competitive fencers repeatedly were heavier than non-athletes [16].

We have also observed that body fat is not associated with exercise performance in fencing. Muscularity is one of the outcome determinants in various sports disciplines, including fencing [14]. In some sports, the fat amount is negatively correlated with exercise performance. We demonstrate that muscle mass but not the fat amount is associated with the FET results.

Earlier studies have also shown that hydration affects muscular performance in combat sports athletes – less hydrated athletes may suffer from more significant muscle fatigue and a worse ability to use force [31]. Elite female fencers risk severe dehydration. It is particularly visible during long-lasting tournaments and prolonged training [31]. We have observed that hydration was also significantly correlated with the performance of female fencers. It indirectly confirms the physiological relevance of hydration and its impact on the exercise to exhaustion during the FET.

Finally, we have not observed any significant correlation between the FET duration and the achieved peak HR during this test. It suggests that either the peak/maximal HR is not the best tool for monitoring female fencers or that HR and the FET duration reflect different features of exercise capacity in such athletes.

Another explanation is also possible. Female fencers on the national level always perform as best as possible, regardless of whether it is a tournament, training, or test. The relative maximal HR, i.e., the ratio of the achieved HR to the predicted maximal HR, was nearly 100%. It confirms that the studied athletes made their best and maximal effort during the test. Therefore, it is unsurprising that all athletes, even those with the shorter FET duration, achieved high HR.

CONCLUSIONS

With this study, we demonstrate that the modified FET is a valuable monitoring tool in the training process of female fencers. Its results correlate with the athlete's ranking position, body, muscle and lean tissue mass, body water content, and relative maximal HR. Whether the test should be recommended as a tool for regular monitoring of female fencers requires further prospective investigation.

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