Somatic determinants of hit precision in female foil fencers

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A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
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Abstract

Background & Study Aim: Achieving success in fencing (connected with hit precision) is determined by many factors. One of them are somatic indicators. Thus, the purpose of this study was knowledge if somatic characteristics, including the amount of morphological asymmetry, would be important in the context of the hit precision by female athletes.

Material & Methods: The research subject was a group of 60 female foil fencers aged 14-17 years (junior category). All athletes underwent anthropometric measurements and body composition analysis which was performed using the bioelectrical impedance method, with segmental assessment. The hit accuracy was made using the Favero EFT-1 electronic board. 3 different tests were performed twice with both the dominant and non-dominant hand. The averaged task completion time for each hand separately was used for analysis.

Results: The somatic characteristics influencing the precision of left-handed hits included lean body mass, muscle mass and total body water content. No such correlations were observed for right-hand precision. It was also shown that the greater the asymmetry in the upper extremities in lean body mass and muscle mass, the lower the precision of the right hand. For left hand precision, no correlations were observed with body components.

Conclusions: The results obtained can be useful for theory and practice in fencing. Coaches should pay attention to the relationship between the hit precision and somatic characteristics, along with segmental analysis of body composition to improve performance of athletes.

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Racket sport – *noun* any of various sports that use a racket and ball or shuttlecock, e.g. Tennis, badminton or squash [57].

Combat sport – *noun* a sport in which one person fights another, e.g. wrestling, boxing and the martial arts [57].

Foil – one of the three weapons used in fencing (foil, epée and sabre), each a separate event. The fencer can only score a hit by striking the point of their weapon on the defined target area of their opponent, limited to the torso.

Hit precision – the accurate hit of a weapon into a well-defined field.

Body composition – the amount of fat, fat-free mass and total water content, whose proportions in the body can influence sport performance.

Bioimpedance analysis – a field method of estimating body composition.

INTRODUCTION

Every sport always has a winner, either an individual or an entire team. One of the most important factors in determining the success of an athlete is their precision and accuracy in performing certain specific actions. In many sports, hitting a target is important, such as precisely striking a point or passing a ball to a well-defined place [1, 2]. This skill often determines the final ranking. Precision is more important in some sports and slightly less so in others. This sport-specific factor can mean slightly different performance.

In individual sports, precision is a factor that can guarantee success or lead to failure [3-5]. In tennis (apart from the discussion whether it is justified to classify racket sports as individual sports since there are doubles games), precision may mean a perfect serve; this is related to the height of the tossed ball [6] and does not depend on the speed of the stroke [7]. In golf, precision is about hitting the ball into the hole with a particular club [8, 9]. For an archer, precision and accuracy can mean hitting the bullseye every time [10]. Precision is also important in team games, such as soccer, where it manifests as the ability to hit the ball into the goal area [1]. Bache and Orellana [11] emphasise the role of movement precision in volleyball, where the rebound of the ball takes no more than a fraction of a second and requires extreme precision.

In combat sports, including fencing, the great importance of precision [12] is inextricably linked to success. The result in this sport is determined by many factors, including morphological, fitness and coordination, biochemical and physiological aspects [13]. The search for the relationship between these factors and sports performance is still ongoing due to the complexity of the problem. Aiming to simplify the issue, a theoretical model of the determinants of the precision of fencing hits was proposed (Figure 1).

This study focuses on one determinant: somatic factors. According to many authors, these are important in achieving success in sports [14-18]. Studies show that the body type of athletes can explain 25% to 65% of the results of physical fitness tests [19, 20]. Although success in sports competitions has often been associated with discipline-specific physique, such data for fencers are limited, inconclusive and presented mainly for descriptive purposes. According to research, fencing success is also determined by the appropriate morphological characteristics [21]. First, length dimensions (body height, arm reach, limb length) are particularly important given the nature of the sport [22-24].

Tsolakis et al. [25] showed a significant relationship between body height, sitting height, body weight and skin–fat fold thickness at the lower angle of the scapula and over the triceps brachii muscle and the physical fitness results obtained by 19-year-old fencers. However, when the participants were divided by sport level, no clear differentiation in somatic indicators was observed between athletes. This suggests that the role of morphological factors is not as significant as supposed [26, 27].

Another study reported no differences in somatotype between individuals aged 18-20 years and those over 20 years [25]. Rather, the predominance of technical, tactical and physiological

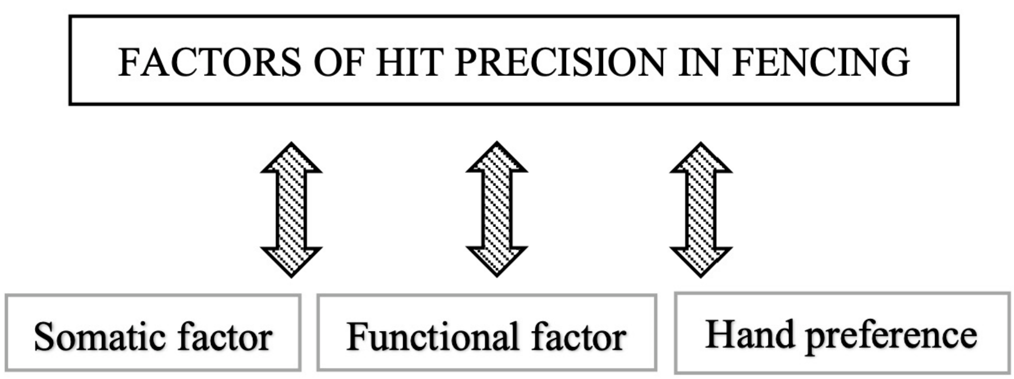

Figure 1. Factors of hit precision in fencing.

elements is emphasised, without denying the role of morphological factors in fencing [13]. Ntai et al. [28] showed disparities in somatic indicators between athletes of different sport levels: more advanced fencers were taller and heavier. Sterkowicz-Przybycień [29] showed that fencers are taller on average (183 cm) compared to the non-sporting population (169 cm).

Depending on their physical conditions, athletes also adapt to a particular playing strategy. Tall athletes use their height and their correspondingly longer lower limbs to cover more distance at a time, whereas shorter athletes expend more energy in fast movements requiring greater agility [13]. Blach [30] determined the level of selected somatic characteristics and body composition of 37 top fencers aged 18–34 years, finding significant differences in somatic characteristics. The medallists were on average 5.8 cm taller and 7.1 kg heavier, and their lean body mass was 4.9 kg higher. Relative body fat and lean body mass were only slightly different between the groups studied. The study showed that in sports, the correct level of body fat mass is important for athletic success [31].

In fencers, the predominance of lean body mass has been demonstrated [32, 33]. A higher proportion of lean body mass in relation to fat mass can generate more power and give an advantage in combat, enabling the athlete to reach their opponent faster and more freely [34]. Another study made a morphological characterisation of fencing athletes, depending on the type of competition practised and thus the different categories of weapons. In addition to the appearance of the weapon, the difference between the three competitions lies mainly in the field of hit. Thus, these differences may determine at least the size of the somatic characteristics of the athletes [35]. Polish fencers competing in sabre had a higher proportion of mesomorphia, a higher body mass index and a higher proportion of lean body mass compared to those competing in fencing and sabre. The level of fat mass was not different between fencers by weapon type and was higher relative to non-fencers [29].

Other studies of fencers representative of different countries have not shown variation in somatic indicators depending on competition [28]. The specific body proportions of fencing athletes are most likely due to the long-term effects of training, as well as the selection system for individuals with specific somatic prerequisites developed over years of training [36].

Since fencing is an asymmetrical sport, the research has also considered the biased variation of somatic indicators in athletes. Training loads, especially those of a unilateral nature, can significantly affect the amount of morphological asymmetry. In fencing, a higher intensity of effort per side of the body is required, resulting in disproportions in body structure [13]. Training is enforced by the regulations of the discipline and geared towards the formation of asymmetric movements. This is justified by the need to constantly increase the motor skills, fitness and strength of one side of the body and maximise performance. The harmonious and dynamic acyclic working movements performed during combat include such elements as changing the direction of movement, acceleration and deceleration, forcing athletes to constantly change the plane of support. Training that focuses on the dominant limb can affect greater functional asymmetry (when performing a specific task), with the dominant limb (which is stronger, faster and more precise) having an advantage [37].

Thus, the purpose of this study was knowledge if somatic characteristics, including the amount of morphological asymmetry, would be important in the context of the hit precision by female athletes.

We hypothesised that female athletes who were taller, more muscular, with lower body fat and more symmetrical body morphology would have greater precision in inflicting hits.

MATERIAL AND METHODS

Study participants

The research participants were 60 female athletes aged 14-17 years (M = 14.43 ±1.36) practising foil fencing in the junior (under 17) category. These fencers represented at least an intermediate level of specialised preparation. Their minimum competitive seniority was 5 years, and the maximum was 12 years. All the examined athletes were qualified to participate in the European Cup of Cadet Women in fencing, which took place in Poznań, January 12–13, 2019. The research was carried out during the starting period, on the eve of the 2019/2020 season competition, in the sports hall. In the annual training cycle, training is constructed for the participation of athletes in eight World Cups, which are held on five continents. Depending on the date, preparation for the Cup lasts from 4 to 6 weeks and is designed to determine the strongest team for the European and World Championships, which take place in late June and early July, followed by a period of de-training. A general preparation period begins in September, followed by a specialised preparation period in October, and then the season begins in November. Under-17 athletes have control starts in World Cups to verify their sports level.

Participation in this study was voluntary, and qualification was purposeful. No participant had medical contraindications to participate in the study.

Approval to conduct the study was obtained from the Bioethics Committee at the Karol Marcinkowski Medical University in Poznań (Resolution No. 255/19). The research team consisted of personnel technically prepared to use the research apparatus necessary to conduct the study.

Measurement of body composition

The athletes underwent anthropometric measurements. The somatic factors included the indicators of body height, body weight and body composition (fat mass, lean body mass, muscle mass, total body water content, bone mass). The study was carried out by a sports anthropologist following Malina's et al. [38] methodology, using standard anthropometry testing instruments with the accuracy allowed by their scales. Body height was determined by the distance from the vertex anthropometric point to the basis point, i.e. the ground on which the athlete under study stood. The measurement was made with an anthropometer (GPM, Switzerland) with an accuracy of 1 mm.

The body composition of the athletes was then analysed with segmental readings including the distribution of body fat, lean body mass and muscle mass on the left and right upper and lower extremities. A bioelectrical impedance analysis method using a TANITA MC 980 MA multifrequency analyser (Japan) was used for this purpose. The measurement was performed according to the manufacturer's stated test procedure. Before the measurement, gender, body type, age and height data were entered into the device's memory. The athletes were required not to consume alcohol, energy drinks, coffee or other caffeine-containing substances in the 24 hours before the test. They approached the body composition test in sports attire, without jewellery or other adornments. They had no contact with electrically conductive elements and proceeded to the measurement after drying their feet with a paper towel [39].

Measurement of hit precision

After the anthropometric examinations, the athletes took a test to assess the precision of their hits, according to the methodology given [40]. The test was performed using the Favero EFT-1 electronic board (Favero Electronics Srl Arcade [TV], Italy).

The Favero EFT-1 can perform nine tests; three were used in the testing procedure. The athlete's task was to perform in the shortest possible time a series of embeddings of the end of the weapon (punts) into randomly appearing, red-lit targets. The tests allowed for accurately determining the precision of inflicting hits in different variations.

Test 1 consisted of hitting two randomly appearing targets, which were illuminated in red in 10 cycles. Each cycle began with the illumination of the first target. A correct, accurate hit on the first target was followed by the illumination of the second target. The task was to complete 10 cycles of hits in the shortest possible time. During the execution of the task, the participants were in a fencing stance at a distance suitable for performing a straight push. In the event of not hitting the target or not performing the hit sequence correctly, a time of 2.50 seconds was added to the test and counted towards the overall average performance of the given program.

Test 2 consisted of hitting three randomly appearing targets that illuminated red in 10 cycles. Each cycle began with the illumination of the first target. A correct, precise hit on the first target was followed by the illumination of the second target. A correct, accurate hit on the second target was followed by the illumination of the third target. The task was to make 10 cycles of hits in the shortest possible time. In case of not hitting the target or not performing the hit sequence correctly, the test subject was credited with a time of 2.70 seconds and counted towards the overall task performance average.

Test 3 consisted of hitting three red-lit targets simultaneously in three cycles. In case of not hitting the target or not executing the hit sequence correctly, the test subject was credited with a time of 3.00 seconds and counted towards the overall task execution average. All tests assessed the precision of making hits in the shortest possible time. The tests were performed twice, using both the dominant and non-dominant hand. The averaged execution time for each hand separately, with an accuracy of 0.01 second was used for analysis.

The precision in all experimental tests was determined by the timing of accurate hits since precise actions in the shortest possible time are crucial in fencing. An off-target hit according to the fencing convention (rules for awarding points) results in surrendering the initiative to the opponent and often ends in receiving a hit from their side. In the tests conducted, the possibility of repeating missed hits was abandoned because the task was to evaluate the effectiveness of the accuracy of thrusts within the elapsed time [35].

Statistical analysis

Statistical analyses were carried out using the IBM SPSS statistics package version 25. The estimation of the results is based on the following indicators: frequency (n); mean (M); minimum (Min); Maximum (Max); standard deviation (SD or ±); probability (*p*). Basic descriptive statistics were calculated, and means were compared, using Student's t-test for two groups with equal variance or the non-parametric Mann–Whitney U test for variables without normal distribution. To determine the relationships between variables, a series of correlation analyses were performed using Pearson's (r) and Spearman's (rho) coefficient. A value of p = 0.05 was taken as the level of statistical significance in this study.

The following formula was used to calculate the asymmetry between limbs [41]:

$$\text{Symmetry index} = \frac{X_R - X_L}{\frac{1}{2}\cdot(X_R + X_L)} \cdot 100\%$$

Where: X_R means the size of the feature under study on the right limb; X_L denotes the size of the feature under study on the left limb.

A positive result indicates greater predominance (dominance) of the right side, and a negative result indicates dominance of the left side. A result closer to zero suggests lesser (weaker) asymmetry between the limbs within the indicator under study.

For the above indicator, the magnitudes of a given indicator for both limbs can refer to both individual values and arithmetic averages for the studied group.

RESULTS

The data of the morphological characteristics of surveyed fencers are included in Table 1.

No somatic characteristics correlated significantly with the precision of the right hand. However, fat-free body mass (kg), total body water content (kg) and muscle mass (kg) correlated significantly with the precision of the left hand. This means that the smaller the size of these components, the higher the precision of inflicting hits (Table 2).

Table 1. Somatic characteristics of the female foil fencers (n = 60).

Somatic characteristics	M	SD	Min	Max
Body height [cm]	163.0	6.46	146.60	180.60
Body weight [kg]	55.94	6.93	37.50	67.60
Body Mass Index [kg/m^2]	20.87	2.09	16.30	25.20
Fat mass [%]	24.62	3.29	17.40	31.50
Fat free mass [kg]	42.03	4.32	29.60	49.30
Total body water [kg]	30.77	3.16	21.70	36.10
Muscle mass [kg]	39.88	4.10	28.10	46.80

Table 2. Correlations of somatic characteristics with right and left hand precision in the female foil fencers (n = 60).

Somatic characteristics	Right hand precision		Left hand precision	
	r	p	r	p
Body height [cm]	–0.09	0.487	–0.24	0.077
Body weight [kg]	–0.21	0.116	–0.25	0.057
Body mass index [kg/m^2]	–0.20	0.130	–0.18	0.178
Fat mass [%]	–0.06	0.639	–0.12	0.394
Fat free mass [kg]	–0.22	0.096	**–0.26**	0.048
Total body water [kg]	–0.22	0.097	**–0.26**	0.050
Muscle mass [kg]	–0.22	0.095	**–0.26**	0.048

Calculations using Pearson's r correlation across the group showed a positive relationship between the amount of asymmetry in lean body mass (kg) and muscle mass (kg) and the precision of inflicting hits. The greater the asymmetry upper limbs of these indicators, the lower then precision of then right hand. In the case of the precision of the left hand, such correlations were not observed (Table 3). The greater the asymmetry of upper limbs of these indicators, then lower the precision of the right hand.

DISCUSSION

Physique and body composition are among the factors distinguishing athletes from non-athletes [42-44]. The magnitude of the differences depends on the particular sport [45] because each requires different training, affecting the athlete's physique and body composition, so determining the so-called optimal body component proportions is difficult [46]. However, excessive levels of body fat negatively affect success in sports [47]. The literature contains little consideration of the relationship of somatic characteristics to the accuracy of performance of a given motor activity, which is an important element of the final result in sports.

Accordingly, factors that may condition such accuracy are being sought. In this regard, the appropriate degree of acquisition of technical elements and the appropriate level of motor skills or motor coordination are important [48, 49]. Precision can manifest as accurately shooting or throwing an object at a target (throwing a ball into a net or basket, service in volleyball, taking a shot in archery, shooting a firearm) or precisely directing an object or body part towards a target (hitting or kicking an opponent in martial arts, striking

Table 3. Correlations of the morphological asymmetry of the female foil fencers with right and left hand precision (n = 60).

Somatic characteristics	Limbs	Right hand precision		Left hand precision	
		r	p	r	p
Fat mass [%]	upper	0.21	0.110	–0.05	0.720
	lower	0.10	0.460	–0.17	0.210
Fat free mass [kg]	upper	**–0.40**	**0.002**	0.24	0.070
	lower	–0.19	0.157	0.22	0.107
Muscle mass [kg]	upper	**–0.40**	**0.002**	0.24	0.070
	lower	–0.17	0.200	0.17	0.219

an opponent with a weapon in fencing). In many sports, an 'efficiency model' is being sought for factors that can increase the probability of achieving a goal through the precision of players' execution of throws, shots or passes. Athletes at a higher level of sports performance are characterised by faster and more precise strikes [50].

Few studies have looked for a relationship between the precision of performing an activity in sports and somatic characteristics, however. Such observations have been made concerning handball players, for example, finding a relationship between the accuracy of a throw into a goal and the width of the hand [51] and between accuracy and body height in standing and sitting positions [52]. In contrast, other studies have shown that somatic indicators are poor predictors of motor skills in young handball players [53]. Another study demonstrated no relationship of height or body mass with shooting precision in air rifle shooters. It highlighted the hypothetical role of other somatic characteristics, such as body component proportions, body fat levels and the length of individual body segments, which could potentially affect movement technique and ultimately the outcome in this discipline [54].

Research in fencing has not been conducted to date, which prompted the authors of the present study to attempt to identify somatic factors that may show a relationship with the accuracy of female athletes' strikes. Based on the existing knowledge assuming a relationship between somatic indicators and success in fencing, we hypothesised that female athletes who were taller, more muscular, with lower body fat and more symmetrical bodies would have higher precision in inflicting hits. This hypothesis was only partially confirmed. The athletes studied were characterised by a relatively small height (M = 163.4 cm), which did not determine the precision of their hits. However, the research showed a correlation of lean body mass, total body water content and muscle mass with the precision of the left hand: the lower these indicators, the better the precision of inflicting hits with the left hand.

Such observations were not made for the right hand. A study of 128 Polish athletes (67 boys and 61 girls) practising fencing between the ages of 14 and 16 showed that for boys, body fat levels were within the correct range, while for girls, they exceeded the population norm, with a trend increasing with age [55]. However, these studies did not analyse the precision of inflicting hits. According to Jagiello et al. [24] fencers, even those of the highest class, have more body fat than the population, which is related to the very intense, short exercise sequences in this sport, where fat as an energy source plays a minor role. A 2020 study on a group of female participants in international tournaments and high-ranking medallists outside the medal zone, significant differences in morphological characteristics were found between them. Female medallists were on average 5.8 cm taller and 7.1 kg heavier, and their body weight was 4.9 kg higher. Other somatic characteristics, such as relative fat mass and lean body mass, differed only slightly among the groups studied. The authors concluded that in fencing, technical and tactical skills are factors that significantly affect the outcome. These traits develop with sports experience, so age may be a determinant affecting the relationship of somatic constitution with sports performance [30]. However, whether it could be a factor relevant to the infliction of precise hits by fencers has not been determined, which is worth considering in further research.

The literature emphasises that in the study of fencers, the segmental distribution of individual somatic indicators should be systematically observed for the effectiveness of athletes [56]. In this discipline, through intensified asymmetric movements of the dominant limb, exacerbated bias differences may exist in the level of the indicators studied in favour of a higher level of lean body mass than fat mass on the dominant limb. Performing such an analysis in the entire group of female athletes in terms of the precision of inflicting hits with the right and left hand showed a positive relationship between the amount of asymmetry of lean body mass and muscle mass of the upper limbs and the precision of the right hand. This means that the greater the asymmetry in the upper limbs in the indicators studied, the lower the precision of the right hand.

In combat sports such as fencing, body composition can be the result of an individual's fighting style or technique. Information on the level of individual body components provides a valuable set of empirical data on athletes, which can be effectively used to enhance their athletic performance. In fencing, the level of fat mass is considered one of the most important factors affecting the achievement of expected results [31]. The results of research conducted in this direction are inconclusive and often give contradictory results, which explains the validity of their systematic monitoring from the first years of fencing training [28]. Notably, no research has been conducted to determine the relationship of somatic characteristics with the precision of strikes inflicted by female fencers. Thus, the issue considered in this work is a novel research problem. The results justify including this factor as an element of monitoring the training process in terms of increasing the effectiveness of fencers by increasing the precision of hits.

In summary, morphological factors are important, but not the only, determinants of success in fencing. Demonstrating that they are more important than other factors is difficult. Compared to other combat sports, good performance in fencing depends largely on coordination skills; this is related to the need to choose actions that can provide an element of surprise to the opponent. The results of the study do not allow clear interpretation, which suggests the need for further research and the need to include additional variables in the analysis, e.g. sports level, age and gender. This would allow explaining with greater probability the potential relationship of somatic characteristics with sports performance in fencing, as manifested by the precision of hits.

CONCLUSIONS

The results obtained will be useful for theory and practice in fencing. Although the results are not conclusive, a relationship was shown of certain somatic characteristics and the magnitude of morphological asymmetry with the precision of hits by female foil fencers. Systematic monitoring of possible changes would allow appropriate measures aimed at optimising somatic characteristics and the magnitude of morphological asymmetry in the context of hit precision.

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