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Anthropometric and Leg Power Factors Affect Offensive Kinetic Patterns in Fencing

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ABSTRACT

International Journal of Exercise Science 14(4): 919-931, 2021. This study aimed to identify potential factors that may influence specific fencing offensive kinetic patterns in a large group of well-trained fencers having different ages, gender level, and training specialization. One-hundred-thirty fencers (males: $n = 72$) and (females: $n = 58$), participating in three different fencing weapons (epee, foil, and sabre), having considerable experience of national and international competitions. All members of seven national fencing teams were measured for basic anthropometric parameters, leg power performance and velocity values for three specific kinetic offensive patterns during an International Fencing camp. A multivariate analysis of variance (MANOVA) revealed a significant velocity multivariate effect in age competitive categories ($Wilks\ \Lambda = 0.129$, $F = 2.112$, $p < 0.01$, $n^2 = 0.060$) gender ($Wilks\ \Lambda = 0.103$, $F = 3.743$, $p < 0.05$, $n^2 = 0.103$), competition levels ($Wilks\ \Lambda = 0.863$, $F = 5.198$, $p < 0.01$, $n^2 = 0.137$) and discipline practiced ($Wilks\ \Lambda = 0.239$, $F = 4.305$, $p < 0.001$, $n^2 = 0.119$) respectively. Significant correlations were observed between lunge and step lunge velocity and long jump (LJ), countermovement jump (CMJ), drop jump (DJ), and reaction strength index (RSI). Age, gender, level of participants, and the choice of the weapon practiced, influenced fencing performance. Different leg power abilities could be decisive factors in training schedules design and monitoring training adaptations.

KEY WORDS: Fencers, age, gender, level, specialization

INTRODUCTION

Fencing is a highly technical sport that depends upon fencers' ability to repeat offensive and defensive leg movements that require dynamical leg patterns, shorts bouts of high-intensity attacks, and long bouts of low-intensity preparatory actions and recovery periods (19). Offensive movements are powerful actions that a fencer aims to make a hit against the opponent on his initiation or immediately after a successful defensive action, executed correctly at the right moment (2).

Fencing lunge is an offensive fundamental explosive skill standardized by the fencers' availability to generate a great amount forces in limited time concerning anthropometric traits (9, 26). In that perception, lunge requires extremely high and well-coordinated motions decisive for combative tasks (4, 20). Recently, kinematic analyses of fencing lunge identified a sequential activation of the elbow extensors of the dominant arm followed by the relative activation of the hip, knee, and ankle muscles that dictates the correct technique associated with fencing success (14, 29).

Fencing lunge has been largely investigated, revealing differences among gender, level, and competitive weapons in hand and postural velocity (30). As well, as reaction (29), neuromuscular coordination of multi-joint movements (30), length of lunges (8), leg power (10), specific hand and leg kinematics parameters (3, 14), and movement quantifications and frequency of attacking actions (1).

However, physiological data describing the association between anthropometric, strength - power abilities, and functional fencing performance (lunges and step and lunge) are relatively sparse. Tsolakis et al. (23) showed a significant correlation between lunge time and body fat percentage, dominant and non-dominant thigh cross-sectional area, and performance in squat jump, countermovement jump, and the reactive strength index that revealed different dynamic requirements. Moreover, lunge velocity significantly correlated with the time to peak squat force, leg length, and flexibility (5), as well as the standing broad jump, and a specific agility performance test (26). Recently, the unilateral triple jumping performance was found to be correlated with the maximum step and lunge velocity in well -trained female fencers, confirming the specific role of each leg in leg fencing performance (6).

More information is needed concerning the association between fencing performance and strength and power measures to create evidence-based conclusions that may be useful to further specialized fencing training. Thus, the present study's purposes are to 1) report velocity normative values in specific offensive kinetic patterns, 2) describe the relationship of velocity and power in specific offensive kinetic patterns to anthropometric measures, and 3) define the relationship of velocity and power in specific fencing offensive kinetic patterns to expertise and discipline. It was hypothesized that males would perform better than females, and older groups better than younger in measures of fencing velocity.

Moreover, it was expected that international fencers would outperform national level fencers, while no differences are expected among the different disciplines of fencing in selected power measures. We also hypothesized that strong correlations between the velocity of the specific kinetic patterns and leg power would be obvious in this large group of fencers (4, 26), and anthropometric measures were expected to influence fencing performance (27). The examination of three different specific offensive kinetic patterns (lunge (L), step and lunge (SL) and step backward – step and lunge (SBSL)) throughout age, gender, competition levels, and discipline groups, and the relative relations to power measures and anthropometry may help fencing trainers to further explain fencing performance. Moreover, using fencing performance as an index of fencers' leg power would establish a useful fitness profile for the adequate program's design for each training level and discipline practiced.

METHODS

Participants

During an international fencing camp, one hundred-thirty experienced fencers, members from seven national teams, participated in data collection. The physical characteristics of the participants are shown in Table 1. Sixteen participants had considerable experience in international competition, while the remaining 103 had national-level experience. The participants were also divided in three age groups, according to the International Fencing Federation competitive rules, (cadet: n = 47, juniors: n = 34, and seniors: n = 49) and three disciplines practiced (epee: n = 33, foil: n = 55, and sabre: n = 42). The participants were systematically trained for at least six months, five times a week for approximately 15 - 18 hours/week, participated in a total of three to five training camps, and competed in 16-20 competitions per year. Before data collection, a thorough description of the risks being involved were disclosed and informed consent was obtained from each participant. The study was approved by the local Institutional Review Board (School of Physical Education and Sports Science, National & Kapodistrian University of Athens), and all procedures were under the Code of Ethics of the World Medical Association (Helsinki declaration of 1964, as revised in 2013). This study was also carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (15).

Table 1. Descriptive statistics for anthropometrics for male and female international and national fencers of different specializations (n = 130).

	Males (n = 72)	Females (n = 58)
Age (years)	20.87±7.35	20.33±5.98
Height (cm)	177.33±9.10	168.20±6.34
Weight (kg)	70.14±11.98	58.02±7.13
BMI (Kg/m^2)	22.21±2.93	20.33±5.98
Years of training	9.32±5.5	8.65±5.15

Protocol

This cross-sectional experimental study was designed to examine in-depth specific fencing offensive performance characteristics in a large group of fencers. This study was conducted during the transitional training period and lasted two weeks (nine trainings/week). During this period, fencers engaged with exercises aimed to improve basic physical condition, that included, alternatively, circuit training, sprint, jumping plyometric drills, and recreational team games (volleyball, football, basketball). Moreover, typical fencing training was devoted to specific leg exercises and technical and tactical fencing issues at moderate to high intensity. All measurements were performed during the afternoon trainings at the same time of the day in groups according to the weapons practiced. Different experienced trainers were used as examiners, after been previously trained in the testing procedures by University researchers.

Participants with recent lower extremity injuries were excluded from the study. Fencers were instructed to avoid any strenuous exercise. However, they were advised to jog for 15 minutes in their personal easy pace and perform easy stretching exercises in the basic muscle groups for 15 minutes the day before, but did not participate in any training the day of the measures. Verbal encouragement given from the examiners during each test helped fencers to perform maximally at each trial.

All measurements were carried out twice on the dominant side. Leg dominance was defined concerning the armed hand (17). All fencers were familiar with the specific fencing kinetic patterns and leg power measures, since they often performed these exercises for training purposes, as well as for monitoring training adaptations. After completing the informed consent, the participants were measured for their height, body mass, arm span, and sitting height. Height was measured to the nearest 0.1 cm with a stadiometer (Seca 220). Body mass was measured to the nearest 0.1 kg with an electronic scale (Seca Alpha 770). Participants were asked to stand barefoot in both measurements. Body Mass Index (BMI) was calculated from body mass and height (kg/m^2).

All measurements were taken twice from the dominant side of each subject. To evaluate jumping and fencing performance, fencers followed a ten-minute typical warm-up, consisting of passive and dynamic stretching exercises, as well as three to five different preparatory plyometric jumps and sport-specific fencing drills (forward and backward steps, bounces, and lunges). All testing procedures for the squat jump (SJ), countermovement jump (CMJ), drop jump (DJ), and long jump (LG), utilized the derived indexes and values of the reliability coefficients of the respective tests that were previously reported (16). The values of the reliability coefficients of each test were 0.96, 0.95, 0.90 and, 0.91 ($p < 0.001$), respectively

Fencing performance (velocity and power of fencing tests) was determined using a linear encoder: Chronojump Boscoconnected with a Chronopic, a chronometric device responsible to receive the changes in the detection device, and Chronojump management software (www.Chronojump.org) The encoder was adjusted with magnets to perpendicular in a stable iron base. The wire was adjusted each time and hooked in a non-flexible belt at the back in the height of the abdominal circumference (midpoint of the line between the rib or costal margin and the iliac crest in the midaxillary line), in order to avoid any inclination. Fencers standing on their guard fencing position and holding their preference weapon were tested while performing a lunge, a step-lunge, and a step backward (step and lunge with maximal effort and rhythm), respectively. All tests were performed twice, and the best result was recorded for further statistical processing. A 30-second rest between trials was used, while the rest between two consecutive tests was approximately three minutes. The test-retest reliability for the lunge, step and lunge and the step backward – step and lunge tests were estimated to be 0.94, 0.91, and 0.89, respectively ($p < 0.001$).

Statistical Analysis

All data was analyzed using SPSS (version 20). Data is presented as mean and standard deviation. A multivariate analysis of variance (MANOVA) was used to evaluate gender differences (male-female), age competitive categories (14-17, 18-20, >20 years old), competition levels (international – national), and discipline (epee – foil – sabre) for fencing performance tests. Significant main effects were analyzed via an ANOVA and Bonferroni-adjusted post hoc tests to examine the differences within groups. Effect sizes were estimated by calculating partial eta squared (η^2) values. According to Richardson (18), η^2 is classified as small (0.01 to 0.059), moderate (0.06 to 0.137), and large (≥ 0.138). Test-retest reliability for all the dependent variables measured in this investigation was determined in separate experiments by calculating the intraclass correlation coefficient (ICC) using a two-way mixed model. Relationships between measures of offensive fencing kinetic patterns velocity and leg power performance were examined by calculating Pearson's product-moment correlation coefficient (r). Moreover, a stepwise multiple linear regression was used to identify the best predictors of lunge, step-lunge, and step backward - step-lunge velocity. For each analysis, statistical significance was set at the $p = 0.05$ probability level.

RESULTS

Age Competitive Groups: The MANOVA revealed a significant multivariate effect for velocity (*Wilks* $\Lambda = 0.129$, $F = 2.112$, $p < 0.01$, $n^2 = 0.060$). A significant interaction was also observed between age competitive groups and level for step backwards step lunge velocity ($F = 4.628$, $p < 0.05$, $n^2 = 0.085$) and between age competitive groups and weapon for step backwards step lunge velocity ($F = 6.741$, $p < 0.001$, $n^2 = 0.212$). Post hoc velocity differences for age competitive groups are presented in Figure 1.

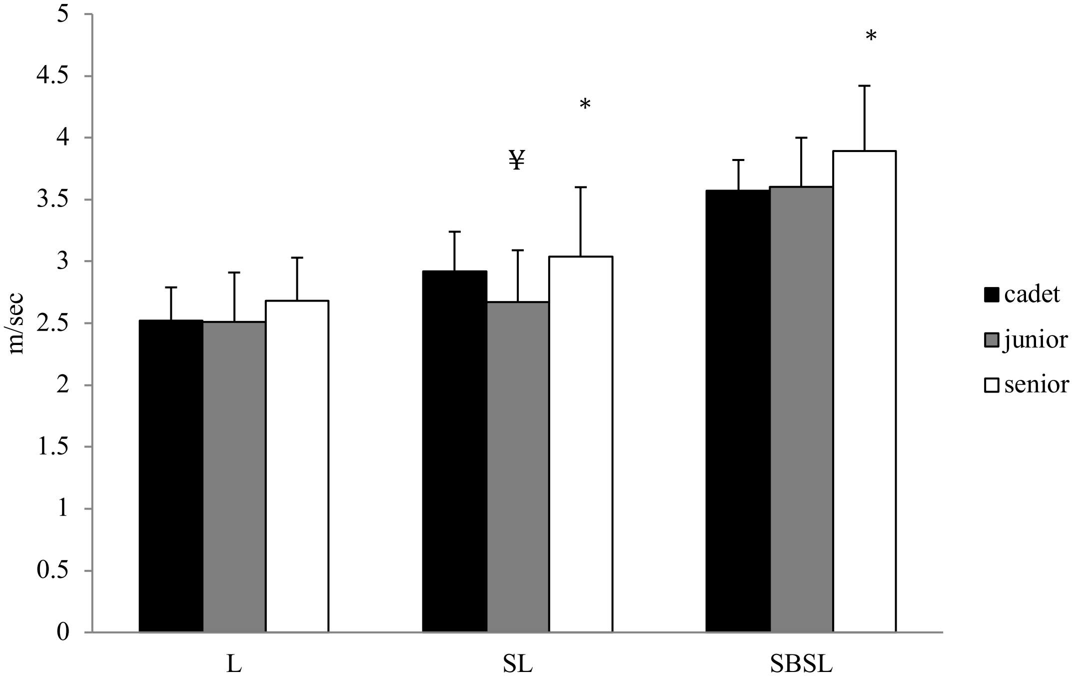

Figure 1. Maximum velocity of offensive patterns between different age competitive groups. Lunge velocity (L), Step - lunge velocity (SL), Step backward step - lunge velocity (SBSL). *Significant differences between cadet and senior ($p < 0.05$), ¥Significant differences between cadet and juniors ($p < 0.05$).

Gender: The MANOVA revealed a significant power multivariate effect (*Wilks* $\Lambda = 3.743$, $F = 2.112$, $p < 0.01$, $n^2 = 0.103$). Significant effects among subjects were observed for lunge power ($F = 3.70$, $p < 0.05$, $n^2 = 0.036$) and for step and lunge power ($F = 9.69$, $p < 0.01$, $n^2 = 0.088$). Post hoc power differences for gender are presented in Figure 2.

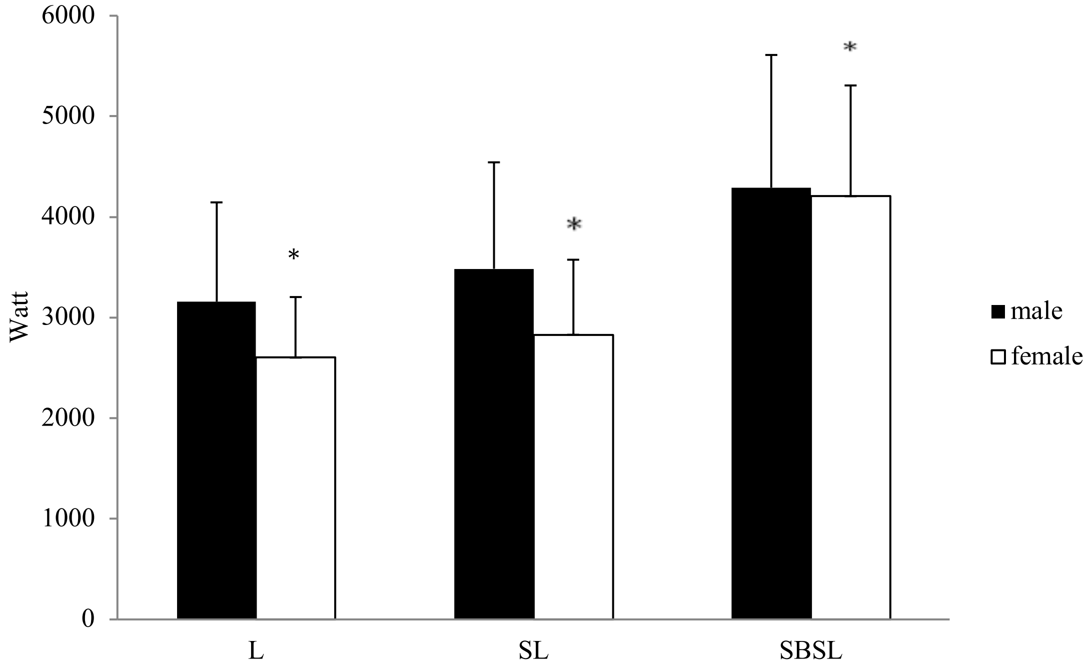

Figure 2. Maximum power of offensive fencing patterns between male and female fencers. *Significant differences between male and female fencers, $p < 0.001$.

Level: The MANOVA revealed a significant velocity multivariate effect (*Wilks* $\Lambda = 0.863$, $F = 5.198$, $p < 0.01$, $n^2 = 0.137$). Significant effects among subjects were observed for lunge velocity ($F = 11.98$, $p < 0.001$, $n^2 = 0.116$) and for step and lunge velocity ($F = 11.36$, $p < 0.001$, $n^2 = 0.102$). Moreover, a significant power multivariate effect (*Wilks* $\Lambda = 0.157$, $F = 6.093$, $p < 0.001$, $n^2 = 0.157$) was also observed. Significant effects among subjects were observed for lunge power ($F = 12.69$, $p < 0.001$, $n^2 = 0.113$) and for step and lunge power ($F = 15.25$, $p < 0.001$, $n^2 = 0.132$). Post hoc velocity differences for athletes' level are presented in Figure 3.

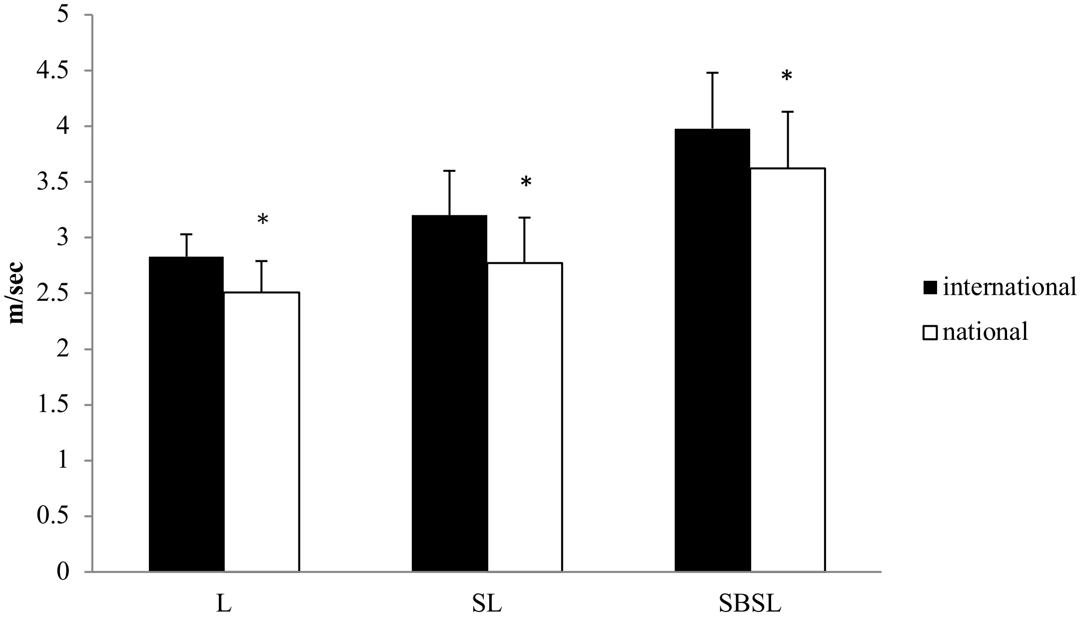

Figure 3. Maximum velocity of offensive patterns between international and national fencers. *Significant differences between international and national fencers, $p < 0.001$.

Discipline: The MANOVA revealed a significant velocity multivariate effect (*Wilks* $\Lambda = 0.239$, $F = 4.305$, $p < 0.001$, $n^2 = 0.119$). Significant effects among subjects were observed for step and lunge velocity ($F = 6.706$, $p < 0.01$, $n^2 = 0.118$). Post hoc velocity differences are presented in Table 2.

Table 2. Descriptive statistics for the velocity of offensive movements in a group of international and national fencers of different specializations ($n = 130$).

	Epee ($n = 33$)	Foil ($n = 55$)	Sabre ($n = 42$)
L (m/sec)	2.52 ± 0.28	2.51 ± 0.32	2.68 ± 0.25*
SL (m/sec)	2.92 ± 0.40	2.67 ± 0.42§	3.04 ± 0.40Ŧ
SBSL (m/sec)	3.57 ± 0.35	3.60 ± 0.56§	3.89 ± 0.53¥

*Significant differences between foil and sabre ($p < 0.05$); § Significant differences between epee and foil ($p < 0.05$); ŦSignificant differences between foil and sabre ($p < 0.001$); ¥Significant differences between foil and sabre ($p < 0.05$).

Correlations – regressions: Significant correlations were observed between lunge velocity and LJ ($r = 0.242$, $p < 0.01$), SJ ($r = 0.237$, $p < 0.01$), CMJ ($r = 0.216$, $p < 0.05$), DJ ($r = 0.180$, $p < 0.05$), RSI ($r = 0.206$, $p < 0.05$). Moreover, step- lunge velocity was significantly correlated to LJ ($r = 0.378$, $p < 0.001$), SJ ($r = 0.388$, $p < 0.001$), CMJ (r = 0.395, p<0.001), DJ (r = 0.274, p<0.01), RSI (r = 0.254, $p < 0.01$). The best predictor step and lunge velocity was CMJ ($R^2 = 0.156$) (Table 3).

Table 3. Multiple Regression model to predict step - lunge velocity (SLV).

Model SLV	B	SEB	β
Constant	2.242	0.132	
CMJ	0.023	0.005	0.395

Step-lunge velocity (SLV), *Significant differences (p < 0.001).

DISCUSSION

This study aimed to identify any differences between gender, competition age categories, level, and discipline practiced in several specific fencing offensive kinetic patterns, and to examine the relationship of them with selected power and anthropometric measures in a large group of well-trained fencers.

The results of the present study, as was expected showed that senior and junior fencers were faster in comparison to their cadet relative counterparts, men were faster than women and international fencers outperformed national fencers in the basic offensive movements studied. Furthermore, significant differences were observed in offensive movements in terms of discipline practiced between sabre fencers and foil in lunge velocity, between sabre and foil and foil and epee respectively in step – lunge velocity, while sabre fencers were faster in comparison to foil and epee in the complex, multi-segmental movements such as step backward – step and lunge pattern. Correlation analysis does not reveal any association between anthropometric measures and fencing performance. On the other hand, significant correlations were observed between strength – power measures and fencing performance. A regression analysis revealed that the best predictor of step – lunge performance was CMJ, however, accounted only for 15% of the variability in the score leaving a substantial part for aerobic capacity, technique, tactics, and psychological contribution to the fencing performance.
This is the first study that examined in depth different offensive leg movements in fencing.

The lunge is the most common offensive kinetic pattern that requires an arm-foot movement sequence, determines fencing success, and is dependent on fencers' leg power. Most of the lunges executed at the end of a submaximal period of preparation actions aimed to land a winning hit to the opponent (22, 23).

In the present study, fencers were asked to execute three different offensive kinetic patterns that are commonly presented in a fencing competition keeping the choice weapon without hitting a target. The velocity of the lunge is an identical measure of fencers' explosive ability; however, practically it cannot be performed isolated during a fencing bout. The final attack is a multifactorial issue and is an interactive result of linear anthropometric dimensions, the fighting distance, and the tactical choices decided between the two opponents (2). In consequence, fencers from the early stages of training, are taught to attack immediately after an opponent pause, or after successive forward and backward leg movement to hit explosively and precisely the opponent with a rule-conventional advantage (2).

The velocity of the fencers' body in the present study was found to be between the reported by others' velocity values, adding to the literature supportive data to the already existed information. Up to our knowledge, different methods and tasks were used for this reason. More specifically, the time of lunge was previously measured by photocells placed at a lunge distance determined to fencers' 2/3 leg length in adolescence fencers (24), while the different maximal velocity of the center of mass and body segments were measured after a displacement step-lunge test on a force plate in elite fencers with international experience (9). Moreover, Turner et al. (25) and Kontochristopoulos et al. (11) have used Kinovea sport analysis system to calculate lunge velocity as distance/time in similar to ours age group fencers. Recently, fencing performance lunge and step-lunge maximum velocity was calculated with the use of a new robotic system resistance device to explore the impact of leg asymmetries in fencing performance (Table 4) (6).

Table 4. Lunge and step lunge performance in elite level fencers of different age groups.

	Participants	Equipment	Lunge (m/sec)	Step-lunge (m/sec)
Tsolakis & Vagenas (23)	33 adolescents	Polifermo photocells	Elite: 180 ± 30 Non-Elite: 210 ± 40	
Gulheim et al. (9)	10 senior females	Platform Kistler		2.59 ± 0.24
Turner et al. (26)	70 junior athletes	Video/Kinovea	3.35 ± 0.70	
Kontochristopoulos et al. (11)	20 cadet males	Video/Kinovea		2.44 ± 0.22
Drakoulaki et al. (6)	38 adolescents	Motion 1080	Male: 3.55 ± 0.69 Female: 2.68 ± 0.68	Male: 3.98 ± 0.92 Female: 2.99 ± 0.64

Age competitive groups: Significant differences in the velocity of the offensive movements were observed across age competitive groups in the present study. As it was expected, senior (> 20 years old) and junior fencers (18-20 years old) were faster than the younger counterparts (14-17 years old), suggesting that the fencing-related adaptations occurring during the growth and maturation process may be responsible for this finding (12). Fencing is characterized by repeated fast and highly controlled muscular contractions, especially by the extensor muscles of the legs, and this may cause significant increases in muscle mass and force, which in turn can enhance the speed of the offensive specific kinetic patterns in fencers participating in systematic training (13).

Gender: Male fencers of the present study outperformed females in all selected specific offensive kinetic patterns. Drakoulaki et al. (6), in a recent study, found that male fencers of similar age were faster than females in lunge (3.55 ± 0.69 vs. 2.68 ± 0.68 m/sec) and step and lunge (3.98 ± 0.92 vs. 2.99 ± 0.64 m/sec), respectively, by using a robotic system resistance device. Moreover, a performance analysis of international competitions identified that male sabre fencers were faster, performed more frequently in selected attacking variables, and significantly differ in the total brake time, time of direction change, and action/break ratio in comparison to female (1). The results of these studies dictate that specific gender strength training programs can be tailored to enhance physiological speed-strength abilities for males and females, as well as to protect specifically females from fencing-related injuries connected to training or competition in comparison to male fencers (21).

Level: Elite fencers have a greater capacity to discriminate stimulus in choice reaction tasks, a shorter reaction times (7), and seem to be faster in more complex experimental protocols (30). Furthermore, elite fencers can reach their maximum velocity of the armed hand faster than legs, executing corrects forms of offensive kinetic by an initial extension of the armed hand, followed by the forward propulsion of the dominant leg (22). On the other hand, medium level fencers accelerate forward simultaneously both armed and foot and perform in interrupted sequence the compound foot offensive movements (10). International fencers in the present study were faster in almost all specific offensive kinetic patterns, confirming a previous study that demonstrated significant differences in absolute and body mass-dependent expressions of leg functional power characteristics by measuring the time of lunge and the time of a fencing shuttle test. This finding reflects not only the excessive abilities required for elite fencing performance, but also the higher intensity of training loads and competition level that overload fencer's body (23).

Disciplines: Only one study has examined different and specific kinetic patterns between the disciplines of fencing. Turner et al. (25) found similar performance in specific fencing agility and endurance lunge ability tests when comparing foil, epee, and sabre fencers from a large group of British male and females aged 14 - 20 years old. This suggests that fencers would rather focus on the development of their individual weaker abilities than to follow training schemes appropriate for the unique competition demands of their specialization.

The results of the present study report significant between disciplines differences in the selected specific offensive kinetic patterns. More specifically, sabre fencers seem to be faster in almost all velocity tests. This finding can be explained by the competition characteristics of sabre, which consist of a large number of short duration (2.5 - 2.9 sec) and extremely high-intensity accelerations that are associated with the final attempt to touch the opponent and performing successive lunges that impact the neuromuscular system of the fencers' body (1).

The epee fencers of the present study seem to be slower than foil fencers in step - lunge and also slower than sabre fencers in step backward - step and lunge. Sabre and foil are both conventional weapons and have different time-motion characteristics comparing to epee (19). Also, the sabre and foil competitions involve a higher number of complex kinetic patterns, requiring eccentric muscle leg contractions to change from one activity to another (offensive-defensive-offensive patterns) in the minimum amount of time, and reveals a different technical and tactical approach among disciplines (1, 19, 30). The aforementioned differences among disciplines provide useful information for strength trainers, regardless of the discipline, since the demand for successive lunges is of common interest for fencing. However, due to the different tactical characteristics among disciplines, which translated to different energetic contributions, the strength - power programs must be closely connected to the specific metabolic demands of each weapon (26).

Correlations: Although in the past it was believed that the somatotype and the physique of fencers could influence fencing success, recently published data identified that anthropometric measures were rather used as simple descriptors than possible determinants of fencing performance (24). Also, two relevant studies found that there was not any relationship between anthropometric traits and fencing performance; an observation that was also evident in the current study (23, 25).

On the other hand, elite fencing was found to be influenced by the relationship between lunge kinetics, kinematic indices, and dynamic power parameters (3, 9, 22). From a physiological perspective, fencing performance was found to correlate to different forms of strength and power measures. For example, Tsolakis et al. (23) reported that the time of lunge was predicted by the drop jump and the arm–driven countermovement jump. Moreover, Turner et al. (25) confirmed previous findings that show that long jump performance was the best predictor of lunge velocity. Recently, Drakoulaki et al. (6) reported that peak lunge velocity was correlated to unilateral triple jump in young female fencers and concluded that fencing performance depends on the differential biomechanical and physiological parameters required during their competitive efforts.

In the present study, long jump, squat jump, countermovement, and drop jump performance, as well as the derived reaction strength index, were all significantly correlated to lunge velocity and step and lunge velocity, respectively. These findings reveal that concentric explosive strength, strength – power, and reactive strength are important qualities of fencing performance, dictating thus the need for a specific training approach on each strength component to enhance fencing performance

The present in-depth analysis of fencing performance suggested that, in contrast to the suggestions of Turner et al. (28), fencing coaches and strength trainers do need specific conditioning training, according to the players' specialization. Different forms of strength training can be incorporated in the training schedules for elite fencing performance enhancement. The velocity values in the present study can offer adequate information concerning the selected offensive patterns for monitoring training procedures. Furthermore, several factors, such as age, gender, and skill level of participants, deserve attention, as it was identified that execution velocity is influential in the kinetic patterns of the most common fencing offensive movements. However, the evaluation of physiological parameters in an isolated condition in fencing are of low importance. Consequently, more future studies in simulated bouts or real competition conditions are needed to examine the velocity of identical kinetic patterns concerning the metabolic demands of fencing.

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