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CORRELATION BETWEEN UPPER LIMB MUSCLE STRENGTH AND EXPLOSIVE POWER AND ITS COMPARISON AMONG THREE TYPES OF FENCERS: AN OBSERVATIONAL STUDY

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Abstract: Background: Fencing is a high-intensity sport involving rapid upper limb movements, precision, and explosive power. Upper Limb Muscle Strength and explosive power play a key role in performance and injury prevention, but factors are understudied across disciplines

Aim- To study and investigate the correlations of upper limb explosive power with scapular muscle strength, radio ulnar deviators, and hand grip strength and compare the upper limb muscles' strength and explosive power among three different types of fencers.

Objective: To evaluate the correlation between upper limb muscle strength and explosive power, and compare these variables among Saber, Epee, and Foil fencers.

Methods: A cross-sectional observational study was conducted on 63 state-level male fencers. Scapular and wrist muscle strength was measured using a Handheld Push Pull dynamometer, grip strength with a JAMAR Hydraulic Hand dynamometer, and upper limb explosive power with the Seated Medicine Ball Throw (SMBT).

Results: Saber fencers exhibited significantly higher strength in all measured muscle groups and greater explosive power than Epee and Foil fencers ($p < 0.0001$). A moderate positive correlation was found between upper trapezius strength and explosive power in Saber fencers (p: 0.030), while Foil fencers showed a negative correlation with rhomboid strength (p: 0.029). Grip strength showed no significant correlation with explosive power.

Conclusion: Upper trapezius strength appears crucial for explosive performance in Saber fencing. These findings support targeted strength training programs tailored to fencing styles for performance enhancement and injury prevention.

I.INTRODUCTION

Because Fencing is an open skilled attacking sport first practiced indoors in SPAIN in 16th century by both the genders in which two athletes fight indirectly through the weapon and physical contact is restricted by rules [(1)].One of the very few sports that has been included in every modern Olympic Games [(2)]. All scoring is completed on the 14 x 2 m strip known as "PISTE" due to the fast-paced nature of the game [(2)]. Fencing needs quick body movements to avoid becoming stuck while attempting to strike the opponent to score point [(3)].The game is played in three disciplines: Epee, Foil, and Saber. Each of the three weapons in fencing has its own rules and strategies. The foil is a light thrusting weapon with a maximum weight of 500 grams. The foil targets the torso, but not the arms or legs. The epee is a thrusting weapon like the foil, but heavier, with a maximum total weight of 775 grams. In epee, the entire body is a valid target. The saber is a light cutting and thrusting weapon that targets the entire body above the waist, including the head and both the hands. Sabre is the newest weapon to be used. Like the foil, the maximum legal weight of a saber is 500 grams [(2,4,5)].

The scoring target area in each discipline are unique. Foil and epee are "point" weapons, wherein one needs to touch the opponent with the tip of the weapon through thrusting actions to score. Saber is a cutting weapon, where scoring occurs when any part of the blade contacts opponents through cutting/slashing motions [(2,5)]. fencing not only involves hits on opponents, but it is also necessary to defend against these hits and touches [(2,6)].

As it is a high-intensity sport that involves rapid, asymmetrical movements placing significant biomechanical demands on the upper body, particularly the shoulder complex. At the core of shoulder function is the scapula, which acts as a mobile and stable base for humeral motion, enabling powerful and controlled actions of the weapon arm. Coordinated scapular movements—such as upward rotation, posterior tilting, and internal rotation—are essential for full arm elevation and for maintaining the integrity of the glenohumeral joint during dynamic movements like lunges and thrusts [(7)]. These movements allow for optimal load transfer and help prevent shoulder pathologies such as impingement and instability [(7)]. For optimal performance during a fencing action—such as executing a lunge or an explosive attack—the coordinated integration of movements from the lower body, trunk, shoulders, and upper limbs is essential. Similar to the kinetic chain in other sports, fencing relies on a series of synchronized motions that collectively generate the force and precision needed for effective blade work. The scapulae (shoulder blades) play a crucial role in providing stability and acting as a key link for force transmission during rapid arm movements. They help transfer energy generated from the legs and core, through the shoulder and elbow, down to the hand and ultimately to the weapon, enabling precise and powerful strikes[(8)].Serratus anterior is an important muscle for maintaining scapular stability. It originates from first eight ribs continues along the rib cage to the medial border of the scapula Muscle with its many attachment sites, plays a critical role for scapular stability during arm elevation, as well as protracting the scapula and allowing it to slide over the rib cage. The other significant muscles, i.e., upper trapezius and levator scapulae, support the scapula in elevation and help in upward rotation. Upper trapezius originates from the superior nuchal line, the external occipital protuberance of the skull, and the seventh cervical vertebra, and attaches to the distal scapula. It is necessary for overhead arm motion [(9)].

The middle trapezius fibers, which retract the scapula, originate from the spinous processes of C7 to T3 and insert on the medial margin of the acromion and the superior border of the scapular spine. Starting from the spinous processes of T4 to T12, the lower trapezius fibers stretch laterally and upward before inserting via an aponeurosis on the smooth triangular region. at the medial end of the scapular spine and connecting to a tubercle at its apex. Rotation and scapular depression are mainly caused by these fibers. Furthermore, the lower trapezius fiber inferomedial position enables them to support the scapula's external rotation and posterior tilting during arm elevation [(10,11,12)]. Rhomboid muscles are significant scapular stabilizers that are located between the spine and the medial edge of the scapula. Rhomboid minor arises from the spinous processes of C7 to T1 and from the nuchal ligament, while rhomboid major arises from the spinous processes of T2 to T5. Both muscles enter at the scapula's medial edge [(13)]. Their major role is to retract the scapula, rotate it downward, and fix it to the thoracic wall, which is necessary during upper- limb motions to preserve postural control and shoulder joint stability [(13)]. These coordinated muscular actions collectively ensure optimal scapular mechanics, which are essential for efficient upper limb movement and the prevention of shoulder injuries. In the context of fencing, the scapula's role becomes even more critical, as efficient upper limb motion and fine motor control are fundamental for performance. Elite fencers have been shown to exhibit more synchronized neuromuscular activation patterns compared to novices, particularly in the muscles surrounding the scapula, resulting in greater precision, speed, and control during offensive and defensive maneuvers [(14,15)]. The high-speed offensive and defensive actions in fencing, requires precise neuromuscular control of the upper extremities [(16)]. While the role of lower limb power in lunging and movement is well established, upper limb strength, particularly at the wrist and forearm, plays a critical role in fine motor control and technical execution [(17)]. The muscles responsible for radial and ulnar deviation collectively known as radioulnar deviators. The radial deviators flexor carpi radialis and extensor carpi radialis longus and brevis—help abduct the wrist, whereas the ulnar deviators—flexor carpi ulnaris and extensor carpi ulnaris help adduct the wrist. Their synchronized motion is critical for fine motor control, grip strength, and force transfer during dynamic hand movements, which are especially significant in upper-limb sports like fencing or tennis [(18)]. They are essential for the stabilization and manipulation of the fencing weapon during attacks, parries, and feints. These small yet powerful muscle groups allow for rapid directional changes of the blade and are vital in executing techniques such as flicks and disengages, which require nuanced wrist movement [(18)]. Additionally, strong radioulnar deviators contribute to injury prevention by absorbing repetitive mechanical stress during high-intensity bouts and maintaining wrist alignment under load [(16)]. Despite their biomechanical importance, these muscles are often underemphasized in traditional training, underscoring the need for sport-specific conditioning that targets wrist and forearm stabilizers [(19)]. Fencer's wrists, susceptible to strain due to the weight and dynamic movements of the weapon, require well-designed grips to minimize abnormal joint motion and reduce the risk of injury [(20)].

Injuries to the wrist can result from actions like whip-hits that is ulna deviation and defensive- parry movements pronation and supination of the wrist [(5)]. In China and Taiwan, common hand and wrist injuries among fencers include contusions, sprains, and cumulative trauma disorders [(14)]. Cumulative trauma disorders, constituting 23.3% of injuries, are primarily attributed to high speed and excessively forceful actions. Fencers with over two years of experience are more prone to sports injuries. Apart from frequent occurrences of sprains and strains, fencers commonly experience cumulative trauma disorders like tenosynovitis, trigger finger, and carpal tunnel syndrome, averaging around six incidents per year [(15)]. However, historical data spanning two years revealed a total of 15 injuries, with 13.33% affecting the upper limb and 20% involving the trunk. Upper limb injuries occurred suddenly, while lower limb and trunk injuries manifested gradually [6].

Grip is a very crucial factor for high performance in fencing; therefore, training of the grip has an impact on athlete's overall performance [21]. A firm grip enhances a fencer's ability to control their weapon, leading to more precise attack and effective defense. A study examining Jordanian fencers found a significant correlation between grip strength and attack accuracy across all three fencing weapons, concluding that grip strength plays a crucial role in determining accuracy for fencers using any of the three weapons [22].

Movements in fencing, including lunges, thrusts, and parries, rely heavily on upper limb strength, which supplies the essential force for execution. These actions demand quick arm extensions. The elite fencers exhibit coordinated sequence of muscle activations starting from the shoulder and progress to arm enabling swift and powerful movements of upper limb for effective attack and defense [16].

Given that fencing is a sport with significant technical and strategic demands, the assessment of players' fitness levels involves evaluating specific prerequisites. Strength and power, flexibility, agility, core strength, balance, reaction time, hand grip strength, proprioception, anthropometric measures, psychological aspects, and other pertinent factors are all included in these criteria. Therefore, a comprehensive understanding is essential for fencers' performance. The current focus centers on exploring the correlation between upper limb muscle strength, particularly scapular muscle strength, and the radio ulnar deviators strength, along with hand grip strength, to understand their relationship with explosive power and compare them among three different types of fencers. Although existing literature has extensively addressed various physical attributes influencing fencing performance such as lunge speed, reaction time, agility there remains a noticeable gap concerning the specific role of upper limb strength and power.

This study aims to bridge that gap by highlighting the significance of upper limb strength and explosive power in fencers' performance. Therefore, research in this area is crucial.

II. RESEARCH METHEDOLOGY

2.1 Ethical Approval

The institutional ethical committee has approved this cross-sectional observational study to be conducted from fencing academies across Chhatrapati Sambhajinagar. MGM-ECRHS/2024/62 is the ethical approval number

2.2 Population and Sample

The study population was conducted on male fencing players of age group between 18- 25 years in fencing academies across Chhatrapati Sambhajinagar

The prior written consent was obtained from the participants. Participants were selected based on the selection criteria: The study included male fencers aged between 18 and 25 years who were actively participating in one of the three distinct fencing events: Epee, Saber, or Foil. Participants were required to have a minimum of three years of fencing experience and to practice at least three times per week. Players were excluded from the study if they had any upper limb injuries, had undergone upper limb surgery, experienced spine or upper limb pain, or had any restrictions in their movement.

2.3 Sample Size Calculation

The sample size was calculated using G-Power analysis software

2.4 Theoretical Framework

The study was conducted following approval from the Institutional Ethical Committee. Participants were recruited from fencing academies across Chhatrapati Sambhajinagar, with prior permission obtained from the academy coaches. The study objectives and procedures were explained to the participants by the principal investigator in the language best understood by them, and written informed consent was obtained. Participants were screened and recruited based on predefined inclusion and exclusion criteria. A total of 76 fencers were initially screened for upper limb muscle strength and explosive power, and 63 participants met the inclusion criteria and were included in the study. General characteristics, including name, age, gender, dominant hand, and type of weapon, were recorded. Upper limb muscle strength was assessed using the Hand-Held Push-Pull Dynamometer to measure scapular muscles (upper trapezius, serratus anterior, middle and lower trapezius, rhomboids) and radioulnar deviator strength of the dominant side in kilograms, while handgrip strength of the dominant side was measured using the Jamar Hydraulic Hand Dynamometer. Explosive power of the upper limbs was evaluated using the Seated Medicine Ball Throw Test. After completing each assessment, the investigator calculated the scores, and all data were entered into statistical software for further analysis.

2.5 Statistical tools and Analysis

MS Excel Windows 8/9/10 was used to enter the data, which was then moved to the latest version of SPSS 25 (Statistical program for the social sciences) software for more advanced analysis. Age, gender, height, weight and other demographic characteristics were taken into consideration when tabulating the acquired data. Additionally, Descriptive statistics, including mean, standard deviation (SD), standard error of the mean (SE), and percentages, were calculated for demographic characteristics, scapular muscle strength, radioulnar deviator strength, handgrip strength, and upper limb explosive power. Categorical data were presented using bar graphs, and the normality of the data was assessed using the Shapiro-Wilk test. To compare muscle strength and explosive power among the three fencing groups (Epee, Saber, and Foil), a one-way Analysis of Variance (ANOVA) was performed. Following a significant ANOVA result, Tukey's Post Hoc Test was applied for pairwise comparisons. Pearson's correlation coefficient (r) was used to examine the relationship between muscle strength and seated medicine ball throw performance within each group. A p-value of <0.05 was considered statistically significant.

III. RESULTS AND DISCUSSION

III.1 Results of Descriptive Statistics of Study Variables

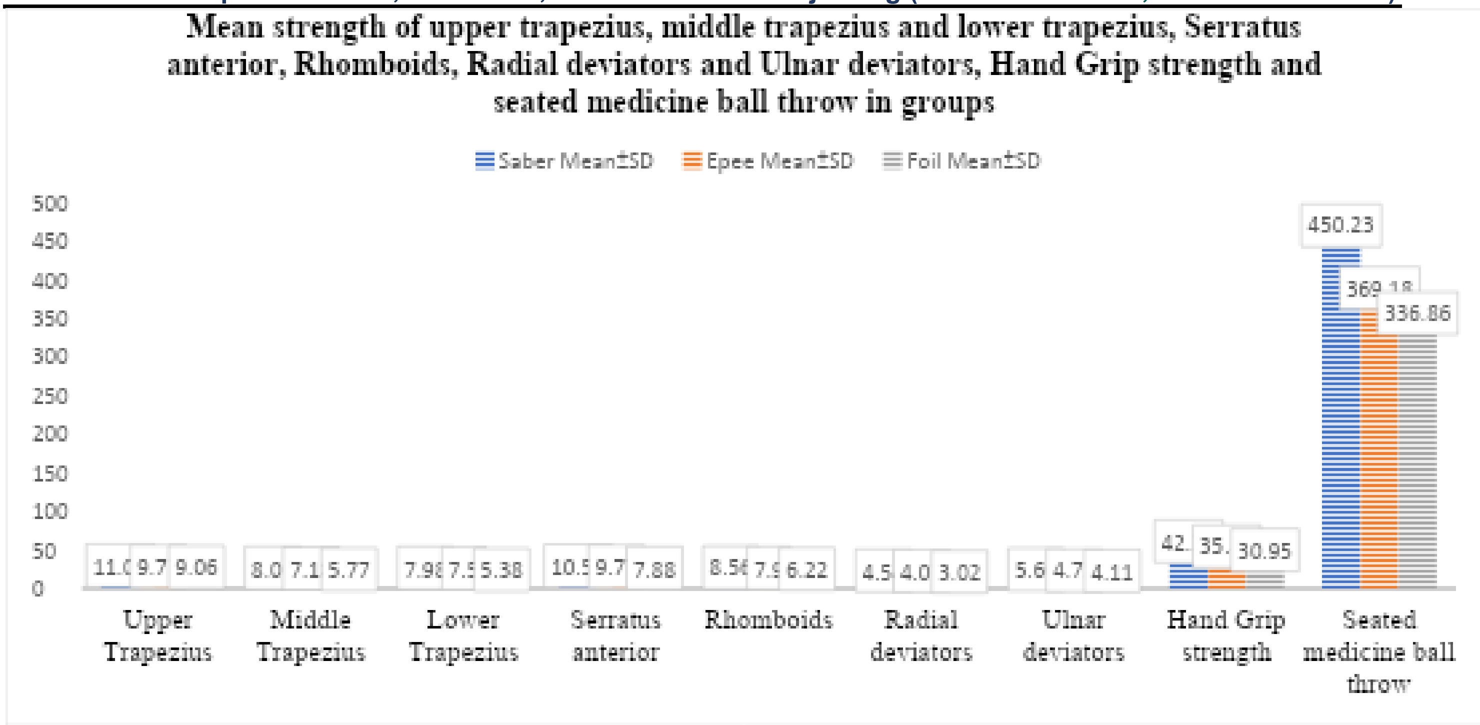
Table 1: Normality test of outcome's variables

	Saber		Epee		Foil	
	Shapiro-Wilk Statistic	Sig.	Shapiro -Wilk Statistic	Sig.	Shapiro-Wilk Statistic	Sig.
upper trapezius	0.958	0.446	0.955	0.082	0.970	0.104
middle trapezius	0.968	0.672	0.972	0.360	0.977	0.271
lower trapezius	0.921	0.082	0.954	0.081	0.930	0.101
Serratus anterior	0.925	0.098	0.961	0.140	0.965	0.056
Rhomboids	0.902	0.132	0.935	0.075	0.946	0.76
Radial deviators	0.912	0.053	0.957	0.104	0.963	0.069
Ulnar deviators	0.890	0.119	0.942	0.128	0.953	0.094
Hand Grip strength	0.945	0.256	0.984	0.808	0.983	0.823
upper limb length	0.936	0.161	0.913	0.103	0.897	0.101
seated medicine ball throw	0.935	0.159	0.887	0.112	0.769	0.065

INFERENCE -The Shapiro-Wilk procedure assumes that the null hypothesis is that data is normally distributed. Since the p-value obtained was not significant, the null hypothesis was accepted, and the alternative hypothesis was rejected. Thus, it was found that data is normally distributed. So, of trapezius, Serratus anterior, Rhomboids, Radial deviators, Ulnar deviator, Hand Grip strength, upper limb length and seated medicine ball throw in the study groups Saber, Epee and Foil.

Table 2: Comparison of the Mean strength of upper trapezius, middle trapezius and lower trapezius , Serratus anterior, Rhomboids, Radial deviators and Ulnar deviators , Hand Grip strength and seated medicine ball throw in groups.

Strength in kg	Saber Mean±SD	Epee Mean±SD	Foil Mean±SD	F-value	P-value
Upper Trapezius	11.09±1.57	9.77±1.60	9.06±1.78	8.45	P=0.001 S
Middle Trapezius	8.02±1.40	7.18±1.01	5.77±0.91	22.43	P<0.0001 S
Lower Trapezius	7.98±0.63	7.50±0.76	5.38±0.92	68.79	P<0.0001 S
Serratus anterior	10.57±1.44	9.77±1.45	7.88±1.11	8.45	P=0.001 S
Rhomboids	8.56±1.35	7.90±1.08	6.22±0.72	22.43	P<0.0001 S
Radial deviators	4.54±0.63	4.07±0.76	3.02±0.76	68.79	P<0.0001 S
Ulnar deviators	5.66±0.69	4.75±0.51	4.11±1.10	29.11	P<0.0001 S
Hand Grip strength	42.36±9.47	35.82±5.82	30.95±5.58	13.91	P<0.0001 S
seated medicine ball throw	450.23±51.98	369.18±36.99	336.86±78.19	22.09	P<0.0001 S

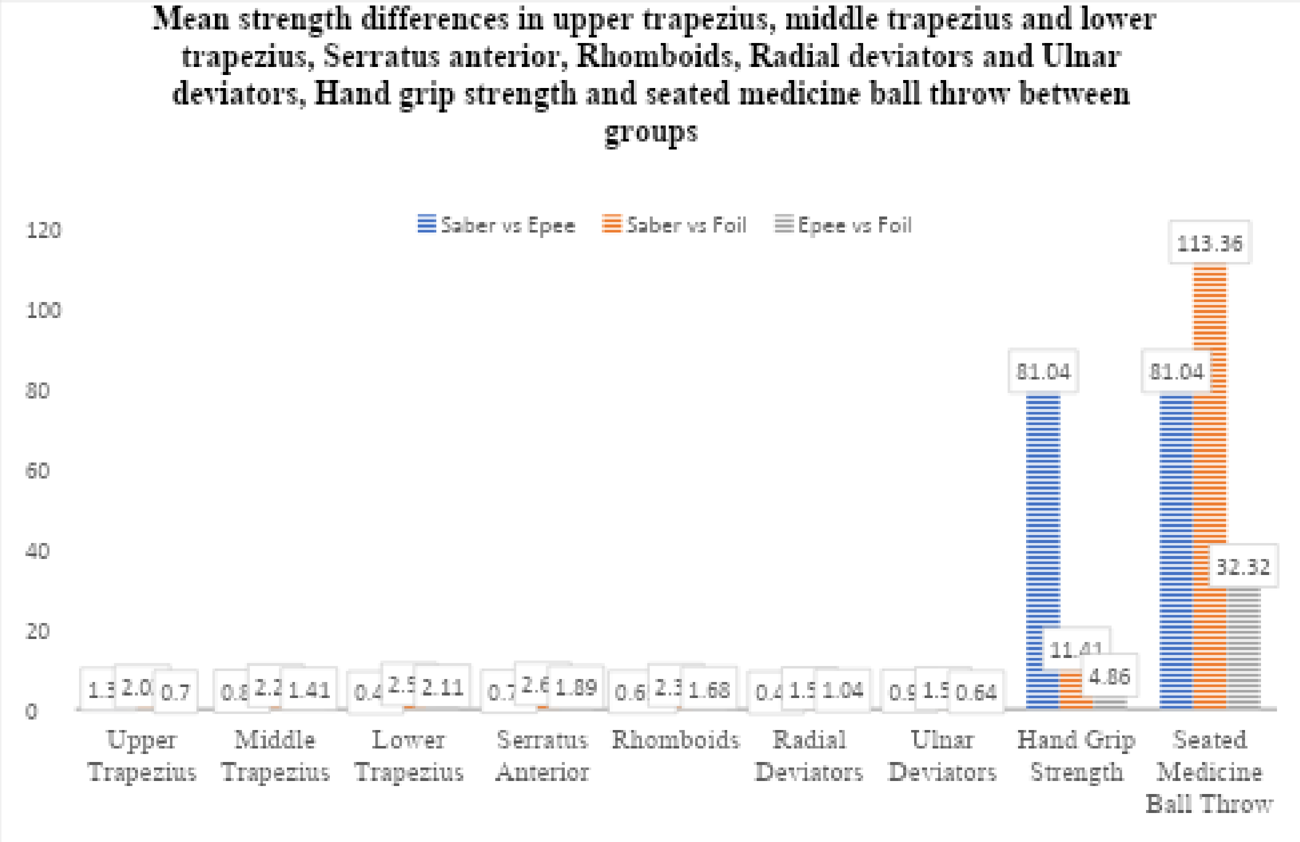


INFERENCE – Saber fencers showed significantly higher muscle strength across all trapezius regions compared to Epee and Foil fencers. For the upper trapezius, strength was highest in Saber (11.09 ± 1.57 kg), followed by Epee (9.77 ± 1.60 kg) and Foil (9.06 ± 1.78 kg) with F = 8.45, p = 0.001. In the middle trapezius, values were 8.02 ± 1.40 kg (Saber), 7.18 ± 1.01 kg (Epee), and 5.77 ± 0.91 kg (Foil), F = 22.43, p < 0.0001. For the lower trapezius, strength was7.98 ± 0.63 kg (Saber), 7.50 ± 0.76 kg (Epee), and 5.38 ± 0.92 kg (Foil), F = 68.79, p < 0. 0001.These results highlight significantly greater trapezius strength in Saber fencers. Significant differences were found in serratus anterior, rhomboids, radial and ulnar deviator strength across fencing types. Saber fencers had the highest mean strength in all muscles: serratus anterior (10.57 ± 1.44 kg, F = 8.45, p = 0.001), rhomboids (8.56 ± 1.35 kg, F= 22.43, p < 0.0001), radial deviators (4.54 ± 0.63 kg, F = 68.79, p < 0.0001), and ulnar deviators (5.66 ± 0.69 kg, F = 29.11, p < 0.0001). Overall, Saber fencers showed significantly greater upper body strength than Epee and Foil fencers. Analysis of hand grip strength across the three fencing disciplines showed clear differences. Saber fencers had the highest average grip strength at 42.36 ± 9.47 kg. Epee fencers followed with 35.82 ± 5.82 kg, while Foil fencers had 30.95 ± 5.58 kg. A one-way ANOVA highlighted a significant difference among the groups, with an F-value of 13.91 and a p-value of less than 0.0001. This finding indicates that Saber fencers have notably greater hand grip strength than Epee and Foil fencers.

A comparison of seated medicine ball throw among groups showed a significant difference in performance. Saber fencers had the longest throwing distance, averaging 450.23 ± 51.98 cm. Epee fencers followed at 369.18 ± 36.99 cm, while Foil fencers reached 336.86 ± 78.19 cm. A one-way ANOVA confirmed a significant difference between the groups (F = 22.09, p < 0.0001). This indicates that upper body explosive power, measured by the seated medicine ball throw, was notably higher in Saber fencers compared to Epee and Foil fencers.

Table 3: Comparison of the Mean strength differences in upper trapezius, middle trapezius and lower trapezius, Serratus anterior, Rhomboids, Radial deviators and Ulnar deviators, Hand grip strength and seated medicine ball throw between groups.

strength in kg	**Saber Vs Epee**		**Saber Vs Foil**		**Epee Vs Foil**	
	Mean Difference	**P-value**	**Mean Difference**	**P-value**	**Mean Difference**	**P-value**
Upper Trapezius	1.32	P=0.028 S	2.02	p<0.0001 S	0.70	P=0. 342 NS
Middle Trapezius	0.84	P=0.042 S,	2.25	P<0.0001 S	1.41	P<0.0 001 S
Lower Trapezius	0.48	P=0.113 NS	2.59	P<0.0001 S	2.11	P<0.0 001 S
Serratus Anterior	0.79	P=0.120 NS	2.68	P<0.0001 S	1.89	P<0.0 001 S
Rhomboids	0.659	P=0.118N S	2.34	P<0.0001 S	1.68	P<0.0 001 S
Radial deviators	0.48	P=0.068 NS	1.52	P<0.0001 S	1.04	P<0.0 001 S
Ulnar deviators	0.91	P=0.001 S	1.54	P<0.0001 S	0.64	P=0.0 30 S
Hand Grip Strength	81.04	P<0.0001 S	11.41	P<0.0001 S	4.86	P=0.0 71 NS
Seated medicine ball throw	81.04	P<0.0001 S	113.36	P<0.0001 S	32.32	P=0.1 65 NS



INFERENCE - Saber fencers had significantly greater upper trapezius strength than Epee (1.32 kg, $p = 0.028$) and Foil (2.02 kg, $p < 0.0001$); Epee vs. Foil was not significant. In the middle trapezius, Saber exceeded Epee (0.84 kg, $p = 0.042$) and Foil (2.25 kg, $p < 0.0001$), and Epee surpassed Foil (1.41 kg, $p < 0.0001$). For the lower trapezius, Saber was stronger than Foil (2.59 kg, $p < 0.0001$), but not Epee (0.48 kg, $p = 0.113$); Epee was stronger than Foil (2.11 kg, $p < 0.0001$).

Saber fencers showed significantly greater strength than Foil fencers in all muscles. In the serratus anterior, they also surpassed Epee fencers, though not significantly (0.79 kg, $p = 0.120$); Epee was stronger than Foil (1.89 kg, $p < 0.0001$). For the rhomboids, Saber > Foil (2.34 kg, $p < 0.0001$), Epee > Foil (1.68 kg, $p < 0.0001$), but Saber vs. Epee was not significant. In radial deviators, Saber > Foil (1.52 kg, $p < 0.0001$), Epee > Foil (1.04 kg, $p< 0.0001$), while Saber vs. Epee was not significant ($p = 0.068$). In ulnar deviators, all differences were significant: Saber > Epee (0.91 kg, $p = 0.001$), Saber > Foil (1.54 kg, $p < 0.0001$), and Epee > Foil (0.64 kg, $p = 0.030$).

Saber fencers showed significantly higher hand grip strength than Epee (6.54 kg, $p = 0.010$) and Foil fencers (11.41 kg, $p < 0.0001$). The Epee–Foil difference (4.86 kg, $p = 0.071$) was not statistically significant. This indicates superior grip strength in Saber fencers, with no conclusive difference between Epee and Foil.

Saber fencers showed significantly higher seated medicine ball throw scores than Epee (81.04 units, $p < 0.0001$) and Foil fencers (113.36 units, $p < 0.0001$). The Epee–Foil difference (32.32 units, $p = 0.165$) was not statistically significant, confirming superior performance in Saber fencers, with no clear difference between Epee and Foil

Table 4: Correlation between Seated Medicine Ball Throw(Power) and strength

Correlation		**Saber**	**Epee**	**Foil**
Upper Trapezius Vs Seated Medicine Ball Throw	r-value	0.464	0.188	-0.067
	P-value	P=0.030 S	P=0.403 NS	p=0.768 NS
middle trapezius Vs Seated Medicine Ball Throw	r-value	0.221	-0.106	-0.257
	P-value	P=0.323 NS	P=0.637 NS	P=0.248 NS
lower trapezius Vs Seated Medicine Ball Throw	r-value	-0.259	0.196	0.052
	P-value	P=0.245 NS	P=0.382 NS	P=0.817 NS
Serratus anterior Vs Seated Medicine Ball Throw	r-value	0.329	-0.222	-0.205
	P-value	P=0.134 NS	P=0.321 NS	P=0.361 NS
Rhomboids Vs Seated Medicine Ball Throw	r-value	-0.235	0.204	-0.466*
	P-value	p=0.293 NS	P=0.362 NS	P=0.029 S
Radial deviators Vs Seated Medicine Ball Throw	r-value	0.214	0.266	0.336
	P-value	P=0.339 NS	p=0.231 NS	P=0.126 NS
Ulnar deviators Vs Seated Medicine Ball Throw	r-value	0.403	-0.056	-0.136
	P-value	P=0.063 NS	p=0.805 NS	P=0.546 NS
Hand Grip strength Vs Seated Medicine Ball Throw	r-value	-0.130	-0.004	0.177
	P-value	P=0.563 NS	p=0.985 NS	P=0.432 NS

INFERENCE – In Saber fencers, upper trapezius strength had a moderate positive correlation with SMBT ($r = 0.464$, $p = 0.030$). Ulnar deviators showed a near-significant trend ($r = 0.403$, $p = 0.063$). Epee fencers did not show any significant correlations, with the highest being for radial deviators ($r = 0.266$, $p = 0.231$). In Foil fencers, there was a significant negative correlation between rhomboid strength and SMBT ($r = -0.466$, $p = 0.029$). Other muscles did not show significant relationships.

III.2**Discussion**

The goal of this study was to see if there was a correlation between upper limb muscle strength and explosive power among three types of fencers Saber, Epee, and Foil—and compare their performance across multiple muscle groups. The Dominant hand of each player was recorded. In the study we hypothesized that there will be significant correlation between upper limb power with scapular muscles strength, radio ulnar deviators strength and hand grip strength and will there be a significant comparison of those strength and explosive power among three types of fencers. Total 63 fencing players were included in this study and were conveniently sampled. The Shapiro-Wilk procedure assumes the null hypothesis that data is normally distributed. One-way Anova was applied to compare means of muscle strength and explosive power across the three groups when data was normally distributed. The P value less than 0.05 was considered significant as the p-value for age was 0.251, exceeding 0.05, indicating no significant age differences among Saber, Epee, and Foil fencers. This suggests that any performance or strength differences are unlikely to be influenced by age, enhancing the internal validity of the comparisons. The results of the study revealed that Saber fencers consistently demonstrated significantly greater upper limb muscle strength and explosive power compared to their Epee and Foil counterparts. Across all measured muscle groups including trapezius, serratus anterior, rhomboids, radial and ulnar deviators, and hand grip strength. Saber fencers outperformed the other two groups, with statistically significant differences in most pairwise comparisons. The seated medicine ball throw (SMBT), used to assess upper-body explosive power, also showed significantly superior performance in Saber fencers. Correlation analysis indicated a moderate, significant positive relationship between upper trapezius strength and SMBT performance in Saber fencers, while in Foil fencers, rhomboid strength showed a significant negative correlation with SMBT. No significant correlations were found between hand grip strength and explosive power in any group. In the comparison of trapezius muscles, Significant differences ($p < 0.05$) were found in the mean strength values of the upper, middle, and lower trapezius muscles across the three fencing groups. Upper and middle trapezius strength were highest in Saber, followed by Epee and Foil while the largest disparity was seen in lower trapezius strength where Saber fencers significantly outperformed both Epee and Foil. These differences likely reflect the distinct biomechanical demands of each discipline. Saber fencing involves rapid, explosive upper limb movements that rely heavily on strong scapular stabilizers like the trapezius [34,38]. Greater lower trapezius strength in Saber may contribute to shoulder stability during rapid arm actions [46] in contrast, Foil fencers—who emphasize precision and control had the lowest trapezius strength, with Epee fencers displaying intermediate values. These muscle strength variations may relate to discipline-specific adaptations which has been linked to performance in fencing actions [47]. Tukey's post hoc test showed significant trapezius strength differences across all three groups, mainly between Saber and Foil fencers. Saber fencers had stronger upper and middle trapezius muscles than Epee fencers ($p < 0.05$) likely due to the explosive, high-intensity movements such as cutting and slashing that activate scapular elevators and retractors [34]. Lower trapezius strength did not differ significantly, suggesting similar demands for scapular stabilization during defensive actions. Saber fencers outperformed Foil fencers in all trapezius regions ($p < 0.0001$), reflecting their explosive, multi-directional arm actions. Epee fencers showed greater middle and lower trapezius strength than Foil ($p < 0.0001$), likely due to broader movement demands, but upper trapezius strength was not significant ($p = 0.342$), possibly due to the less explosive yet sustained arm use and shared upright blade posture between Epee and Foil [47]. One-way ANOVA revealed highly significant differences ($p < 0.0001$) in the strength of the serratus anterior, rhomboids, radial deviators, and ulnar deviators among the three fencing groups, with Saber fencers consistently showing the highest values. Serratus anterior strength was notably greater in Saber fencers ($p = 0.001$), a key muscle for scapular protraction and stabilization essential for their rapid thrusting and cutting motions [34,46]. Rhomboid strength ($p< 0.0001$) was also greatest in Saber athletes, aiding in scapular retraction during quick arm recovery and transitions[38] . Significant differences in radial deviator strength ($p < 0.0001$) highlighted Saber's superior wrist stability and control during arcing strikes [47]. Similarly, ulnar deviator strength was highest in Saber fencers ($p < 0.0001$), supporting wrist stability and absorbing impact during rapid parries and rotational actions important for injury resistance and effective blade handling under load. Significant differences in radial deviator strength ($p < 0.0001$) highlighted Saber's superior wrist stability and control during arcing strikes [47]. Similarly, ulnar deviator strength was highest in Saber fencers ($p < 0.0001$), supporting wrist stability and absorbing impact during rapid parries and rotational actions important for injury resistance and effective blade handling under load. Tukey's post hoc analysis showed significant strength differences in the serratus anterior, rhomboids, radial, and ulnar deviators, mainly between Saber vs Foil and Epee vs Foil, with both Saber and Epee fencers outperforming Foil. Between Saber and Epee, no significant differences were found for the serratus anterior, rhomboids, or radial deviators, indicating comparable upper limb demands, though Saber fencers had stronger ulnar deviators ($p = 0.001$), likely due to higher wrist stabilization needs during fast parries. In Saber vs Foil, all muscle groups differed significantly ($p < 0.0001$), Saber's explosive, sweeping strikes place greater demands on scapular control and wrist strength, particularly involving the serratus anterior and rhomboids for dynamic blade work [38]. Epee fencers also showed significantly higher strength than Foil fencers in serratus anterior, rhomboids, radial deviators ($p < 0.0001$), and ulnar deviators ($p = 0.030$). This reflects Epee's higher requirement for upper limb control and endurance during longer bouts and diverse blade actions [47]. One-way ANOVA showed a significant difference in seated medicine ball throw distances across groups ($p < 0.0001$), with Saber fencers throwing the farthest, followed by Epee and Foil. Saber outperformed Epee ($p < 0.0001$), likely due to the explosive strikes and rotational torso movements characteristic of their style [34].

The significant difference between Saber and Foil ($p < 0.0001$) highlights Saber's greater demand for explosive power, while Foil focuses more on precision and control [48]. Epee fencers also showed greater power than Foil ($p = 0.033$), reflecting the greater upper body engagement needed for extended lunges and varied blade work in Epee [47].

Tukey's post hoc test revealed significant differences in hand grip strength between Saber and both Epee ($p = 0.010$) and Foil ($p < 0.0001$), but no significant difference between Epee and Foil ($p = 0.071$). Saber fencers showed greater grip strength, reflecting the demands of fast, powerful strikes and rapid blade control [34,48]. In contrast, Epee and Foil fencers, who prioritize control and precision, had similar grip strength, with less emphasis on explosive power [38].

One-way ANOVA revealed significant differences in upper body explosive power across groups ($P < 0.0001$), with Saber fencers throwing the farthest, followed by Epee and Foil. Tukey's post hoc test showed significant differences between Saber and both Epee ($P < 0.0001$) and Foil ($P < 0.0001$), but no significant difference between Epee and Foil ($P = 0.165$).Saber's superior performance reflects its focus on rapid, powerful strikes requiring strong upper body and core engagement [34]. Epee and Foil showed no significant difference, as both styles emphasizes control, accuracy, and strategic movement rather than explosive force [38]. While assessing the correlation between strength and explosive power the Pearson correlation coefficient test was used to analyze within each group. Correlating between Upper Trapezius and Seated Medicine Ball Throw for Saber fencers, a moderate positive correlation ($P = 0.030$) was observed, indicating that stronger upper trapezius muscles are associated with better explosive power. This relationship likely reflects the dynamic shoulder and neck movements required in Saber, where the upper trapezius plays a role in forceful strikes and rapid shoulder stabilization. [34]. However, no significant correlation was observed in Epee ($P = 0.403$) and Foil fencers ($P = 0.768$), suggesting that upper trapezius strength may not play as crucial a role in their explosive power, possibly due to the different movement patterns involved in these fencing disciplines.

In comparison between middle trapezius or lower trapezius strength with seated medicine ball throw, no significant correlation was found across all three fencing groups. The middle trapezius primarily functions in scapular retraction and stabilization, while the lower trapezius contributes to scapular stabilization and postural support during lunges and attacks. However, the seated medicine ball throw is an explosive movement that relies heavily on rapid torso rotation, upper limb extension, and core engagement. As such, neither the middle nor lower trapezius appears to significantly influence the force generation required for this whole-body action. This supports the idea that larger, more dynamic muscle groups, particularly in the shoulders and chest, play a more prominent role in explosive throwing movements [34,47]. While comparing Serratus Anterior and Seated Medicine Ball Throw, no significant correlation was found in Saber (P value = 0.134), Epee (P value = 0.321), Foil (P value = 0.361). The serratus anterior primarily facilitates scapular protraction and stabilization, ensuring the scapula remains flush against the thoracic wall during arm movements. This function is crucial for maintaining proper shoulder mechanics, especially during overhead activities and in preventing scapular winging. In contrast, the seated medicine ball throw emphasizes power generation from the core and upper limbs, specifically focusing on rapid extension and rotational movements. This difference in movement patterns explains why the serratus anterior role in stabilization may not correlate with performance on this explosive task [46]. While comparing Rhomboids and Seated Medicine Ball Throw a significant negative correlation was observed between rhomboid strength and seated medicine ball throw performance in Foil fencers (P = 0.029). This indicates that higher rhomboid strength may be linked to reduced performance in explosive upper-body movements like the medicine ball throw. As the rhomboids are primarily involved in scapular retraction and stabilization, their role in generating explosive force appears limited in Foil fencing. This finding may suggest that excessive development or stiffness in these muscles could impair the fluid, dynamic motion required for such power-based actions [38]. In contrast, the correlations observed in Saber and Epee fencers were not statistically significant, which aligns with the greater emphasis in these disciplines on speed, reactivity, and explosive agility areas and less reliant on rhomboid activation for performance. Similarly in Radial Deviators or ulnar deviators with Seated Medicine Ball Throw, there were no significant correlations in any fencing discipline. The radial and ulnar deviators may assist in stabilizing the wrist during precise movements, but they likely do not contribute significantly to explosive throwing power, which depends more on larger upper body muscles [48]. In Hand Grip Strength and Seated Medicine Ball Throw, there was no significant correlation across all three fencing groups. Although grip strength plays a vital role in fencing for weapon control and precision, these results suggest that it may not be a key contributor to the explosive power required for the medicine ball throw. This implies that explosive performance in this test is likely driven more by the strength and coordination of larger upper body and core muscles rather than grip strength alone [34,48]. role in stabilization may not correlate with performance on this explosive task [46]. While comparing Rhomboids and Seated Medicine Ball Throw a significant negative correlation was observed between rhomboid strength and seated medicine ball throw performance in Foil fencers (P = 0.029). This indicates that higher rhomboid strength may be linked to reduced performance in explosive upper-body movements like the medicine ball throw. As the rhomboids are primarily involved in scapular retraction and stabilization, their role in generating explosive force appears limited in Foil fencing. This finding may suggest that excessive development or stiffness in these muscles could impair the fluid, dynamic motion required for such power-based actions [38]. In contrast, the correlations observed in Saber and Epee fencers were not statistically significant, which aligns with the greater emphasis in these disciplines on speed, Reactivity, and explosive agility areas and less reliant on rhomboid activation for performance. Similarly in Radial Deviators or ulnar deviators with Seated Medicine Ball Throw, there were no significant correlations in any fencing discipline. The radial and ulnar deviators may assist in stabilizing the wrist during precise movements, but they likely do not contribute significantly to explosive throwing power, which depends more on larger upper body muscles [48].

In Hand Grip Strength and Seated Medicine Ball Throw, there was no significant correlation across all three fencing groups. Although grip strength plays a vital role in fencing for weapon control and precision, these results suggest that it may not be a key contributor to the explosive power required for the medicine ball throw. This implies that explosive performance in this test is likely driven more by the strength and coordination of larger upper body and core muscles rather than grip strength alone [34,48].

The finding of this study indicates that upper limb muscle strength particularly in scapular stabilizers varies significantly among fencing styles and plays a role in supporting explosive movements, especially in disciplines like Saber. However, the relationship between individual muscles and explosive power remains generally low, highlighting that fencing performance is influenced by a combination of muscular, technical, and tactical factors.

IV. CONCLUSION

This study concludes that Saber fencers exhibit greater strength in scapular stabilizers, radio- ulnar deviators, and hand grip, while Foil fencers show the lowest strength and explosive power, while Epee fencers falling in between. A significant correlation was found between the strength of upper trapezius muscle and explosive power in Saber fencers, Whereas Negative correlation was observed in rhomboid muscle strength and explosive power within Foil fencers. Other muscles like the middle and lower trapezius, serratus anterior, and radio ulnar deviators showed no significant correlations with explosive power. These findings suggest that while scapular strength aids explosive performance especially in Saber fencers, performance is multifactorial, relying heavily on technical and tactical skills

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