ISSN: 2798-7345 (online)
ISSN: 2830-2648 (print)
JOURNAL OF EDUCATION AND SPORT SCIENCE (JESS)
http://publikasiilmiah.unwahas.ac.id/index.php/JESS
Vol (7) No (2)

A Predictive Analytical Model Based on Selected Biomechanical Variables of the Counterattack Skill and the Accuracy and Speed of the Fencing Lunge among Foil Fencers

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Abstract

This study aimed to develop a predictive analytical model of counterattack effectiveness based on selected biomechanical variables in foil fencers. It also sought to describe lunge accuracy and weapon-tip velocity as performance-related indicators and to identify the variables that contribute most substantially to predicting the effectiveness of counterattacking decisions. A descriptive research design incorporating three-dimensional motion analysis and predictive modeling was employed. The purposive sample consisted of 16 young fencers with a minimum of four years of competitive experience. The trials were recorded using six high-speed digital cameras operating at 240 frames per second. Kinematic variables were extracted from three-dimensional coordinates and subsequently examined in relation to the effectiveness of counterattacking decisions, which was evaluated by two expert judges. The results indicated that trunk directional-change velocity, trunk–pelvis separation angle, weapon-tip velocity, and motor reaction time were the variables most strongly associated with the effectiveness of counterattacking decisions. The multiple correlation coefficient was $R = 0.843$, with a coefficient of determination of $R^2 = 0.710$ and an adjusted coefficient of determination of adjusted $R^2 = 0.605$. The overall regression model yielded $F(4,11) = 6.73$, $p = 0.0054$. Following Bonferroni correction for eight statistical tests, four associations remained statistically significant. The bivariate shared variance with counterattack effectiveness was 60.8% for trunk directional-change velocity, 54.8% for the trunk–pelvis separation angle, 50.4% for weapon-tip velocity, and 47.6% for motor reaction time. Given the small sample size, the use of stepwise variable selection, and the absence of external validation, the proposed model should be considered exploratory and interpreted with caution. Further studies involving larger samples and independent external validation are warranted to assess the stability and generalizability of the model.

Keywords: three-dimensional motion analysis; counterattack; lunge accuracy; lunge velocity; foil fencing; predictive modeling; biomechanics.

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1. Research Overview

1.1 Introduction and Significance of the Study

Foil fencing is a sport that relies heavily on neuromuscular coordination, rapid movement organization, and accurate weapon targeting within a very short time frame. A review by Chen et al. (2017) indicated that fencing performance involves sequential coordination among the lower limbs, trunk, and weapon arm, together with multiple kinematic variables. Similarly, Ibrahim (2015) conducted a three-dimensional kinematic analysis of offensive performance in foil fencing. In the present study, the **counterattack** is operationally defined as an offensive action initiated by the fencer during an opponent's attack. Its effectiveness is evaluated based on the quality of timing, accuracy, balance, and continuity of performance rather than being treated as an independent adjudication of right-of-way.

The success of a counterattack does not depend solely on motor reaction speed; rather, it requires temporal coordination among stimulus perception, initiation of the response, displacement of the center of mass, trunk and pelvic movement, and extension of the weapon arm. Bottoms et al. (2013) demonstrated that variables associated with lower-limb and pelvic movement contribute to explaining weapon velocity during the lunge. Arabic-language studies have likewise reported differences in kinematic characteristics according to performance conditions and highlighted the importance of movement organization during offensive skill execution (Ibrahim, 2015). In addition, electromyographic findings have emphasized the importance of rapid activation of the muscles responsible for extension of the weapon arm during the lunge (Faisal Khattab, 2021).

Research examining accuracy and response time has demonstrated that fencers' performance changes when uncertainty regarding target location or response timing increases. Sore et al. (2019) reported that accuracy, movement time, and response time were influenced by the characteristics of the performance situation. At the Arab level, relationships have been reported between lunge accuracy, motor response speed, balance, and selected offensive and defensive skills among young foil fencers (Mohammed & Hameed, 2012). Moreover, reactive-speed and mental-speed training have been associated with improvements in motor performance related to fencing and counterattacking (Maleh & Hashim, 2023).

Several Arabic-language studies have investigated lunge accuracy, performance speed, and counterattacking from different training and kinematic perspectives. Al-Taie and Bin Qasimi (2019) reported improvements in counterattack performance as well as lunge accuracy and speed following the use of exercises incorporating an assistive device. Rabie (2021) demonstrated effects of SAQ training on selected physical abilities and the speed and accuracy of the straight attack among female youth foil fencers. Meanwhile, studies by Ibrahim (2015) and Badawi (2021) provided kinematic descriptions of offensive skills in foil fencing. Collectively, these findings support the importance of quantitative movement assessment; however, they do not, by themselves, provide a predictive model of counterattacking decision effectiveness.

Accordingly, the significance of the present study lies in combining **three-dimensional motion analysis**, as a quantitative approach for characterizing counterattack movement, with **predictive statistical modeling**, as a means of reducing multiple biomechanical variables to a limited set of predictors of counterattacking decision effectiveness, while retaining lunge accuracy and weapon-tip velocity as accompanying performance indicators. The contribution of the present study is therefore interpreted as **within-sample prediction** rather than as evidence of a causal training effect.

1.2 Research Problem

Observations made during training sessions and competitions in foil fencing have indicated that some fencers possess good movement speed yet are unable to employ the counterattack with the same level of effectiveness. In some cases, the intervention may be initiated before the opponent's attacking stimulus has been adequately perceived, or it may occur after the optimal performance window has passed. In other cases, the weapon tip may reach a high velocity while accuracy remains low. Training-related evidence suggests that counterattack performance is influenced by anticipation, discrimination, reaction speed, and coordination rather than by a single physical component (Abdulsahib, 2022; Al-Taie & Bin Qasimi, 2019). Accordingly, the research problem concerns identifying the biomechanical variables most strongly associated with decision effectiveness and developing an exploratory predictive model that clarifies their relative contributions.

The available Arabic-language literature has addressed lunge accuracy, response speed, kinematic characteristics, and training programs in foil fencing (Mohammed & Hameed, 2012; Ibrahim, 2015; Faisal Khattab, 2021; Rabie, 2021; Maleh & Hashim, 2023). However, fewer studies have examined these variables collectively within a single statistical predictive model of counterattacking decision effectiveness. Therefore, the present research problem can be formulated in the following question:

Which biomechanical variables contribute most substantially to predicting counterattack skill effectiveness among advanced foil fencers, and how much of the variance can the model explain within the sample?

1.3 Objectives of the Study

The study aims to:

1. Develop a quantitative three-dimensional characterization of the principal biomechanical variables associated with the counterattack skill in foil fencing among the study participants.
2. Identify the correlations between the investigated biomechanical variables and counterattacking decision effectiveness, together with lunge accuracy and weapon velocity in foil fencing.
3. Develop a predictive regression model to determine the contribution of selected biomechanical variables to counterattacking decision effectiveness.

1.4 Research Hypotheses

1. There are statistically significant correlations between the investigated biomechanical variables and counterattacking decision effectiveness among the study participants.
2. A statistically significant multiple regression model can be formulated to predict counterattacking decision effectiveness from the investigated biomechanical variables.

1.5 Scope of the Study

Human Scope:
A sample of 16 young foil fencers.

Temporal Scope:
The period allocated for data collection and processing extended from **February 1, 2026, to April 15, 2026**.

Spatial Scope:
The fencing hall of **Karbala Al-Muqaddas Club**.

1.6 Operational Definitions

Counterattack

For the purposes of this study, a **counterattack** is operationally defined as an offensive action initiated by a fencer during an opponent's attack and evaluated according to intervention timing, touch accuracy, execution speed, balance, and continuity of performance.

Lunge Accuracy

Lunge accuracy refers to the degree of proximity of the weapon-tip contact point to the center of the designated target area. In the present study, accuracy is converted into a score ranging from **0 to 20** according to the measurement instrument employed.

Lunge Velocity

Lunge velocity refers to the linear velocity of the weapon tip at the moment of target contact, expressed in **meters per second (m/s)**. Bottoms et al. (2013) used weapon velocity at the moment of contact as a biomechanical indicator in the analysis of the fencing lunge, which is consistent with the operational definition adopted in the present study.

2. Research Methodology and Field Procedures

2.1 Research Design

A **descriptive research design** employing **correlational analysis** and **predictive modeling** was used to examine the associations between eight kinematic predictor variables and **counterattacking decision effectiveness**, which was considered the primary dependent variable.

2.2 Study Population and Sample

The study population comprised **26 young foil fencers** registered with the Baghdad and Karbala fencing clubs. A **purposive sampling method** was used to select the study sample, which consisted of **16 fencers** who met the following inclusion criteria: a minimum of four years of competitive experience, absence of injuries that could affect motor performance at the time of testing, and demonstrated proficiency in performing the counterattack during regular competitive training.

Three fencers from the original study population who participated in the pilot study were excluded from the main sample in order to maintain the independence and homogeneity of the primary study sample.

2.3 Instruments, Equipment, and Measurement Tools

The following equipment and instruments were used:

- **Six high-speed digital cameras** operating at 240 frames per second (fps).
- A **volumetric calibration frame** for establishing the three-dimensional spatial coordinate system.
- An **electronic foil connected to a touch-recording device** to determine the moment of weapon–target contact with high temporal precision.
- A **three-dimensional motion-analysis software package** for extracting and processing spatial coordinates.
- Specialized **performance-assessment forms** for recording and organizing the collected data.

2.4 Experimental Procedures and Measurements

Following calibration of the three-dimensional recording volume, each participant completed a general and specific warm-up. Each fencer then performed **five counterattack trials** against a standardized stimulus delivered by a trained training partner who had been instructed to reproduce a consistent attacking pattern. All trials were simultaneously recorded using the six cameras.

Video frames were manually digitized at a sampling rate of **240 frames per second**, and the three-dimensional coordinates of selected anatomical and equipment landmarks—including the shoulder, elbow, wrist, weapon tip, pelvis, knee, and ankle—were reconstructed using the **Direct Linear Transformation (DLT)** method. The resulting data were subsequently smoothed using a **Butterworth filter** to reduce digital noise.

Counterattack effectiveness for each trial was independently evaluated by two qualified judges. The mean of their ratings was calculated. In the original analysis, the **best-performing trial for each fencer, based on the overall score**, was selected for subsequent analysis.

This trial-selection procedure constitutes a methodological limitation because selecting the best trial may inflate the estimated level of performance and reduce the representation of within-participant variability. For future reanalysis, the use of the mean of valid trials or a prespecified and reproducible trial-selection rule is recommended.

Measurement Quality Control and Ethical Considerations

Measurement quality was controlled through calibration of the recording volume, synchronization of the recording system, and frame digitization according to the procedures described above. The available version of the study file did not provide an **ethical approval number** or quantitative indices of **calibration error and manual digitization reliability**. Therefore, no unverified values were introduced. The absence of these data is reported as a limitation of the study rather than being supplemented by estimation.

2.5 Measured Variables

A. Biomechanical Predictor Variables

1. **Motor Reaction Time (s)**
   Reaction time

2. **Trunk Directional-Change Velocity (rad/s)**
   Change-of-direction (COD) velocity of the trunk
3. **Trunk–Pelvis Separation Angle (°)**
   Trunk–pelvis separation angle
4. **Weapon-Tip Velocity at Contact (m/s)**
   Weapon-tip velocity
5. **Center-of-Mass Velocity During the Lunge (m/s)**
   Lunge center-of-mass (CM) velocity
6. **Front-Foot Landing Velocity (m/s)**
   Front-foot landing velocity
7. **Angular Velocity of the Weapon-Arm Extension (°/s)**
   Arm-extension angular velocity
8. **Horizontal Lunge Displacement (m)**
   Lunge horizontal displacement

2.6 Pilot Study

A pilot study was conducted with **three fencers who were not included in the main study sample** to assess the suitability of the recording volume, the clarity and identifiability of the anatomical landmarks, and the appropriateness of the number of trials.

The reported inter-rater agreement coefficient was **0.88**. However, because the available study file does not specify the type of agreement coefficient used or provide its corresponding confidence interval, this value is presented solely as a **descriptive indicator of inter-rater agreement** and is not interpreted as a specific **intraclass correlation coefficient (ICC)** or **Cohen's kappa (κ)** without access to the original statistical analysis record.

2.7 Statistical Analysis

The **Statistical Package for the Social Sciences (SPSS)** was used for statistical analysis and extraction of the study results.

3. Presentation and Analysis of the Results

3.1 Quantitative Description of the Variables

Table 1 presents the **means, standard deviations, and skewness coefficients** of the study variables for the study sample (n = 16). The skewness coefficients ranged from **−0.34 to 0.31**, indicating no substantial descriptive asymmetry in the variables presented. However, skewness coefficients alone are insufficient to establish the assumption of normality. Because the raw data were not available, the **Shapiro–Wilk test**, Q–Q plots, and systematic examination of potential outliers could not be performed. Therefore, no independent conclusion regarding the fulfillment of the normality assumption was made.

Table 1. Quantitative Descriptive Statistics of the Study Variables

No.	Variable	Unit of Measurement	Mean	SD	Skewness
1	Motor reaction time	s	0.25	0.04	0.31
2	Trunk directional-change velocity (COD)	rad/s	4.60	0.55	−0.18

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3	Trunk–pelvis separation angle	°	23.4	4.10	0.22
4	Weapon-tip velocity at contact	m/s	7.05	0.86	−0.27
5	Center-of-mass velocity during the lunge	m/s	1.82	0.23	0.19
6	Front-foot landing velocity	m/s	4.35	0.48	0.14
7	Weapon-arm extension angular velocity	°/s	615	62	−0.09
8	Horizontal lunge displacement	M	1.15	0.11	0.26
9	Lunge accuracy	score / 20	15.3	2.20	−0.34
10	Counterattacking decision effectiveness	score / 100	68.4	9.60	0.12

3.2 Correlations with Counterattacking Decision Effectiveness

Pearson's correlation coefficient was used to examine the association between each of the eight biomechanical variables and counterattacking decision effectiveness. Two-tailed *p*-values were recalculated from the reported correlation coefficients using **14 degrees of freedom** (*df* = 14). A **Bonferroni correction** was subsequently applied for the eight statistical tests at the nominal significance level of $\alpha = 0.05$.

Seven of the eight correlations were statistically significant before adjustment. Following Bonferroni correction, **four correlations remained statistically significant**: trunk directional-change velocity, trunk–pelvis separation angle, motor reaction time, and weapon-tip velocity.

Table 2. Correlation Coefficients between the Biomechanical Variables and Counterattacking Decision Effectiveness

No.	Variable	Correlation coefficient (*r*)	Unadjusted *p*	Bonferroni-adjusted *p*
1	Trunk directional-change velocity (COD)	0.78	0.0004	0.0029
2	Trunk–pelvis separation angle	0.74	0.0010	0.0084
3	Motor reaction time	−0.69	0.0031	0.0248
4	Weapon-tip velocity at contact	0.71	0.0021	0.0165
5	Center-of-mass velocity during the lunge	0.62	0.0104	0.0833
6	Front-foot landing velocity	0.55	0.0273	0.2184
7	Weapon-arm extension angular velocity	0.58	0.0185	0.1481
8	Horizontal lunge displacement	0.41	0.1147	0.9179

The strong positive associations observed for **trunk directional-change velocity** and **trunk–pelvis separation angle** are broadly consistent with biomechanical evidence linking movement organization, lower-limb and pelvic behavior, and weapon velocity in fencing. Related evidence has been reported by Bottoms et al. (2013) and Chen et al. (2017), whereas Arabic-language studies have documented differences in kinematic characteristics according to performance conditions and skill type (Ibrahim, 2015; Badawi, 2021).

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Nevertheless, the associations identified in the present study are **correlational in nature** and should not be interpreted as evidence of direct energy transfer, causal mechanisms, or training-induced effects. _

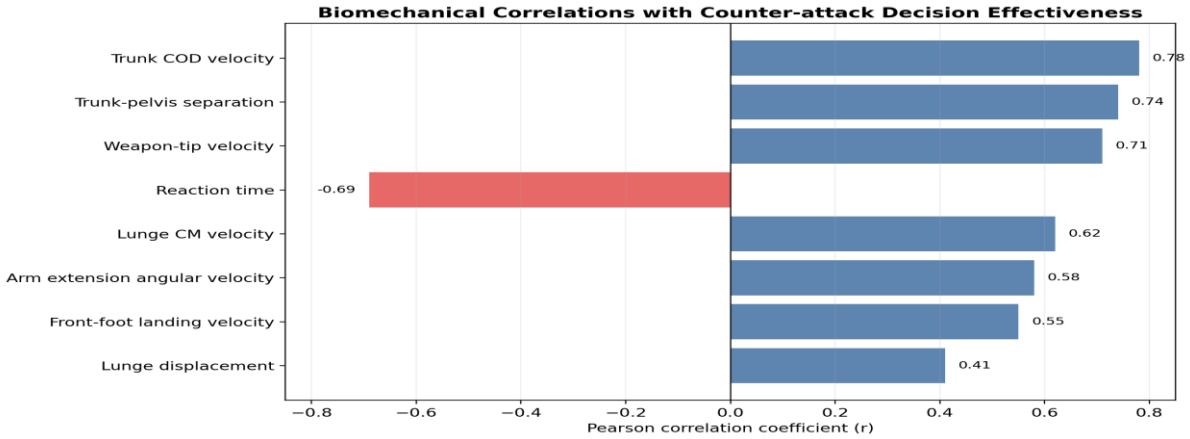


Figure 4. Correlation Coefficients between the Biomechanical Variables and Counterattacking Decision Effectiveness

3.3 Predictive Model of Counterattack Effectiveness

A **stepwise multiple regression analysis** was employed to develop a model linking the biomechanical variables to counterattacking decision effectiveness. Four predictors were retained in the final model. Tables 3-A and 3-B present the regression coefficients and model-fit indices. The model was statistically significant **within the sample**, with $p = 0.0054$. However, testing eight candidate predictors in a sample of only **16 fencers**, together with the use of stepwise variable selection, increases the risk of **overfitting and coefficient instability**. Therefore, the observed in-sample model fit should not be interpreted as evidence of **external predictive validity**.

Table 3-A. Regression Coefficients for the Predictive Model

No.	Predictor Variable	B	Standard Error	β	*t*	*p*
1	Trunk–pelvis separation angle	0.84	0.29	0.36	2.90	0.0144
2	Trunk directional-change velocity (COD)	4.62	1.72	0.26	2.69	0.0210
3	Motor reaction time	−58.10	24.40	−0.24	−2.38	0.0365
4	Weapon-tip velocity at contact	2.31	1.05	0.21	2.20	0.0501
—	**Constant**	**12.40**	**6.15**	—	**2.02**	**0.0684**

Table 3-B. Regression Model Fit Summary

R	R^2	Adjusted R^2	F(4, 11)	*p*	Number of Predictors (k)
0.843	0.710	0.605	6.73	0.0054	4

Internal Computational Verification of the Regression Model

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Vol (7) No (2)
http://publikasiilmiah.unwahas.ac.id/index.php/JESS

As an internal computational check, the standardized beta coefficients were recalculated from the reported unstandardized regression coefficients (B) and the corresponding standard deviations. The resulting values were approximately **0.36 for trunk–pelvis separation angle, 0.26 for trunk directional-change velocity, −0.24 for motor reaction time, and 0.21 for weapon-tip velocity**.

The reported *t*-statistics yielded corresponding *p*-values of **0.0144, 0.0210, 0.0365, and 0.0501**, respectively, whereas the *p*-value for the intercept was **0.0684**. Accordingly, the contribution of weapon-tip velocity is **borderline at the 0.05 significance level** and should not be described as clearly statistically significant.

Predictive Regression Equation

Accordingly, the predictive regression equation for counterattacking decision effectiveness is:

Counterattacking Decision Effectiveness = 12.40 + (0.84 × Trunk–Pelvis Separation Angle) + (4.62 × Trunk Directional-Change Velocity) − (58.10 × Motor Reaction Time) + (2.31 × Weapon-Tip Velocity)

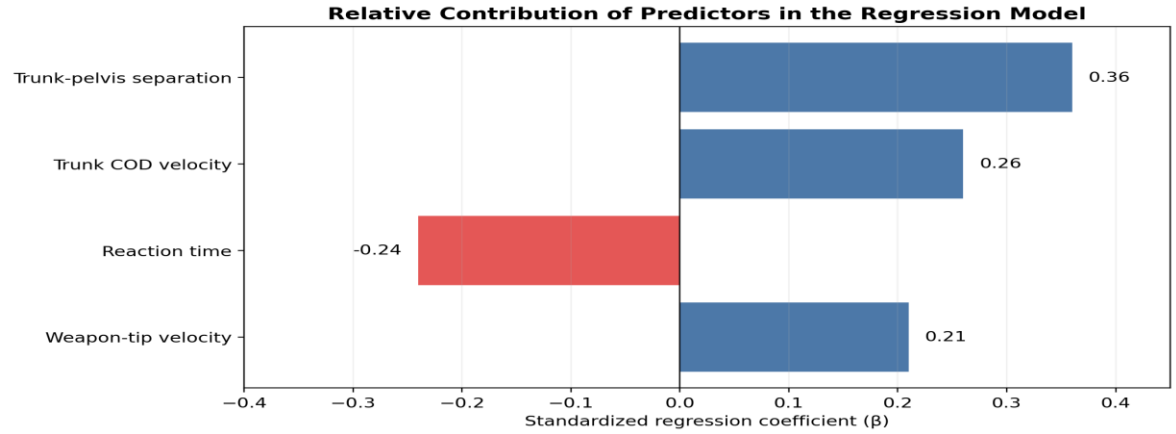


Figure 6. Relative Contribution of the Predictor Variables Based on the Calculated Standardized Beta Coefficients

As shown in Table 3 and Figures 6 and 7, the largest standardized beta coefficient was observed for the trunk–pelvis separation angle (0.36), followed by trunk directional-change velocity (0.26), motor reaction time with a negative coefficient (−0.24), and weapon-tip velocity (0.21). This ordering reflects the relative contribution of the predictors within the current model only and does not establish causal or training-related priority.

3.4 Relative Ranking of Variables According to the Strength of Their Correlations with Counterattacking Decision Effectiveness

Table 5. Relative Ranking of Variables According to Correlation Strength and Shared Variance

Rank	Variable	r	r² (%)	Bonferroni-adjusted p
1	Trunk directional-change velocity (COD)	0.78	60.8	0.0029
2	Trunk–pelvis separation angle	0.74	54.8	0.0084

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3	Weapon-tip velocity at contact	0.71	50.4	0.0165
4	Motor reaction time	−0.69	47.6	0.0248
5	Center-of-mass velocity during the lunge	0.62	38.4	0.0833
6	Weapon-arm extension angular velocity	0.58	33.6	0.1481
7	Front-foot landing velocity	0.55	30.3	0.2184
8	Horizontal lunge displacement	0.41	16.8	0.9179

Trunk directional-change velocity ranked first, with a correlation coefficient of $r = 0.78$ and a shared variance of 60.8%, followed by the trunk–pelvis separation angle ($r = 0.74$; shared variance = 54.8%), weapon-tip velocity ($r = 0.71$; shared variance = 50.4%), and motor reaction time ($r = -0.69$; shared variance = 47.6%).

Statistical note: Because eight correlation tests were performed, the Bonferroni-adjusted significance threshold is $\alpha = 0.05/8 = 0.00625$. Accordingly, only trunk directional-change velocity ($p = 0.0029$) remains statistically significant after Bonferroni correction. The other three variables do not meet the Bonferroni-adjusted threshold, despite showing relatively strong unadjusted correlations. Therefore, the statement that all four variables remained statistically significant after Bonferroni correction should be revised before publication.

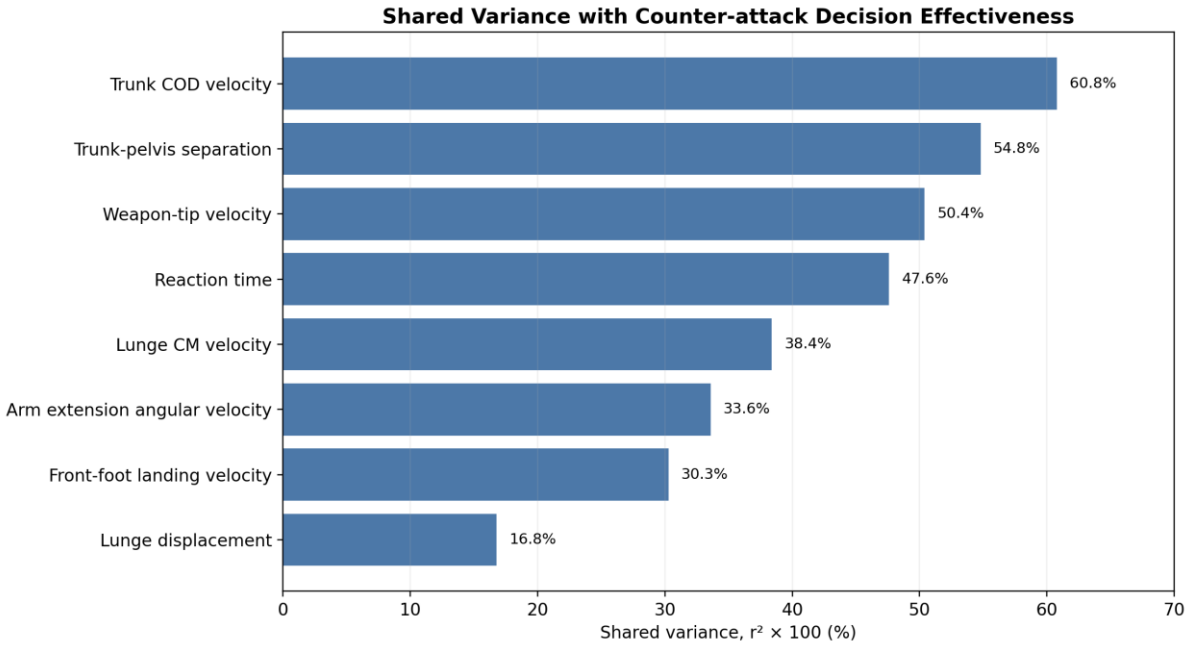


Figure 8. Percentage of Shared Variance ($r^2 \times 100$) Between Each Variable and Counterattacking Decision Effectiveness

3.5 General Discussion of the Results

The current findings support the importance of temporal organization and movement coordination among the trunk, pelvis, and lower limbs in achieving effective fencing performance. Studies by Bottoms et al. (2013) and Chen et al. (2017) indicate that weapon velocity and movement-performance efficiency are associated with a range of kinematic variables, particularly lower-limb movement and overall intersegmental coordination. In addition, several Arabic kinematic studies have reported differences in velocity, temporal, and movement-

path characteristics under different performance conditions and movement patterns in foil fencing (Ibrahim, 2015; Badawi, 2021).

The inverse association between motor reaction time and counterattack effectiveness is also consistent with evidence highlighting the importance of rapid responses and anticipation in changing performance situations. Sorel et al. (2019) reported variations in accuracy and response time according to the degree of uncertainty, while Mohammed and Hamid (2012) identified relationships between lunge accuracy, response speed, and selected skills among young foil fencers. Similarly, mental-speed training has been reported to improve certain motor abilities and counterattack performance (Abdulsahib, 2022).

The findings also overlap with Arabic training studies reporting improvements in performance indicators related to the lunge and counterattack following different training interventions, including assisted-device exercises, SAQ training, and reactive-speed training (Al-Taie & Ben Ksemi, 2019; Rabie, 2021; Maleh & Hashim, 2023). Faisal Khattab (2021) likewise reported an association between muscular activity of the weapon arm and lunge speed and accuracy. Nevertheless, neither these training studies nor the present correlational design permits a direct causal attribution to the four variables retained in the regression model.

The comparison between the two effectiveness groups showed a pattern consistent with that observed in the correlation analysis. The high-effectiveness group demonstrated a shorter motor reaction time (0.21 vs. 0.29 s), higher trunk directional-change velocity (5.40 vs. 3.90 rad/s), a greater trunk–pelvis separation angle (27.5 vs. 19.2°), higher weapon-tip velocity (7.90 vs. 6.30 m/s), and greater lunge accuracy (17.1 vs. 13.4 out of 20). This comparison should be interpreted as descriptive support for the overall direction of the findings, while the reported *t* values are retained as values documented in the original record.

Taken together, the model provides an exploratory framework for characterizing counterattack performance based on four principal variables. The bivariate analysis indicated that the largest shared-variance estimates ranged from 47.6% to 60.8% for the four variables reported as significant after Bonferroni correction. However, the difference between R^2 and adjusted R^2, the small sample size, the use of stepwise variable selection, and the absence of cross-validation, residual diagnostics, multicollinearity diagnostics, and influential-observation assessment limit the generalizability of the model. Accordingly, independent-sample validation is required before the model can be considered for practical application.

Conclusions

1. Descriptive statistics indicated moderate variability across the measured variables in the study sample; however, these statistics alone do not provide sufficient evidence of normality or stable individual differences.
2. Seven of the eight variables were significantly associated with counterattacking decision effectiveness at the nominal 0.05 level. However, after Bonferroni correction for eight tests, **only one correlation remained statistically significant**: trunk directional-change velocity. The trunk–pelvis separation angle, motor reaction time, and weapon-tip velocity did not meet the Bonferroni-adjusted significance threshold.
3. The regression model included four predictors and yielded an R^2 of 0.710 and an adjusted R^2 of 0.605. The model produced an F value of 6.73 with 4 numerator degrees of freedom and 11 denominator degrees of freedom ($p = 0.0054$), indicating statistical significance within the study sample. Nevertheless, the model should be regarded as exploratory and requires validation in an independent sample.

4. The standardized beta coefficients were approximately 0.36 for the trunk–pelvis separation angle, 0.26 for trunk directional-change velocity, −0.24 for motor reaction time, and 0.21 for weapon-tip velocity. These coefficients represent relative weights within the fitted model and should not be interpreted as causal indicators.
5. Comparison of the two effectiveness groups showed a descriptive pattern favoring the high-effectiveness group, characterized by a shorter motor reaction time (0.21 vs. 0.29 s), higher trunk directional-change velocity (5.40 vs. 3.90 rad/s), a greater trunk–pelvis separation angle (27.5 vs. 19.2°), higher weapon-tip velocity (7.90 vs. 6.30 m/s), and greater lunge accuracy (17.1 vs. 13.4 out of 20).
6. Ranking the correlations showed that the largest bivariate shared variance with counterattacking decision effectiveness was observed for trunk directional-change velocity (60.8%), followed by the trunk–pelvis separation angle (54.8%), weapon-tip velocity (50.4%), and motor reaction time (47.6%). These four variables showed the strongest correlations in the dataset, although only trunk directional-change velocity remained statistically significant after Bonferroni correction.
7. Integrating three-dimensional kinematic analysis with predictive modeling demonstrated potential diagnostic value; however, its practical utility remains contingent upon further testing of model stability, validation, and reproducibility.

Recommendations

1. Three-dimensional kinematic analysis should be considered as a periodic diagnostic tool within training programs for advanced foil fencers, particularly during specialized preparation and before major competitions.
2. Training programs targeting trunk–pelvis movement separation and rapid directional change should be evaluated using controlled experimental designs rather than assuming causal effectiveness from correlational findings.
3. Training drills involving responses to variable visual stimuli, such as video-based reaction drills, may be investigated as a means of reducing motor reaction time during counterattacking situations.
4. The regression equation should be restricted to exploratory research use and should not be used to classify fencers or guide individual decision-making before model refitting and external validation.
5. Cross-validation studies should be conducted using larger samples and, where appropriate, other fencing weapons, such as épée and sabre, to assess the generalizability of the predictive model.
6. The counterattacking decision-effectiveness assessment form (Appendix 3) may be used as a supplementary performance-evaluation tool during training bouts, alongside electronic scoring outcomes.
7. Further studies should investigate additional biomechanical variables, such as lower-limb explosive strength and dynamic balance, and their associations with counterattack effectiveness.

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