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Article

The biomechanical characteristics of fencing lunge movements and their implications for physical training

Shen Wei, Dongyuan Wei*

Department of Physical Education, Guilin University of Electronic Science and Technology, Guilin 541000, China
*** Corresponding author:** Dongyuan Wei, Weidongyuan1989@sina.com

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Abstract: Fencing is a unique combat sport characterized by its dynamic movements, strategic interactions, and the need for rapid decision-making. Central to a fencer's performance is the lunge, a foundational movement that enables athletes to engage their opponent effectively while maintaining balance and control. It executes precise and explosive movements, particularly during lunges, which are critical for both offensive and defensive strategies. Understanding the biomechanical characteristics of this action is critical for maximizing performance, improving training regimens, and lowering injury risk. The objective of this study is to investigate the biomechanical characteristics of fencing lunge movements and their implications for physical training. A total of 126 fencers participated in this study. They are randomly divided into two groups: Group A, who received physical training based on biomechanical intervention, and Group B, who received traditional physical training. Using motion capture data through cameras, sensors and force plates, the lunge technique of competitive fencers is analyzed, examining variables such as joint angles, force application, and ground reaction forces. The data analysis and statistical methods include descriptive statistics, *t*-tests, and ANOVA to identify significant differences between the groups. The findings demonstrate Group A significantly improved the optimal lunge execution, which is characterized by specific patterns of joint movement, particularly at the ankle, knee, and hip, which correlate with successful reach and stability. Also, Group A identified the importance of muscular strength, flexibility, and reaction time in enhancing lunge performance to Group B. The study describes that integrating these biomechanical concepts into training programs, coaches, and players can enhance performance, reduce the risk of injury, and encourage long-term fencing success.

Keywords: fencing lunge movements; biomechanical; physical training; fencer

1. Introduction

Fencing is an open-skill sport where two competitors battle with one of 3 weapons: épée, foil, or sabre. In épée and foil, touches are made by pushing, whereas sabre touches are made with the blade's edge [1]. Because of its asymmetrical form, the sport demands a great degree of collaboration, explosive strength, speed, and accuracy. The lunge attack is the most typical type of attack. Some come from in-stance counterattacks and the fleche [2]. Athletes' ability to execute a precise and potent forward unilateral lunge is crucial to their success in fencing, an Olympic sport. The push-off portion of these lunges involves the powerful flexion of the forward knee, and the forceful extending of the back legafter the upper limb motion [3]. Furthermore, there is a dearth of information about fencing anthropometry and how it relates to performance during the formative stage. Furthermore, insufficient thought is given to how youth fencers' lunge mechanics change according to their gender. Their motor abilities are not as developed as those of their older others, and they might not use the same motor patterning. The methods recommended by instruction manuals and the real movement patterns seen in biomechanical research also differ from one another [4].

Every fencer begins in the “engarde” position, which is an L-shaped stance with the feet shoulder-width apart, the front foot pointed forward, and the back foot perpendicular beneath the hip for support. The fencer elevates their front foot first and then their rear foot to advance, or proceed ahead. The fencers improved their back foot before raising their front foot to retreat or go backward. The fencer executes a strong lunge to end an assault, kicking the front foot forward and straightening the rear leg. Above all, the side of the weight-bearing leg and the hand gripping the weapon must match [5]. To help their muscles adjust to eccentric loads, fencers frequently employ the “repeat bout effect” of plyometric training. Youth athletes can enhance their neurological functioning through safe and practical physical preparation through plyometric training. To activate the neural patterns of activation throughout the stretch-shortening cycle (SSC), plyometric training is typically utilized to overload the eccentric portion of movements [6]. A biomechanical understanding of the lunge may help discover ways to prevent injuries. More than any other factor associated with the sport, injuries of the lower limbs are common among fencers and often result from this activity. Once risk factors of injury appear to be embedded in an incorrect lunge technique, coaches and practitioners can institute corrective techniques and conditioning programs to try and reduce the incidence of injury [7]. This study aims to investigate the biomechanical characteristics of fencing lunge movements and their impact on performance and injury prevention. By comparing fencers who received biomechanical-based training with those undergoing traditional training.

The study’s remaining parts are the following: Part 2 describes the related article based on the fencing lunge movements’ biomechanical characteristics, Part 3 provides a methodology of participant demographic details and survey questions, Part 4 analyzes the performance of results and finally, Part 5 discusses the overall study conclusion.

2. Related articles

The effectiveness of the base of support (BOS) width on armed upper limbs and centre of mass (COM) kinematics during lunging, as well as early postural adjustment (EPA), was examined in [8]. Eight top female fencers took part; the COM and center of foot pressure (COP) displacement were recorded. The results revealed that EPA had a minor COP displacement, which decreased with BOS width. Greater BOS width resulted in greater elevation of the COM throughout foot off and maximum during fencer lunging. A small COP amplitude might affect COM acceleration.

The evaluated the biomechanical parameters of the fencing lunge by elite female and male senior fencers. The results indicated that male fencers had higher response velocities and times in comparison to female fencers [9]; however, no significant differences were found between male and female fencers in other kinematic variables. Such factors might point to developing a different training approach that better prepares fencers for decision-making and fast movements.

The discussed the impact of target breadth and length on the preparation and execution phases of a fencing lunge [10]. Eight of the highest female fencers participated, and force plates were used to monitor foot pressure displacement, tibialis anterior activity of muscles, and COM mechanics. The results showed no influence on early postural changes or acceleration. Therefore, the competent technique and the ballistic nature of lunges can reduce task factors.

The attempted to test 2D video analysis for fencing lunges by analyzing both 2D and 3D analysis of motion to determine the lower limb angle of joints. Two digital video cameras as well as eight motion capture cameras recorded the lunges of twenty-two male fencers [11]. The results indicated significant biases in ankle angles, moderate correlations for hip angles, and substantial correlations for knee angles, suggesting that greater optimization would be needed.

Surface electromyography was utilized in [12] to measure the muscle activity of fencers. The results were achieved through a single session of therapy by using the Mann-Whitney U Test. Vastusmedialis and rectus femoris muscle activation related to pain were not significantly dissimilar from each other, according to the result ($p = 0.034$), even though there were differences in the activation of both muscles associated with pain.

The purpose of [13] was the identification of which of the across-age, gender, competition level, and weapon specialization variables influenced the offense kinetic patterns in 130 well-experienced fencers. It could be found out from the above MANOVA that the velocity was mainly influenced by age, gender, competition level, and discipline. In due course, since leg power measurements and lunge velocities were correlated, training adaptations for better performance should consider those variables.

To develop an instructional training with 3-dimensional sensors to improve the physical abilities in lunge technique for female students of first grade at Helwan University of the [14]. The approach used a single-group pretest-posttest design for participants counted at 25 and led to some noticeable improvements in critical skill measures to demonstrate the positive effects of the 3-D models on skill understanding and cognitive development.

The aimed to enhance technical-tactical movements in female fencers aged 14–16 using personalized training approaches. Eight fencers undertook physical and technical exams before and after the competition season [15]. The results revealed considerable gains in physical fitness and several technical indicators, emphasizing the efficacy of targeted training and the significance of continual adaptation to improve competition performance.

Comparing attack times and lower limb biomechanics in college fencers using fencing shoes with heel cups (FSH), fencing shoes (FS), and court shoes (CS)was the goal of [16]. Thirteen people did lunges, and data were obtained using 3D motion analysis and force plates. The results indicated that both FS and FSH had shorter attack periods, and FSH had a lower limb impact than CS.

The investigation looked at how target distances affected the leg joints used in fencing lunges. Joint angles were measured in the sagittal plane as fifteen fencers executed lunges from three distances [17]. The results indicated that the flexion angles, ranges of motion, and extensions varied significantly. Flexion of the back knee joint increased with increasing distance, which was followed by extending the hip and knee joints, plantar flexion, and increased peak acceleration. The significance of different resistance workouts in fencing is the main topic of the research. It attempts to enhance players' performance in various scenarios as well as their stabbing accuracy and quickness. A fencing coach performed the study with the goal of improving stabbing accuracy and physical ability [18]. Young players from Nasiriyah District's Specialized Fencing Centre were included in the investigation's single-group approach. The results indicate that different resistance training can improve fencing skills. The examined how the breadth of the base of support affected the armed upper limb and center of mass (COM) kinematics throughout pushing as well as early postural adjustments (EPA). Eight top-tier female fencers took part, and their centre of foot pressure (COP) and COM displacements were recorded [19]. The findings indicated that EPA's COP displacement was little and decreased as the base of support (BOS) breadth increased. The COM deceleration at foot-off and peak while lunging was enhanced by a wider BOS. According to the study, COM acceleration might be impacted by a little COP amplitude. The influence of visual perception and cognitive skills on novice fencers' accuracy of challenges was investigated. Third-year students participated in the study, receiving visual processing exercises for eight weeks after being randomly allocated to an experimental group [20]. Post-test results revealed that the experimental group had improved their visual awareness and accuracy, exceeding the control group. The suggested that to increase challenge accuracy, fencing lunge instruction should include visual sense training programs.

3. Materials and methodology

The research will implement the experimental comparative approach to determine the effects of biomechanical-based physical training compared to traditional training on fencing lunge performance. The research workflow model is shown in **Figure 1**.

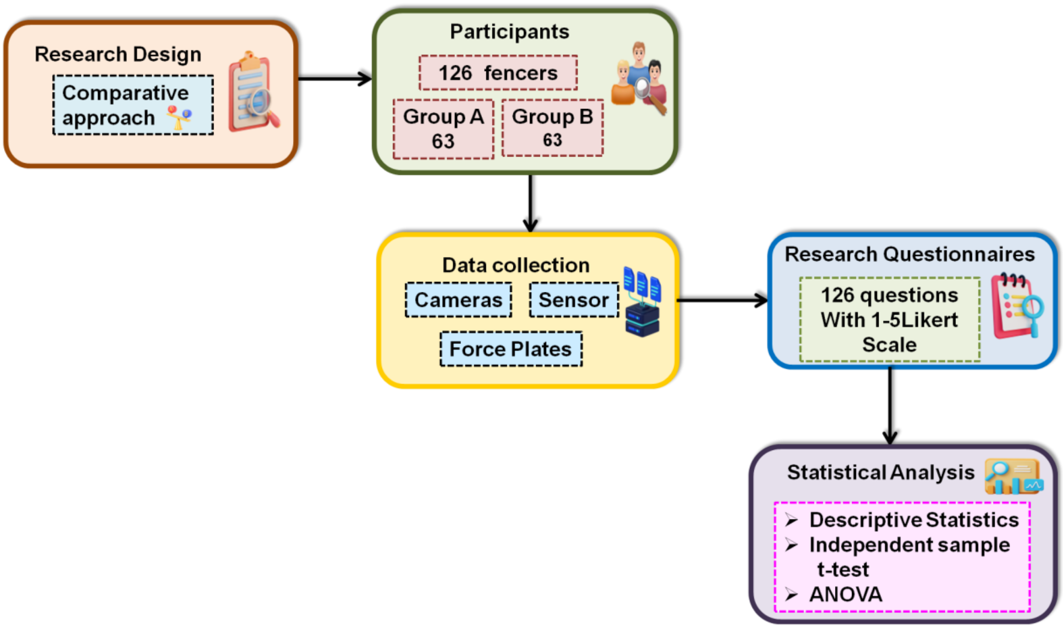

Figure 1. Model of research workflow.

3.1. Participants

The dataset includes 126 fencers, randomly assigned to two training groups: Group A (63 participants) received biomechanical-based physical training focused on optimizing lunge movements through targeted exercises, while Group B (63 participants) underwent traditional fencing training without a biomechanical approach. The participants, aged 18 to 29 years, included both male and female fencers, ensuring a balanced gender distribution. Experience levels ranged from novice to advanced, allowing for varied skill assessments. Height and weight measurements were recorded for analyzing their influence on training outcomes. This data enables a comprehensive evaluation of the impact of biomechanical training on fencing biomechanics across different demographics and experience levels. The study aims to assess whether biomechanical training improves performance metrics such as joint angles and force application during lunges. **Table 1** describes the participant's demographic data.

Table 1. Participant's demographic data.

Demographic characteristic	Group A (N = 63)	Group B (N = 63)	Total (N = 126)
Age			
18–20	12 (19.0%)	10 (15.9%)	22 (17.5%)
21–23	25 (39.7%)	24 (38.1%)	49 (38.9%)
24–26	16 (25.4%)	18 (28.6%)	34 (27.0%)
27–29	10 (15.9%)	11 (17.5%)	21 (16.7%)
Gender			
Male	40 (63.5%)	38 (60.3%)	78 (61.9%)
Female	23 (36.5%)	25 (39.7%)	48 (38.1%)
Experience Level			
Novice	15 (23.8%)	14 (22.2%)	29 (23.0%)
Intermediate	27 (42.9%)	26 (41.3%)	53 (42.1%)
Advanced	21 (33.3%)	23 (36.5%)	44 (34.9%)
Height			
160–170 cm	10 (15.9%)	12 (19.0%)	22 (17.5%)
171–180 cm	27 (42.9%)	28 (44.4%)	55 (43.7%)
181–190 cm	26 (41.3%)	23 (36.5%)	49 (38.9%)
Weight			
60–70 kg	15 (23.8%)	12 (19.0%)	27 (21.4%)
71–80 kg	29 (46.0%)	31 (49.2%)	60 (47.6%)
81–90 kg	19 (30.2%)	20 (31.7%)	39 (30.9%)

3.2. Data collection

Fencing lunge movement data was collected in 3D motion analysis. Each trial's 3D coordinate data were recorded using the analytic software after the tracking markers, which were attached to each fencer's skin and had a width of 12.0 millimetres, were photographed. There were eight motion cameras placed around the fencer, namely Optitrack Prime 17W, OptiTrack, Corvallis with a sample frequency established at 200 Hz. The data were logged and captured using a dedicated cable on Motive software. The organized structure was stationary in this study: The X axis was orthogonal to the Y axis, the Z axis was vertical, and the y-axis would stand for the lunge track. Foils and masks were used on every participant, and the shoes were individual. The ground reaction forces during the lunging movements were measured from force plates mounted on the floor.

3.3. Research questionnaire

200 questionnaires were presented through fencing lunge training to gather information for evaluation. 126 questionnaires were accepted for the study due to the balance of questionnaires that were incomplete or empty. A Likert scale of five points was employed to assess 126 participants.

1) How was the significance of optimal joint angles (ankle, knee, and hip) evaluated throughout the lunge execution in fencing training sessions?
2) How significant is the application of force during the lunge movement for effective performance in fencing?
3) How can the analysis of ground reaction forces be integrated into the training procedure for fencers?

The Likert scale is used for multiple-choice questions with options ranging from 1 to 5.

- Disagree, scale 2
- Strongly agree, scale 5
- Neutral, scale 3
- Agree, scale 4
- Strongly disagree, scale 1

3.4. Statistical analysis

Data statistical analysis of this study on fencing lunge biomechanics was using SPSS statistical version 26. Descriptive statistics include frequency, percentages, and means. Comparisons between the effectiveness of biomechanical-based training (Group A) and the traditional approach (Group B) were also made. An independent *t*-test was performed on the joint angles application forces and ground reaction forces to check on inter-group differences in performance metrics throughout lunge performance. One-way ANOVA was used in the analysis of significant differences across various variables, with a significant level set at $\alpha = 0.05$.

4. Performance analysis

The performance of the study examines the impact of fencing lunge movements on physical training. The research utilizes several statistical tests, like descriptive statistics tests, independent *t*-tests, and ANOVA.

4.1. Descriptive statistics test

Descriptive statistical tests summarize and describe the major features of data. It provides insights into measures, such as central tendency and variability. The fencing lunge movements are obtained using descriptive statistics, assisting in quantifying performance-critical elements including speed, accuracy, and stability. By looking at metrics like muscle activation, response time, and average lunge distance, trainers can gain a greater understanding of the muscular requirements of the lunge and indicate areas that need development. Important metrics like as mean, median, standard deviation (SD), and range show general performance patterns and highlight athlete differences in lunge technique. Physical training is directly impacted by these revelations. Trainers can implement physical activity to improve core endurance and coordination of generate a more controllable and forceful action if data indicates inconsistency in lunge consistency. Players can improve their reactions during a match by doing speed and agility workouts that are informed by statistics on reaction time. The trainers can customize training plans by use descriptive statistics to examine lunge motions, which enhances fencing performance and lowers their chance of injury. Descriptive statistics compare the biomechanical training results of two groups of fencers: Group A (Biomechanical Training) and Group B (Traditional Training). **Tables 2** and **3** and **Figures 2** and **3** illustrate the analysis of descriptive statistic outcomes.

Table 2. Descriptive statistic outcome for Group A.

Variable	Mean	Standard Deviation (SD)	Minimum	Maximum
Joint Angle of Ankle	45.2	5.4	32	55
Joint Angle of Knee	120.3	6.2	105	130
Joint Angle of Hip	90.1	4.8	80	98
Force Application	320.5	30	260	400
Ground Reaction Forces	450.8	40.5	350	500

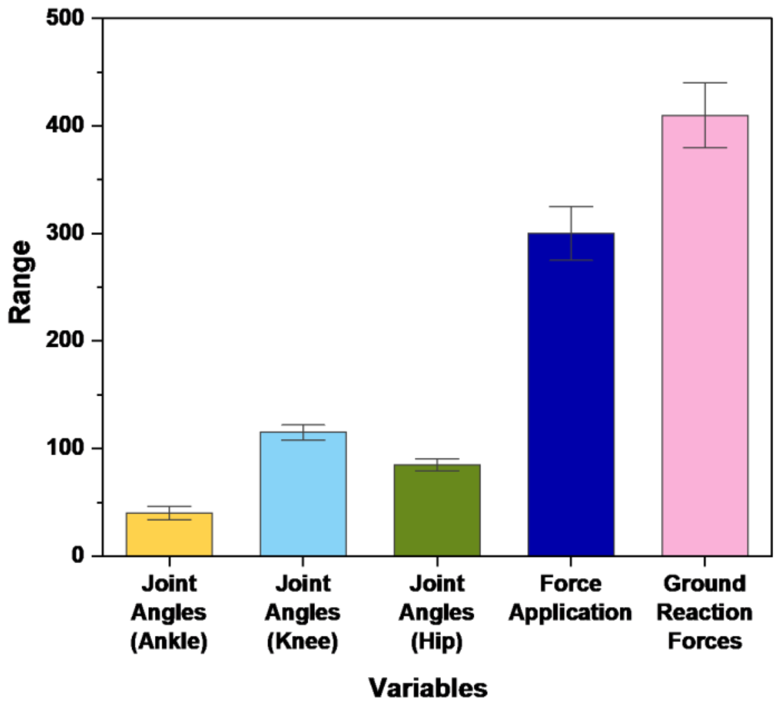

Figure 2. Group A descriptive statistical analysis (mean ± SD).

Table 3. Descriptive statistic outcome for Group B.

Variable	Mean	Standard Deviation (SD)	Minimum	Maximum
Joint Angle of Ankle	38.5	6.1	28	48
Joint Angle of Knee	115	7	100	125
Joint Angle of Hip	85.3	5	75	95
Force Application	290.3	25	240	340
Ground Reaction Forces	410.2	38	310	470

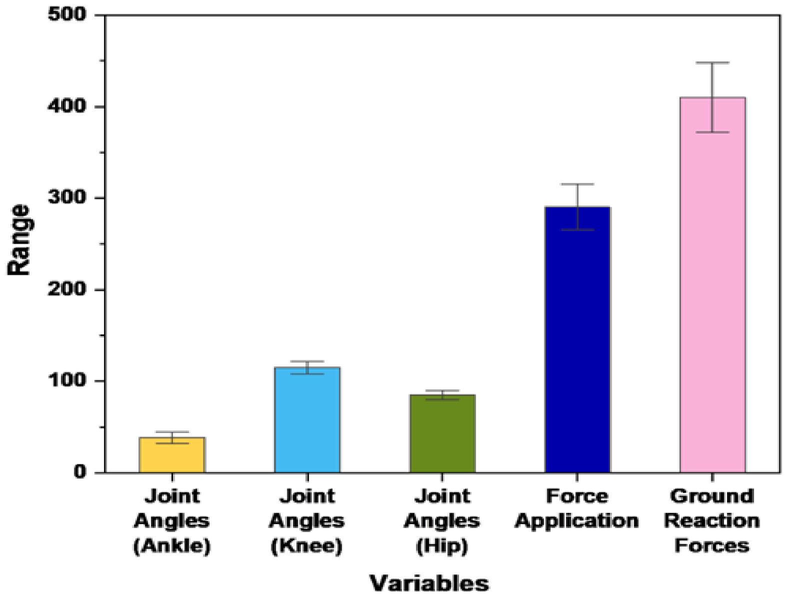

Figure 3. Group B descriptive statistical analysis (mean ± SD).

The outcomes illustrate that Group A had significantly high mean values for all measured variables, which included joint angles of the ankle, knee, and hip, force application, and the ground reaction forces. For instance, the mean ankle angle was 45.2 in biomechanical training (Group A) contrasted to 38.5 in traditional training (group B); force application was 320.5 in Group A while that of Group B was 290.3. This suggests that the biomechanical training has consequences for the execution as well as the effectiveness of the lunge technique in Group A. Demonstrating the effectiveness of the biomechanical training intervention in enhanced performance metrics and suggesting that such training can improve the execution of lunge movement in fencing competitive

4.2. Independent sample (IS) *t*-test

An IS *t*-test analyzes 2 different groups to evaluate whether there are any differences in statistical significance across them. It's substantially used to contrast separated groups, including test scorers from 2 separated trainings. Group A shows significantly superior mean values for all examined variables: joint angles for the ankle, knee, and hip, force application, and ground reaction forces. For instance, Group A shows the mean ± SD value of the joint angle of the ankle 50.0 ± 4.0; consequently, Group A translates to a more accurate lunge technique execution. The lower means and higher *p*-values in Group B reflect no significant differences compared to Group A. The *p*-value for the knee joint angle is P = 0.135, which reflects that traditional training was not associated with meaningful improvements in biomechanical performance. **Tables 4** and **5** and **Figures 4** and **5** show an analysis of the IS t-test outcome. To ascertain whether there are notable variations in the fencing lunge motions of two different groups, such as those undergoing various forms of fencing instruction, the t-test is employed. Through the analysis of factors such as ground reaction forces, force application, and joint angles, the t-test assists in determining which training approach produces better lunge performance. That biomechanical training leads to improved joint angles and force application, for example, this implies that specialized training can maximize lunge technique, providing important information for physical training regimens intended to improve fencing effectiveness and lower injury chance.

Table 4. IS t-test outcome for Group A.

Variable	Mean ± SD	*t*-value	df	*p*-value
Force Application	350.0 ± 30.0	4.8	124	0.0005
Joint Angle of Knee	125.0 ± 5.0	5	124	0.0003
Ground Reaction Forces	480.0 ± 35.0	5.2	124	0.0002
Joint Angle of Ankle	50.0 ± 4.0	6.25	124	0.0001
Joint Angle of Hip	95.0 ± 3.0	7	124	0.0001

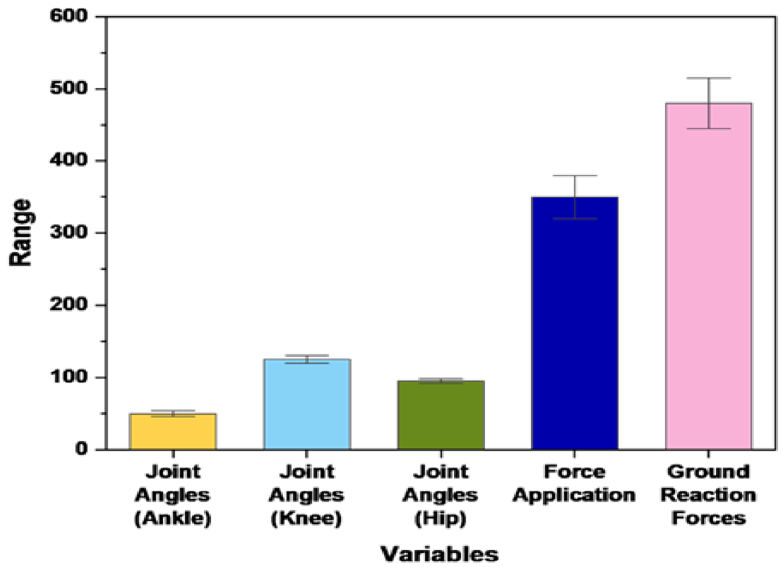

Figure 4. Group A IS t-test analysis (mean ± SD).

Table 5. IS t-test outcome for Group B.

Variable	Mean ± SD	*t*-value	df	*p*-value
Force Application	300.0 ± 25.0	0.8	124	0.42
Joint Angle of Hip	85.0 ± 5.5	1.8	124	0.075
Joint Angle of Ankle	40.0 ± 6.0	1	124	0.32
Ground Reaction Forces	410.0 ± 30.0	1.2	124	0.23
Joint Angle of Knee	115.0 ± 7.0	1.5	124	0.135

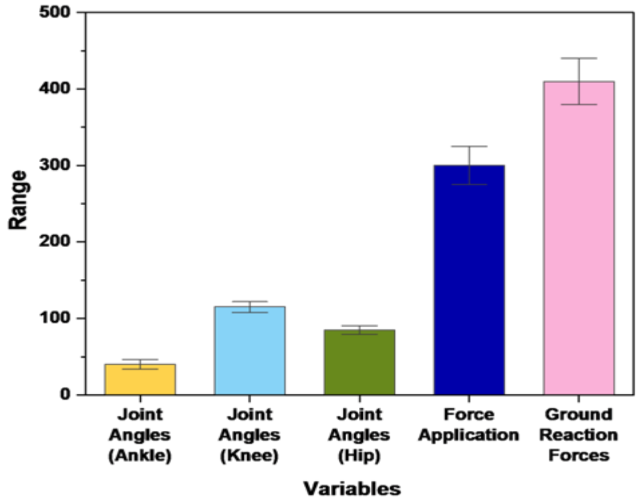

Figure 5. Group BIS t-test analysis (mean ± SD).

Group A performs highly due to improved biomechanical performance, as demonstrated by lower *p*-values and higher averages across all evaluated variables. This demonstrates the efficacy of biomechanical training in improving fencer performance, as standard training methods in Group B did not produce significant results. Biomechanical training (Group A) significantly improved performance through physical strength, flexibility, and growth of reaction times, suggesting a decrease in injury risk and possibly long-term success for fencers.

4.3. ANOVA test

The findings of an ANOVA examining many biomechanical factors associated with fencing lunge motions are display in this ANOVA. It compares two groups' force application, ground response forces, and ankle, knee, and hip joint angles. Every variable has a high *F*-value and a very low *p*-value, suggesting that there are statistically significant variations across the groups. When compared to conventional training approaches, these results indicate that biomechanical training significantly improves lunge technique and performance, as demonstrated by more optimum joint angles and better force application. Group variability is reflected in the error term. The statistical technique known as ANOVA is used to contrast the averages of multiple groups to determine if there are significant variations between the groups. It examines the effect of one or a single dependent factor with several independent factors by focusing on the variation within and between the groups so that researchers can determine which particular groups differ from each other while maintaining the type of error in control. The *p*-value for all joint angles is below 0.05. This suggests that at the different joint angles, Group A and B are significantly different because their high *F*-values represent this significant difference. Where Group A significantly performed better than Group B. **Table 6** shows the results of the ANOVA statistical test for Group A and Group B.

Table 6. ANOVA statistical test for Group A vs. Group B.

Variable	The sum of Squares (SS)	df	Mean Square (MS)	F-Value	p-Value
Force Application	5800	1	5800	13.87	0.0003
Joint Angle of Hip	210.6	1	210.6	10.12	0.002
Ground Reaction Forces	8000	1	8000	14.5	0.0002
Joint Angle of Ankle	320.5	1	320.5	12.32	0.001
Joint Angle of Knee	540.8	1	540.8	15.45	0.0002
Error (within groups)	4150	124	33.47		
Total	21,021.90	125			

In these variables, p-values are very high and significant ($p < 0.05$), which indicates that the force application and ground reaction force of biomechanical training Group A is better than traditional training of Group B. Group A indicates a statistically significant improvement in each of the important variables, demonstrating the importance of biomechanical intervention in training. Group B doesn't show similar benefits.

4.4. Discussion

In this study, the physical training for fencing lunge movements with two groups of comparison were analyzed. Descriptive statistics, independent sample t-tests, and ANOVA were applied to compare the performance between Group A with biomechanical training and Group B with traditional training. In comparison with Group B, in Group A, the mean values for joint angles in all directions, force application, and ground reaction forces were higher. The Independent Sample t-test shows that Group A significantly outperformed Group B for all the measured biomechanical parameters, in this case, the angle of the ankle joint level at 50.0 ± 4.0, $p = 0.0001$. Meanwhile, there was no significant improvement in Group B as demonstrate for the angle of the knee joint at level $115.0 \pm 7.0, p = 0.135$. The ANOVA results also indicated significant differences related to the angles of joints ($p = 0.001$ for ankle, p = 0.0002 for knee and $p = 0.002$ for hip), force application ($p = 0.0003$), and ground reaction forces ($p = 0.0002$) and supported better performance on the elements of Group A. Such findings indicate that the biomechanical intervention significantly enhanced the lunge performance through muscular strength, flexibility, and development of reaction time and implies a decrease in injury risk and possible long-term success for fencers.

5. Conclusion

This study effectively examined the biomechanics characteristics of fencing lunge movement and implications for physical training. Using the performance analysis of 126 fencers separated into groups, such as Group A with biomechanical training and Group B with traditional training, a significant finding was consequently established. Descriptive statistics determined that in Group A, key elements were more significant than in Group B. Independent sample t-tests showed significant recovery of the joint angles at the ankle ($p = 0.0001$), knee ($p = 0.0003$), and hip ($p = 0.0001$)

in Group A. The analysis by ANOVA also supported these findings and was further validated by a significant variation in the value of force application ($p = 0.0003$) and ground reaction forces ($p = 0.0002$). That biomechanical intervention will lead to better execution of lunge through increasing muscular strength, flexibility, and reaction time, hence contributing to improvement in better performance, less risk of injury, and long-term success in fencing.

Limitation and future scope

Biomechanics research on current fencing lunge shows a lack of generalizability because it focuses on a particular population and environment. Moreover, additional variation may not be obtained due to differences in the techniques of fencers and various styles among them. Future studies should investigate other athlete demographics, use high-definition motion capture technology, and then consider the long-term implications of targeted training interventions. Further research can be provided with injury prevention strategies and beneficial methods to improve the performance of an athlete in the sport of fencing and safety.

Author contributions: Conceptualization, SW and DW; methodology, SW and DW; data curation, SW and DW; writing—original draft preparation, SW and DW; writing—review and editing, SW and DW. All authors have read and agreed to the published version of the manuscript.

Ethical approval: Not applicable.

Conflict of interest: The authors declare no conflict of interest.

References

1. Magyar, P. And Oraviţan, M., 2021. Effective Training Interventions For The Development Of Speed In Fencing: A Systematic Review. Discobolul-Physical Education, Sport &Kinetotherapy Journal, 60(4).
2. Aresta, S., Musci, M., Bottiglione, F., Moretti, L., Moretti, B. and Bortone, I., 2023. Motion Technologies in Support of Fence Athletes: A Systematic Review. Applied Sciences, 13(3), p.1654.
3. Drakoulaki, V., Kontochristopoulos, N., Methenitis, S., Simeonidis, T., Cherouveim, E., Koulouvaris, P., Savvidou, O. and Tsolakis, C., 2021. Bilateral asymmetries in male and female young elite fencers about fencing performance. Isokinetics and Exercise Science, 29(2), pp.113-121.
4. Cicchella, A. and Mocco, A., 2020. Anthropometric and Kinematics Determinants of Lunge Velocity and Amplitude in Young Foil Fencers.
5. Thompson, K., Chang, G., Alaia, M., Jazrawi, L. and Gonzalez-Lomas, G., 2022. Lower extremity injuries in US national fencing team members and US fencing Olympians. The Physician and sportsmedicine, 50(3), pp.212-217.
6. diCagno, A., Iuliano, E., Buonsenso, A., Giombini, A., Di Martino, G., Parisi, A., Calcagno, G. and Fiorilli, G., 2020. Effects of accentuated eccentric training vs plyometric training on performance of young elite fencers. Journal of sports science & medicine, 19(4), p.703.
7. Kurniawan, A., Santosa, T. and Santoso, N.P.B., 2023. Analysis Of Surface Electromyography Of The Quadriceps Muscle During Lunge Movements In The Sport Of Fencing With A History Of Knee And Quadriceps Corner Pain (Q-Angle). Journal Of Indonesia Sport Education and Adapted Physical Education (JISEAPE), 4(1), pp.1-13.
8. Fogarty, K., Wolf, A., Taylor, A. and Wilhelm, J., 2022. Stabilization Training Compared to Strength Training in Preventing Lower Extremity Injuries (Doctoral dissertation, Azusa Pacific University).
9. Akbaş, A., Marszałek, W., Bacik, B. and Juras, G., 2021. Influence of base of support on early postural adjustments and fencing lunge performance. Sports Biomechanics, pp.1-13.

10. Riyahi, F., Sadeghi, H. and Shirzad, E., 2024. Kinematic Analysis Of Upper Extremity Of Elite Male And Female Fencers During Fencing Lunge. Research in Sport Medicine and Technology, 22(27), pp.1-14.
11. Akbaş, A., Marszałek, W., Brachman, A. and Juras, G., 2023. Influence of target width and distance on postural adjustments in a fencing lunge. Journal of Human Kinetics, 87, p.35.
12. Chida, K., Inami, T., Yamaguchi, S., Nishioka, T., Yoshida, Y. and Kohtake, N., 2024. Assessing the validity of two-dimensional video analysis for measuring lower limb joint angles during fencing lunge. Frontiers in Sports and Active Living, 6, p.1335272.
13. Ntai, A., Tsolakis, C., Smirniotou, A. and Paradisis, G., 2021. Anthropometric and Leg Power Factors Affect Offensive Kinetic Patterns in Fencing. International Journal of Exercise Science, 14(4), p.919.
14. Reda, R., Mohamed Helmy, N. and Nabil, S., 2024. The Effect of a Proposed Program Using 3D Models On The Physical Skillful Performance and The Lunge Skill in Fencing Sport. International Journal of Sports Science and Arts, 25(1), pp.178-211.
15. Paul, P.L., Importance Of The Individual Lesson In The Technical-Tactical Improvement Of Fencing Athletes.
16. Wang, S.T., Chang, C.C., Chao, T., Nicholls, A. and Tsai, Y.S., 2024. Shoe choice may affect fencing lunge attack performance. Frontiers in Bioengineering and Biotechnology, 12, p.1276025.
17. Chida, K., Inami, T., Yamaguchi, S., Yoshida, Y. and Kohtake, N., 2024. Effects of Different Target Distances on the Kinematics of Hip, Knee, and Ankle Joints in the Fencing Lunge. Biomechanics, 4(2), pp.309-318.
18. Abd Jabbar, A., 2024. The effect of variable resistance exercises to developing some physical abilities and the accuracy and speed of the fencing lunge movement. Sciences Journal Of Physical Education, 17(2).
19. Akbaş, A., Marszałek, W., Bacik, B. and Juras, G., 2024. Influence of base of support on early postural adjustments and fencing lunge performance. Sports Biomechanics, 23(10), pp.1783-1795.
20. Hamid, M.T., 2022. The effect of visual sensation in the development of some cognitive abilities (kinesthetic sense) in the accuracy of Lunge for beginner fencing players. Sciences Journal Of Physical Education, 15(6).