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ORIGINAL

THE INFLUENCE OF CHEST AND BACK MUSCLE STRENGTH ON STRAIGHT PUNCHING PERFORMANCE IN ELITE AMATEUR BOXERS

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ABSTRACT

Introduction: Boxing performance is influenced by upper body strength, but the specific role of chest and back muscle strength in determining punching force remains unclear. This study examines the relationship between chest and back muscle strength and straight punching performance in elite amateur boxers. **Methods:** A cross-sectional design was employed, involving twenty Thai national amateur boxers who had participated in international competitions. Chest and back muscle strength were measured using the 1RM bench press and bench pull tests, with adjustments made for body weight. Punch force and related parameters for both jab and straight punches were assessed using force plates and motion capture equipment. Pearson's correlation coefficients were utilised to identify significant relationships between variables, with statistical significance set at $p<0.05$. **Results:** Chest muscle strength did not show significant correlations with jab frequency, velocity, or straight punch performance. However, both cumulative jab force ($r=0.616$, $p=0.004$) and jab punch force ($r=0.761$, $p<0.001$) were significantly correlated with chest muscle strength. No significant correlations were found between any of the punching performance metrics and back muscle strength. While no relationship was observed between the chest-to-back strength ratio and straight punch performance, notable positive correlations were identified with jab punch force and cumulative jab force. **Discussion:** The findings suggest that while straight punches rely on biomechanical factors such as trunk rotation and the transfer of force from the lower body, jab performance is influenced by chest muscle strength. Research indicates that a balanced chest-to-back strength ratio contributes to enhanced jab punch power. Trainers should ensure the proper balance of antagonist muscles and focus on developing chest strength for boxers who utilise jab techniques. Future biomechanical studies should explore the impact of neuromuscular coordination and lower limb involvement on straight punching mechanics.

KEYWORDS: Amateur Boxing, Chest Muscle, Back Muscle, Muscle Imbalance, Punching Performance

1. INTRODUCTION

Boxing stands as one of the most prominent and widely followed combat sports globally. The inherently demanding nature of boxing necessitates a synthesis of strength, speed, precision, and tactical acumen, rendering it a compelling discipline subject to ongoing scholarly inquiry into its specific physical and physiological demands (Herrera-Valenzuela et al., 2021). Based on observations conducted during international boxing events by the present researcher, who is also a national coach for the Thai amateur boxing team, it has been consistently noted that Thai boxers often exhibit delayed arm retraction to the defensive facial guard following the execution of straight punches. This latency not only compromises the fluidity of successive strikes but also heightens susceptibility to counterattacks. Such inefficiency may stem from inadequate muscular strength or coordination in the pectoral and dorsal regions, thereby elevating the risk of conceding points and negatively influencing match results (Cid-Calfucura et al., 2023). Although a substantial body of literature addresses diverse training methods and factors contributing to the overall performance of boxers, there remains a paucity of research specifically examining the role of chest and back musculature in enhancing the effectiveness of straight punches (McCabe, Martin, & McMahon, 2023), particularly in the context of elite amateur athletes. This gap in knowledge presents a barrier to the development of optimised training frameworks intended to fully realise athletic potential (McCabe et al., 2023). Punching, as a motor skill, involves delivering impact to a target with maximal force and velocity to impair an opponent. Each variant—jabs, straight punches, hooks, and uppercuts—carries distinct tactical benefits and applications. Among these, the straight punch is regarded as one of the most fundamental and strategically vital techniques in both offensive and defensive engagements due to its efficiency in scoring and its prevalence in competitive settings. Empirical findings have underscored that straight punches, particularly those targeting the head, are markedly more frequent among victors than defeated competitors in early match rounds, surpassing hooks and uppercuts in utilisation—with uppercuts being the least employed (Kılıc et al., 2019). Consequently, enhancing the execution of straight punches represents a strategic imperative for optimising scoring opportunities, delivering effective strikes, and improving the probability of victory (Zhang et al., 2024). The technique underlying effective straight punching is intricately linked to neuromuscular coordination, encompassing upper-body control, muscular strength, rapid execution, and precise targeting. The primary muscular contributor to the forward propulsion involved in a straight punch is the pectoralis major, which facilitates arm flexion and projection of force towards the target to generate maximal impact. Concurrently, the latissimus dorsi plays a critical role in swiftly retracting the arm to a defensive position, thus maintaining guard integrity post-strike (de Azevedo, Guerra Jr, Caldas, & Guimarães-Ferreira, 2019). The coordinated action of these muscle groups not only contributes to the force delivered upon impact but also supports postural stability and readiness for subsequent offensive or defensive actions (Štyriak, Hadža, Arriaza, Augustovičová, & Zemková, 2023). Accordingly, the present study seeks to explore the influence of chest and back muscle strength on the efficacy of straight punches among elite amateur boxers. The ultimate aim is to generate detailed insights that can inform the design of targeted training programmes, thereby fostering long-term athlete development and enhancing competitive performance (Ambroży et al., 2020).

2. Research Objectives

1. To examine the influence of chest and back muscle strength on straight punching performance in elite amateur boxers.

2. To study the relationship between chest and back muscle strength and straight punching performance in elite amateur boxers.

3. Methods

3.1 Population and Sample

The participants comprised male and female Thai national amateur boxers who had secured medals in a minimum of two national-level competitions. A total of 20 athletes, all affiliated with the Amateur Boxing Association of Thailand training facility, were included. Each had accumulated over two years of formal training and had earned medals in more than two international tournaments. The selection of participants was conducted through purposive sampling.

3.2 Variables

The independent variables encompassed the strength of the chest and back muscles, while the dependent variables comprised punch force, total punch force, punch frequency, and punch velocity.

3.3 Data Collection

This study employed a single-session experimental design to investigate the strength of the chest and back muscles and their association with straight punching performance among elite amateur boxers. Through purposive sampling, 20 Thai national amateur boxers were selected, all of whom had trained continuously for a minimum of two years and had earned medals in at least two international competitions. All participants were undergoing regular training at the Amateur Boxing Association of Thailand. Data collection was conducted at the Biomechanics Laboratory, Department of Sports Science, Srinakharinwirot University, Ongkharak Campus. Testing was scheduled on Mondays to ensure full recovery following rest on Sundays. Assessments were carried out in two sessions—morning (08:00–12:00) and afternoon (14:00–18:00)—with a minimum of five hours' rest between them. During the morning session, participants' body composition was assessed using a body composition analyser. This was followed by a 13-minute warm-up comprising 10 minutes of dynamic muscle stretching and 3 minutes of light focus mitt punching at 60–70% of the participants' maximum heart rate. Straight punching performance was then evaluated using motion analysis systems and force plates to determine punch velocity and impact force. Two testing formats were employed:

(1) single straight punches delivered with maximum force and speed to assess punch force and velocity, and (2) continuous punching over a three-second interval to assess punch frequency and cumulative punch force. A three-minute rest was provided between each test. The afternoon session focused on evaluating maximal muscle strength via bench press and bench pull exercises. Participants initially warmed up with light weights for 5–10 repetitions, followed by a one-minute rest. Subsequently, they selected a load they could lift no more than 10 times. Lifting continued until momentary muscular failure was achieved, and both the load and repetition count were recorded. The one-repetition maximum (1RM) was estimated using the Beachle, Earle, and Wathen equation.

To allow comparisons across athletes of different body weights, the absolute strength values were normalised to relative strength by dividing by body mass. Participants rested for three minutes between each strength assessment. All procedures were conducted under standardised conditions using competition-grade equipment, including 10-ounce boxing gloves, hand wraps, and focus mitts equipped with calibrated impact force sensors. Equipment was inspected and calibrated prior to each test to ensure precision and reliability of the measurements.

3.4 Data Analysis

The researchers utilised computer software to analyse the test results. Descriptive statistics, including means and standard deviations, were employed to summarise the data. To examine the relationships between chest and back muscle strength and straight punching performance—specifically punch force, cumulative punch force, punch frequency, and punch velocity—Pearson's product-moment correlation coefficient was applied. Statistical significance was established at the p-value threshold of <0.05.

3.5 Ethical Consent

Ethical approval for the study was granted by Nakhon Ratchasima Rajabhat University (approval number HE-014-2567). Participants were fully informed of the research objectives, procedures, and their rights, including the freedom to participate voluntarily or withdraw at any stage without any repercussions to their other entitlements. Measures were implemented to ensure the confidentiality and protection of personal data. To ensure participant safety during the testing process, professional nurses were present onsite to provide medical care and first aid in the event of an emergency.

4. Results

The investigation into the effect of chest and back muscle strength on straight punching performance among elite amateur boxers yielded the following outcomes:

4.1 Chest Muscle Strength and Punching Performance

Chest muscle strength exhibited a positive correlation with jab punch force, with a Pearson correlation coefficient of 0.616 ($p = 0.004$), indicating a statistically significant association. Furthermore, chest muscle strength showed a stronger positive correlation with cumulative jab punch force, with a coefficient of 0.761 ($p < 0.001$), reflecting a highly significant statistical relationship (Table 1). However, no significant correlation was observed between chest muscle strength and jab punch frequency, with a coefficient of -0.106 ($p = 0.655$), nor with jab punch velocity, with a coefficient of -0.191 ($p = 0.419$). Regarding straight punches, the study found no statistically significant relationship between chest muscle strength and straight punching performance in Thai amateur boxers. The correlation coefficient for straight punch force was 0.307 ($p = 0.188$), for cumulative straight punch force it was 0.416 ($p = 0.068$), for straight punch frequency it was -0.133 ($p = 0.577$), and for straight punch velocity it was -0.304 ($p = 0.193$). None of these variables showed significant correlations in this study. As detailed in Table 1, a significant relationship was found between chest muscle strength and both jab punch force and cumulative jab punch force, but no such relationship was observed for the straight punch performance metrics.

Table 1: Correlation Analysis Between Chest Muscle Strength and Punching Performance

PUNCHING PERFORMANCE METRIC	CORRELATION COEFFICIENT (R)	P-VALUE	STATISTICAL SIGNIFICANCE
JAB PUNCH FORCE	0.616	0.004	Significant
CUMULATIVE JAB PUNCH FORCE	0.761	<0.001	Highly Significant
JAB PUNCH FREQUENCY	-0.106	0.655	Not Significant
JAB PUNCH VELOCITY	-0.191	0.419	Not Significant
STRAIGHT PUNCH FORCE	0.307	0.188	Not Significant
CUMULATIVE STRAIGHT PUNCH FORCE	0.416	0.068	Not Significant
STRAIGHT PUNCH FREQUENCY	-0.133	0.577	Not Significant
STRAIGHT PUNCH VELOCITY	-0.304	0.193	Not Significant

4.2 Back Muscle Strength and Punching Performance

Back muscle strength did not demonstrate statistically significant associations with jab punching performance in Thai amateur boxers (Table 2). The correlation coefficient for jab punch force was 0.383 ($p = 0.096$), and for cumulative jab punch force, it was 0.413 ($p = 0.071$). Regarding jab punch frequency, the coefficient was -0.127 ($p = 0.594$), while jab punch velocity had a coefficient of -0.346 ($p = 0.136$). Similarly, back muscle strength exhibited no statistically significant relationship with straight punching performance in the same group of boxers. The correlation coefficient for straight punch force was 0.366 ($p = 0.113$), and for cumulative straight punch force, it was 0.371 ($p = 0.107$). For straight punch frequency, the coefficient was -0.511 ($p = 0.051$), while straight punch velocity had a coefficient of -0.386 ($p = 0.093$). None of these associations were statistically significant in this study. As shown in Table 2, both jab and straight punching performance in Thai amateur boxers did not demonstrate statistically significant correlations with back muscle strength.

Table 2(a): Presents the Correlation Analysis Between Back Muscle Strength and Punching Performance

PUNCHING PERFORMANCE METRIC	CORRELATION COEFFICIENT (R)	P-VALUE	STATISTICAL SIGNIFICANCE
JAB PUNCH FORCE	0.383	0.096	Not Significant
CUMULATIVE JAB PUNCH FORCE	0.413	0.071	Not Significant
JAB PUNCH FREQUENCY	-0.127	0.594	Not Significant
JAB PUNCH VELOCITY	-0.346	0.136	Not Significant

Table 2(b): Presents the Correlation Analysis Between Back Muscle Strength and Punching Performance

PUNCHING PERFORMANCE METRIC	CORRELATION COEFFICIENT (R)	P-VALUE	STATISTICAL SIGNIFICANCE
STRAIGHT PUNCH FORCE	0.366	0.113	Not Significant
CUMULATIVE STRAIGHT PUNCH FORCE	0.371	0.107	Not Significant
STRAIGHT PUNCH FREQUENCY	-0.511	0.051	Not Significant
STRAIGHT PUNCH VELOCITY	-0.386	0.093	Not Significant

4.3 Chest-to-Back Strength Ratio and Punching Performance

The chest-to-back strength ratio demonstrated a positive correlation with jab punch force, with a statistically significant Pearson correlation coefficient of 0.487 (p = 0.029). A highly significant positive correlation was also observed with cumulative jab punch force, with a coefficient of 0.654 (p = 0.002). However, no statistically significant relationship was found between the chest-to-back strength ratio and jab punch frequency, with a coefficient of -0.072 (p = 0.761), nor with jab punch velocity, with a coefficient of -0.009 (p = 0.970) (Table 3).

Furthermore, the chest-to-back strength ratio did not exhibit statistically significant relationships with straight punching performance in Thai amateur boxers in this study. Straight punch force had a correlation coefficient of 0.247 (p = 0.293), straight punch frequency had a coefficient of 0.196 (p = 0.407), and straight punch velocity had a coefficient of -0.128 (p = 0.591). None of these relationships were statistically significant.

Table 3: Analysis of Correlation Coefficient between Chest-to-Back Strength and Punching Performance

PUNCHING PERFORMANCE METRIC	CORRELATION COEFFICIENT (R)	P-VALUE	STATISTICAL SIGNIFICANCE
JAB PUNCH FORCE	0.487	0.029	Significant
CUMULATIVE JAB PUNCH FORCE	0.654	0.002	Highly Significant
JAB PUNCH FREQUENCY	-0.072	0.761	Not Significant
JAB PUNCH VELOCITY	-0.009	0.970	Not Significant
STRAIGHT PUNCH FORCE	0.247	0.293	Not Significant
STRAIGHT PUNCH FREQUENCY	0.196	0.407	Not Significant
STRAIGHT PUNCH VELOCITY	-0.128	0.591	Not Significant

Table 3 highlights the highly significant correlations between the chest-to-back strength ratio and both jab punch force and cumulative jab punch force. However, it shows no statistically significant relationships with jab punch frequency, jab punch velocity, or straight punching performance. Correlation coefficients for punching performance across various metrics are depicted in Figure 1, which illustrates the relationship between chest muscle strength, back muscle strength, and the chest-to-back strength ratio. The x-axis represents each performance metric (e.g., Jab Punch Force, Straight Punch Velocity), while the y-axis displays the corresponding correlation coefficients. The bars represent the correlation between each strength measure and different aspects of punching performance. Positive values indicate a positive relationship, whereas negative values denote an inverse relationship.

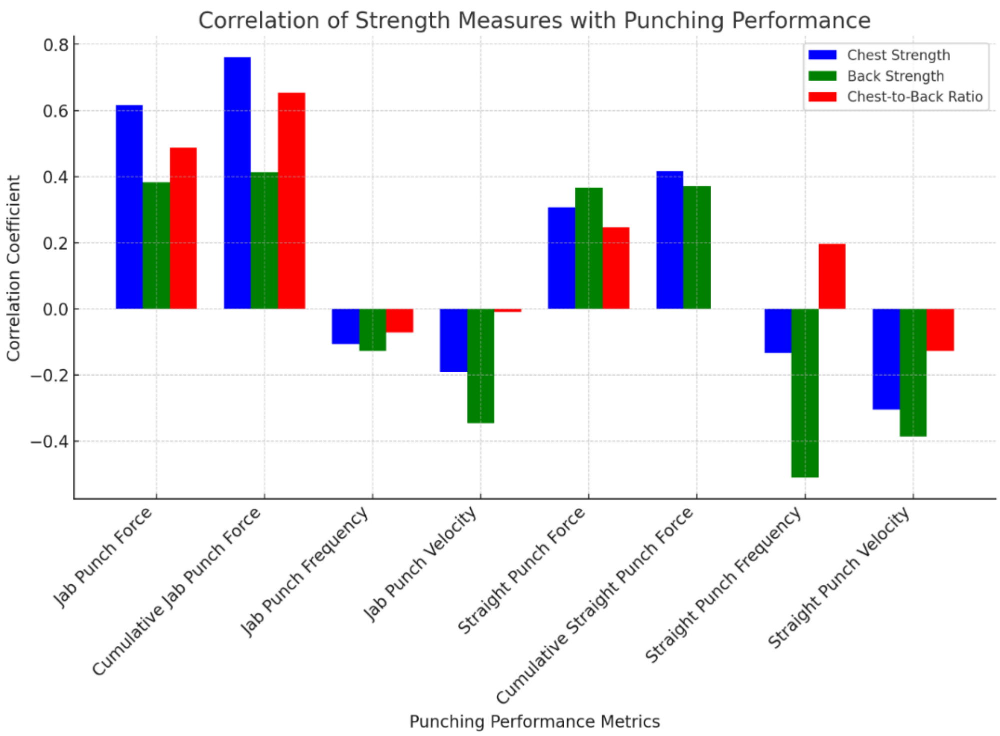

Figure 1: The Correlation of Strength Measures with Punching Performance

The correlations between strength variables (chest muscle strength, back muscle strength, and chest-to-back strength ratio) and punching performance metrics in elite amateur boxers are displayed as a heatmap (Figure 2). A strong positive correlation is observed between chest muscle strength and both jab punch force and cumulative jab punch force, suggesting that increased chest strength enhances the overall force of punches. However, this correlation does not extend to jab punch frequency or velocity and has no significant effect on straight punching performance. No statistically significant relationships were found between jab or straight punches and back muscle strength, indicating that back muscle strength is not a key factor in punching effectiveness. In contrast, a positive correlation is observed between the chest-to-back strength ratio and both jab punch force and cumulative jab punch force, underscoring the importance of balanced strength for optimal punching performance. Despite this, the chest-to-back ratio does not influence punch frequency, velocity, or straight punches. In summary, chest strength and the chest-to-back strength ratio are the primary factors affecting jab punching performance, while straight punches remain unaffected by the measured strength variables.

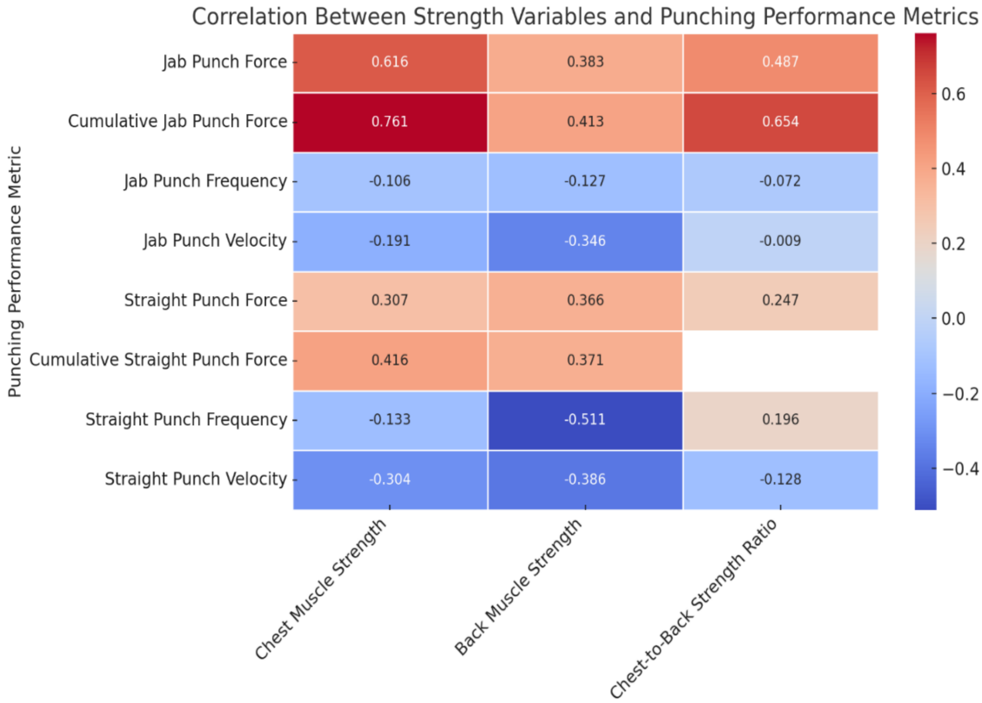

Figure 2: The Correlation Analysis Between Strength Variables and Punching Performance

The correlation between muscle strength variables (back muscle strength, chest-to-back strength ratio) and various punching performance metrics in elite amateur boxers is presented in a scatter plot in Figure 3. A statistically significant positive relationship was found between the chest-to-back strength ratio and jab punch force (r = 0.487, p = 0.029) as well as cumulative jab punch force (r = 0.654, p = 0.002). In contrast, back muscle strength did not show a statistically significant relationship with any of the punching performance variables, as all p-values were greater than 0.05. Moderate correlation coefficients were observed for back muscle strength with jab punch force (r = 0.383, p = 0.096) and cumulative jab punch force (r = 0.413, p = 0.071), but these were not statistically significant. Similarly, no meaningful correlations were found between either of the muscle strength variables and punch frequency or velocity. These results suggest that the chest-to-back strength ratio may be a more influential determinant of jab punching performance than back muscle strength alone, whereas neither variable is correlated with straight punching performance.

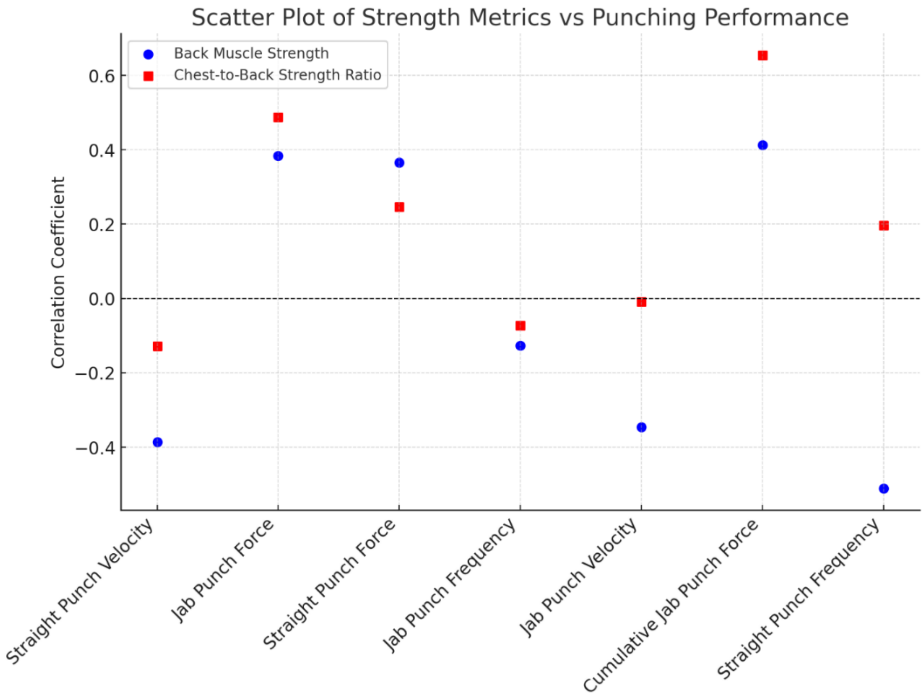

Figure 3: The Correlation Between Strength and Punching Performance

5. Discussion

This study focused on analysing the strength and relationships between chest and back muscle strength and straight punching performance in elite amateur boxers. The findings reveal a significant positive correlation between chest muscle strength and jab punch force, which aligns with the study by Worsey et al.(Worsey, Espinosa, Shepherd, & Thiel, 2020), which identified the chest muscle as the primary muscle responsible for elbow extension in jab punching. The jab punch, characterised by a forward linear movement that does not require extensive trunk rotation, allows chest muscle strength to directly impact punching force (Weir, 2024). The shorter distance involved in a jab punch, compared to straight punches, enhances the efficiency of force transfer from the chest muscles to the target (Vertonghen, Theeboom, Dom, De Bosscher, & Haudenhuyse, 2014). As a result, increased strength in this muscle directly contributes to the force delivered to the target. However, the lack of correlation between chest muscle strength and jab punch speed and frequency may be explained by the fact that these factors rely more on neuromuscular coordination than strength alone. The complex movement involved in the straight punch, which requires trunk rotation and force transmission from the legs and hips to the torso and fist, is more dependent on coordination than on a direct relationship with chest muscle strength (Britton et al., 2025). Moreover, punching efficiency is not solely determined by muscle strength; factors such as muscle contraction timing, the coordination of multiple muscles, and the sequencing of muscle activation play a more significant role than strength alone

(Finlay, Page, Greig, & Bridge, 2022). A relatively weak relationship was observed in the performance of both jab and straight punches in terms of force generated when comparing back muscle strength metrics across both groups. This suggests that the primary function of the back muscles in generating punching force is to maintain postural stability and control, aligning with previous studies that indicate that back muscles act as antagonists during punching to regulate punching speed and accuracy. In this context, the back muscles contribute to eccentric contraction for movement control rather than concentric contraction for force generation. Nonetheless, back muscle strength may be more crucial for injury prevention and posture maintenance than for directly enhancing punching efficiency (Wu et al., 2024). The study also found positive correlations between the chest-to-back strength ratio and jab punch force and cumulative jab punch force, indicating that an appropriate muscle balance aids in movement control, making punches more accurate and efficient. Strong back muscles assist in movement deceleration and punch rhythm control (Wallis et al., 2023). A good balance between chest and back strength supports joint stability, optimising force transmission while preventing injuries and improving continuous training capacity (Yi, Chen, Zhou, Cui, & Wang, 2022). However, the study did not find any significant relationships between the chest-to-back strength ratio and jab punch frequency or velocity. This can be attributed to the fact that these factors are more dependent on neural signal transmission efficiency than on muscle strength. Developing movement speed primarily involves adaptations in the neural system's ability to signal muscles. This is consistent with Matthews and Jordan's (Matthews & Jordan, 2020) study, which concluded that movement frequency depends on motor unit recruitment and the speed of neural signalling. Punching speed and frequency rely more on intermuscular coordination than on the strength of individual muscles, as high-speed movements require efficient coordination of multiple muscles. The study did not identify any statistically significant relationships between the chest-to-back strength ratio and straight punching performance in terms of punch force, cumulative punch force, punch frequency, or punch velocity. The complexity of this finding can be attributed to the involvement of multiple muscle groups along the movement chain in straight punching. The leg muscles generate ground force, while hip and torso rotation provide momentum, and arm extension delivers the force to the target (Dickinson & Rempel, 2016). Additionally, straight punching efficiency is influenced by neural mechanisms, where muscle activation sequencing plays a more significant role in efficiency than strength ratios in antagonistic muscles. The absence of a relationship between the chest-to-back strength ratio and straight punch speed and frequency may therefore be due to the combined effects of movement control and neural system functionality (Giannatos et al., 2022). It is important to note that boxing punching mechanics are complex, and this study focuses specifically on the differences in muscle utilisation and force transfer between jab and straight punches. The findings contribute to the expanding body of research on anaerobic performance and punch efficacy in elite amateur boxing. Previous studies have shown that boxing performance is highly dependent on anaerobic capacity, which directly determines punching power in terms of speed and endurance (Venckunas et al., 2024). This is particularly relevant as boxing involves repeated high-intensity efforts interspersed with brief recovery periods. Our findings corroborate those of Merlo et al (Merlo et al., 2023). who used machine learning techniques to predict performance levels based on boxers' physical characteristics, highlighting the ongoing importance of anaerobic capacity in distinguishing performance levels. In addition to biomechanical factors, punching efficacy is significantly influenced by optimal technique and the effective mass of the punch, as noted by Mosler et al (Mosler, Kacprzak, & Wąsik, 2024). Supporting this, research by Dinu et al.(Dinu, Millot, Slawinski, & Louis, 2020) demonstrated that biomechanical variations across different punch types (e.g., cross, hook, and uppercut) result in differences in force output, aligning with the present study's findings.

Furthermore, these studies provide insights into the impact of fatigue on punch performance, showing reduced striking force and speed during fatigue (Haralabidis et al., 2020). Our research also underscores the critical importance of fatigue management strategies in boxing training to prevent declines in high-intensity performance during a bout. Optimising boxing performance requires targeted strength and conditioning training. The results of Liu et al.(Liu et al., 2024) align with our own, revealing that variable resistance training within complex training regimens enhances punch performance. Post-activation potentiation (PAPE) has also been identified as an effective method for improving explosive power in combat sports athletes (Terbalyan et al., 2025). Therefore, incorporating such strategies into periodised training programs can enhance both punch force and speed simultaneously. Boxing performance is increasingly monitored through advanced technologies, with validated force plates and wearable sensors proving to be reliable tools for quantifying punch force and movement dynamics (Finlay, Page, Greig, & Bridge, 2023; Menzel & Potthast, 2021). Through real-time monitoring, we observed that coaches can utilise training interventions tailored to individual athletes, optimising their force output and refining their techniques. In addition to this, basic technical and tactical training remains essential for success in boxing. Rydzik et al.(Rydzik, Ambroży, Cynarski, Czarny, & Błach, 2024) emphasised the importance of a holistic approach to enhancing performance in combat sports, one that integrates biomechanical, physiological, and psychological factors. Menzel and Potthast (Menzel & Potthast, 2021) further highlighted the critical role of real-time feedback systems in refining technique and strategically executing plans within the ring. Our study corroborates these findings, reinforcing the notion that elite amateur boxers must engage in anaerobic training, optimise their biomechanics, and monitor their performance in real-time. The study underscores the interconnection between anaerobic capacity, biomechanics, strength training, fatigue management, and advancements in boxing performance monitoring. As such, future research should explore personalised training interventions that optimise these variables for peak performance. The study also highlights the importance of maintaining balanced muscle strength, ensuring that chest muscles are developed without neglecting other muscle groups, to prevent injury. These findings have significant implications for the design of training programmes for amateur boxers, suggesting that an effective training regimen should combine muscle strength development with specific skill training to enhance punching efficiency. Nonetheless, further research is needed to investigate additional biomechanical and neuromuscular factors influencing punching ability, such as punching technique.

Nevertheless, the findings of this study provide valuable insights into the relationship between chest and back muscle strength and punching performance among elite amateur boxers. Firstly, the sample size of twenty Thai national amateur boxers is relatively small, which may limit the generalisability of the results to the broader population of amateur boxers globally. This restriction reduces the robustness of the conclusions drawn from the study. Furthermore, the study's cross-sectional design precludes the establishment of causality between the variables. While some strong correlations were observed, it cannot be conclusively stated that increased muscle strength directly results in enhanced punching performance. Additionally, individual variations in technique or execution may contribute to the variability observed in the punching force measurements obtained using force plates and motion capture systems. The study also did not control for factors such as fatigue, mental state, or competition experience, which could influence the outcomes. Consequently, further research with a larger and more diverse sample, along with longitudinal designs, is necessary to validate the findings. Several potential biases could have influenced the results. A selection bias may have occurred as the research participants, with their distinct training strategies and physical characteristics focused on upper body strength, might not be fully representative of amateur boxers in general. This imbalance could skew the study's findings, particularly regarding the relationship between chest and back muscle strength and punching performance. Furthermore, the measurement tools and assessment methods used, including force plates and motion capture systems, could introduce bias, as they may not account for all relevant athlete characteristics such as mental stress or specific training patterns, which can vary among athletes. Additionally, response bias may have influenced the accuracy of the data, as participants may not have accurately reported their training intensity or techniques through self-reported measures. Future research exploring the relationship between muscle strength and performance in boxing should address these potential biases to provide a more comprehensive evaluation.

The implications of these findings are significant for boxing coaches, trainers, and athletes. Understanding how chest muscle strength influences punching performance, particularly the jab, can guide the development of training programmes that target specific muscle groups contributing to performance. Coaches could integrate focused strength training for the chest muscles into athletes' regimens to ensure a balanced development of antagonist muscle groups—chest and back. The observed positive correlation between jab punch force and chest strength suggests that boxing training should not only aim to increase raw muscle strength but also focus on improving muscular endurance and functional strength specific to the demands of boxing. Additionally, athletes may benefit from motion capture analyses to provide biomechanical feedback, helping them refine their technique and enhance punch efficiency while minimising the risk of injury. From a research perspective, the findings highlight the importance of tailoring training programmes to the individual strengths and weaknesses of boxers to optimise competitive performance.

6. Recommendations and Scope for Future Research

Future research should explore several neglected areas that could build upon the findings of this study. A longitudinal approach could be employed to investigate whether changes in chest and back muscle strength over time correlate with improvements in punching performance among elite amateur boxers. This approach would provide insight into the practical implications of strength adaptations and their impact on performance, helping to identify the sequence of events when strength improvements surpass performance gains. Additionally, future studies should aim to include a broader demographic encompassing a wider range of body weights, ages, and boxing experience to determine whether the observed relationships hold across different groups. Controlling for confounding factors such as training frequency, nutrition, and psychological readiness in more extensive investigations could offer a clearer understanding of how these variables influence performance, especially when neuromuscular synchronisation and lower limb engagement do not affect the mechanics of straight punches. In such cases, a deeper understanding of boxing performance could be achieved by examining the roles of these factors. Furthermore, exploring the coordination between different muscle groups and their synergistic action during punches could lead to the development of more effective training strategies that enhance strength, speed, accuracy, and overall efficiency. Multi-dimensional research in this area would significantly contribute to advancing the analysis of boxing performance outcomes.

7. Conclusion

This study investigated the influence of chest and back muscle strength on straight punching performance in elite amateur boxers. The findings revealed that jab punch force and cumulative jab force were significantly correlated with chest muscle strength, while jab punch frequency and velocity showed no significant relationship. Interestingly, no significant correlations were observed between back muscle strength and any performance metrics for jab or straight punches. Although there were positive correlations between chest strength and jab punch force, as well as cumulative jab force, no significant correlations were found with jab frequency, velocity, or other straight punch-related variables. Furthermore, the chest-to-back strength ratio exhibited strong positive correlations. These results suggest that punches, particularly the jab, involve distinct mechanical bases and muscle recruitment patterns. Specifically, chest strength emerged as a key contributor to jab punch performance. However, straight punching appears to be more dependent on the coordinated action of the entire body, involving trunk rotation and the transfer of kinetic forces throughout the body. This finding explains the absence of strong correlations between isolated upper body strength measures and straight punch performance metrics. The robust relationship between the chest-to-back strength ratio and jab force aligns with the notion that muscular balance between agonist and antagonist muscle groups is essential for optimal punching performance and reduced injury risk. These insights carry significant implications for boxing training program design. Given the frequent use of the jab technique, coaches should focus on developing chest strength while ensuring balance between antagonist muscles. Consequently, training should prioritise coordinated movement patterns, neuromuscular timing, and the development of the whole-body kinetic chain, rather than solely emphasising isolated muscle strength for optimising straight punch performance. Future research should explore the role of lower limb strength in straight punching mechanics, analyse three-dimensional movement patterns during different punch types, and examine how neuromuscular coordination and timing influence punching performance. Additionally, longitudinal studies assessing the effects of specific training interventions on various punch types could further enhance our understanding of boxing performance optimisation.

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