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Article

# Modeling the impact of martial arts training on muscle strength and joint stability

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**Abstract:** Martial arts include various fighting techniques, ideologies, and training programs from different civilizations worldwide. Combining mental and physical training, martial arts can be utilized for sport or self-defense. The research aims to investigate how martial arts training affects joint stability and muscular strength. A total of 146 respondents participated in this study. They are arbitrarily separated into two groups. Group A ($n$ = 76) received martial arts (karate) training, and Group B ($n$ = 70) received standard sports training. All participants underwent pretesting and post-testing focused on physical attributes, upper extremity flexibility, muscle strength, motivational level, balance, and joint stability. The data is analyzed using statistical methods such as correlation analysis, $t$-tests, and one-way ANOVA to compare pre-and post-training results. The post-training evaluations revealed that the karate group demonstrated significant improvements in joint flexibility and balance. These enhancements in flexibility, motivational level, balance, and strength are critical as they contribute to muscle strength and joint stability, essential for preventing sports-related injuries during growth. This study underscores the importance of martial arts training in developing physical fitness attributes that promote overall musculoskeletal health in children.

**Keywords:** martial arts; muscle strength; joint stability; karate training

## 1. Introduction

Martial arts training offers significant physical, mental, and social benefits. It enhances fitness, self-defense ability, regulation, and psychological factors while also promoting emotional control and respect for others. The holistic advance to individual growth develops overall well-being and encourages overall development [1]. The different manners that martial arts training affects people, with an emphasis affects social conduct, mental toughness, and physical health in addition to enhancing an individual's emotions of identity and community [2]. Martial arts are heuristic sports that require rapid reactions and competitive dynamics that are unpredictable. When faced with unpredictability, martial artists need to be inflexible and creative to emerge with the most effective strategies. The development of one's personality is essential to martial artists' effectiveness [3]. Martial arts training techniques like striking, grappling, and karate, requires significant muscle engagement and encourages functional movement patterns. The training enhances muscular strength through resistance and dynamic movements while focusing on balance, coordination, and flexibility, improves joint stability and reduces injury risk during training and daily activities [4]. A common approach for promoting health, martial arts is particularly advantageous for middle-aged and older persons. **Figure 1**

represents the overall functions of muscle strength and joint stability, through martial arts. Considering its gradual movement and moderate quantity, it is appropriate for these muscles given that it improves muscular coordination, balance, and flexibility. Knee joints can remain compressed by specific motions [5].

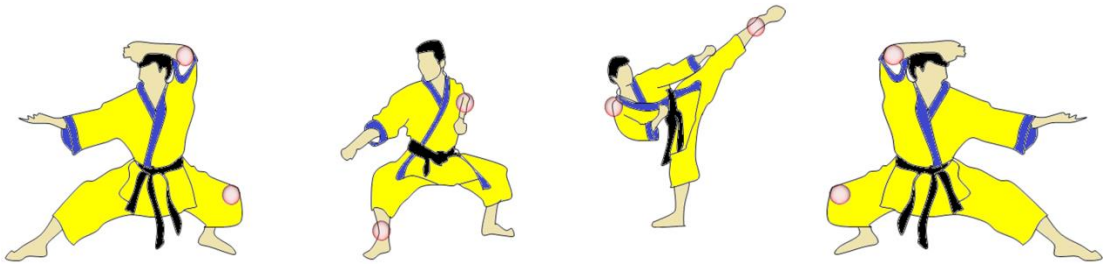

**Figure 1.** Functions of muscle strength and joint stability.

Sports-related knee joint health problems are common and restrict QoL and flexibility. Identify AKD and ACL harm during movements. ACL injuries are frequently observed to occur when athletes engage in activities like extending their knee muscles over the toes during boarding [6]. There are three forms of AKD: knee NETT, aligning LTT, and ETT of the foot. AKD represents the forward motion of the knee during movement [7]. To decrease knee joint pressure and injury concerns, martial arts instructors encourage practitioners to limit forward knee mobility. It is essential to investigate the knee joint's biomechanical behavior to prevent injuries. Muscle imbalances are possible from high-peak knee extension moments in martial arts [8].

Objective of the study: This study aims to investigate the relationship between martial arts training, muscle strength, and joint stability, providing insights into how these factors interact to enhance physical performance and overall well-being.

The remainder of the study is given as follows: Related works are examined in Section 2, Section 3 explains the Materials and Methods of the research. Section 4 illustrates the results and the final conclusion of the study is determined in Section 5.

## 2. Related works

An integrative approach for enhancing pre-computation conditioning for athletes utilizing wrestling or attacking methods in MMA is the goal of the research [9]. The investigation examined the pre-competition process and the outcomes of the 2022 European MMA Championship, involved the Ukrainian national MMA junior squad. In martial arts, the experimental approach increased maximum power by 8.8%, whereas in striking competitors, it increased by 20.6%. 84.4% of bouts prevailed during the World Championship, and 19.0% more bouts ended early due to chokeholds, brutal knockouts, or other methods. According to a study [10] that investigated the effect of PNF stretch on the muscular potency and flexibility of martial arts athletes, the technique successfully maximizes these metrics. The findings demonstrated improvements in muscular strength, joint mobility, and extensor peak moment, as well as expressive changes. Sports settings can benefit from modifications to the PNF stretching workout technique.

Strength training for sports motions studied in [11] is the primary concern of research on martial arts instruction. Strength training for the lower limbs enhanced left and right unipodal balance skills in research involving 20 college martial arts trainees. The experimental group's left unimodal stability increased by 22.213%, while their right unimodal equilibrium increased by 23.249%. To improve athletes' physiological effectiveness, the research suggested incorporating focused training techniques into martial arts training. Chinese martial arts effects on preschoolers' motor skills between the ages of five and six were investigated in [12]. Each group comprised ($n$ = 29) the MAST, MATT, and FA groups were the three groups into which the 87 children were split. The MAST approach considerably raised balance index scores, according to the data, indicating that Chinese martial arts can enhance flexibility and general motor abilities. The effect of cryo-compression treatments on male competitive mixed martial arts fighters' forearm muscles was investigated in the study [13]. Twenty fighters received treatment between three and six min, with an emphasis on metrics such as maximal contractile effect, rigidity, elasticity, muscle tone, circulation, and pressure pain threshold. Cryo-compression technique has a substantial impact on muscle biomechanics characteristics, pain threshold, strength, and perfusion of tissues, according to the results, which demonstrated significant variations between the two treatments. Six Taekwondo practitioners were studied in [14] after completing a 4-week circuit strengthening program with circulatory constriction. The results demonstrated strengthened knee muscles, better-kicking capabilities, and increased jumping ability. A beneficial relationship between jump time and medial thigh muscle movement, and a correlation between kick numbers and lateral thigh muscle displacement. Muscle fiber transportation, strength, explosiveness, and relaxation durations were all enhanced by the regimen. During a single teaching assembly on the flexibility trainer, the research [15] assessed both general and sport-specific adaptations. By offering nearly isokinetic friction throughout a complete range of motion strength training, the gadget causes a reduction in hip-joint muscle tone. The kinematics of double sidekicks and static hip flexion and abduction were examined in fifteen participants both before and after training. Static flexibility tests and VSA at particular movement phases revealed substantial variations. Training with the flexibility trainer produced short-term modifications that outperformed similar studies that demonstrated enhanced flexibility and sport-specific performance. A framework for tracking and forecasting knee joint injuries during wushu fighting sessions is described [16]. It collected data on knee joint determination parameters, built a sports mechanics model, and integrated the causes and components of injuries. WNN were employed by the approach to demonstrate its efficacy. The kneecap damage and abnormalities thresholds in the framework should be adjusted to 0.379 and 0.563, respectively. The technique and safeguards can enhance martial arts sparring training and lower sports injuries. Core stability is essential for enhancing motor performance in wing kicks, according to a study [17] that included 26 male Taekwondo participants. The fundamental stability test, 13 infrared cameras, and epidermal electromyography data revealed a significant negative association between core stability levels and the time took to execute the aerial part of the wing kick. However, it remains unclear how core stability and athletic performance are related. The superior central-muscle

connection was linked to higher levels of core stability. According to the study, wing kick effectiveness is potentially improved by adding stabilization exercises to martial arts exercises. With emphasis on go-ahead, foul play, and assertiveness variables, [18] investigated the aggression and resiliency of martial artists. It employed Makarowski's sports aggression questionnaire and the brief resilience scale with 154 athletes from various sports. The findings indicated that athletes with moderate to severe injuries had higher levels of malicious behavior and perseverance. The kinematics of kick combination actions in point fighting martial arts athletes were examined in the study [19], which classified various kicking structures corresponding to equilibrium and subsequent action features and identified functional motion sequences. The double sidekick performance of 28 participants was recorded using the Vicon® motion analysis technology. An established functional phase model was expanded to provide an extensive biomechanical model. The statistical analysis showed that improved methods have a distinct proximal-to-distal pattern for every kick motion and less directly supported dynamic balance circumstances. The processes underlying skilled martial arts practitioners' superior power in combat performance were developed in [20]. Skin-surface EMG has been employed to assess the muscle groups of nine trained practitioners and nine untrained controls. According to the results, the instructed group produced greater forces, lower pressures, and higher pressures in both tasks. Additionally, they caused the pulmonary, abdominal, and pelvic floor muscles to experience elevated pressures and neuromuscular activation.

## 3. Materials and methods

The study investigates the impact of martial arts training on joint stability and muscular strength of participants from two groups. Pre- and post-tests are conducted to assess physical attributes and the involvement of statistical methods.

### 3.1. Data collection

The purpose the research to determine the technique by which martial arts training impacts muscular strength and joint stability. Demographic details of the research participants, encompass ($n$ = 146) individuals separated into two different groups: Group A ($n$ = 76) participants receiving martial arts training and Group B ($n$ = 70) participants experiencing ordinary sports training are presented in **Table 1**.

Age distribution shows that most participants fall between 18–35. Gender distribution for both groups, with males making up around 68.5% of the total, and females 31.5%. The average height and weight are also close, with Group A and Group B. The Body Mass Index (BMI) across groups is consistent, averaging around 23. In terms of experience, over half of the participants in both groups are Advanced (4+ year), while the rest are mostly at intermediate levels, with a small portion having advanced experience. The intensity of the training in this study varied depending on the specific goals and needs of the athletes. The training regimen was divided into different difficulty levels, with each phase incorporating progressively challenging exercises. Weights used in strength training exercises ranged from moderate to high intensity, depending on the athlete's capability, with repetitions

typically ranging from 8 to 12 per set. Each exercise was performed for 3 to 5 sets, ensuring a balance between endurance and strength development. The program intends to increase physical endurance and strength while ensuring the athletes' safety and minimizing the risk of injury.

**Table 1.** Characteristics of demographic variables.

| **Characteristics** | **Group A (*n* = 76)** | **Group B (*n* = 70)** | **Total (*n* = 146)** |
|---|---|---|---|
| Age (years) | | | |
| 18–20 | 20 | 18 | 38 |
| 21–23 | 22 | 19 | 41 |
| 24–26 | 15 | 17 | 32 |
| 27–30 | 13 | 11 | 24 |
| Above 35 | 6 | 5 | 11 |
| Gender | | | |
| Male | 52 (68.4%) | 48 (68.6%) | 100 (68.5%) |
| Female | 24 (31.6%) | 22 (31.4%) | 46 (31.5%) |
| Height (cm) | | | |
| Mean (SD) | 175.2 (8.4) | 172.6 (7.9) | 173.9 (8.2) |
| Range | 160–190 | 160–185 | 160–190 |
| Weight (kg) | | | |
| Mean (SD) | 70.3 (10.5) | 68.8 (9.8) | 69.6 (10.2) |
| Range | 55–90 | 55–88 | 55–90 |
| BMI ($kg/m^2$) | | | |
| Mean (SD) | 22.9 (3.1) | 23.1 (3.0) | 23.0 (3.0) |
| Experience Level | | | |
| learner (0–1 year) | 10 (13.2%) | 8 (11.4%) | 18 (12.3%) |
| Intermediate (2–3 years) | 26 (34.2%) | 24 (34.3%) | 50 (34.2%) |
| Advanced (4+ years) | 40 (52.6%) | 38 (54.3%) | 78 (53.4%) |

## 3.2. Data splitting

The research aims to investigate the properties of martial arts training on joint stability and muscular strength. A total of $n = 146$ respondents participated and were divided into two groups, wherein Group A received martial arts (karate) training, comprising 76 participants, and Group B received standard sports training, comprising 70 participants. The study implemented a structured 12-week training program for both groups, with sessions conducted three times per week; length of each session is 60 min. On training days, participants completed a single session per day, focusing on their respective routines. Throughout the study, both Group A (martial arts training) and Group B (standard sports training) completed a total of 36 sessions. Each team has been tested pre- and post-testing with respect to the same physical attributes that were identified namely, upper limb flexibility, motivation levels, muscular strength, balance, and joint stability. This random division of the group guarantees non-biased comparison between martial arts and standard sports training impact.

- Group A: It consisted of 76 participants who received martial arts (karate) training throughout the study. The focus of their training is developing not only overall fitness but also specific physical attributes such as flexibility, motivational level, muscular strength, balance, and joint stability. Karate being a martial art engages groups of muscles and focuses body control, which makes this activity ideal for the evaluation of changes in joint stability and muscular strength. The pretests and posttests were used for the measurement of these body attributes before and after this martial arts training program.
- Group B: It includes 70 participants who received standard sports training. The activities in this group were not specialized in martial arts but focused on general fitness routines that are commonly employed in athletic training programs. These activities are aimed at enhancing overall physical fitness without the specific focus on joint stability and muscle strength that karate emphasizes.

Similar participants were involved in Group A and Group B. They underwent pre- and post-testing for measuring physical attributes, flexibility, strength, and joint stability. This makes possible a comparative analysis of how standard sports training impacts these metrics in comparison to martial arts.

### 3.3. Statistical analysis

This study examines the effects of martial arts training on joint stability and muscular strength using several statistical tools, including correlation, *T*-test, and One-way ANOVA. The correlation analysis is primarily applied to investigate the relationship between the physical attributes in the pre- and post-test assessments. Paired *t*-tests were applied to compare results between the martial arts and standard sports groups before and after training. One-way ANOVA is used to compare two groups. Statistical analysis is done using SPSS 24.0 software, and calculated *p*-values are used in determining the significance of the statistical analyses, where a *p*-value below 0.05 indicates measured statistically.

## 4. Results

The research found that karate training significantly improved joint flexibility and balance in participants, which are crucial for muscle strength and joint stability. These improvements are essential for preventing sports-related injuries, especially during growth periods. Research indicates martial arts can enhance children's physical fitness, promote musculoskeletal health, and reduce injury risks by incorporating into training programs. The study used correlation analysis to examine the relationship between physical attributes during pre- and post-test training assessments, comparing martial arts and standard sports groups before and after training. One-way ANOVA was used to analyze differences between the two groups, with a *p*-value indicating statistical significance.

### 4.1. Performance of *t*-test

The *t*-test is a statistical technique for comparing the outcomes of two groups and determine whether it's a substantial distinction. It is functional in analyzing

martial arts training's impact on muscle strength and joint stability because it calculates the probability of observed differences occurring by chance.

### 4.1.1. Assessment of group A

**Figure 2** presents the pre- and post-training evaluation results for Group A across five physical attributes: upper extremity flexibility, muscle strength, joint stability, balance, and motivational level. Each attribute shows significant improvements post-training, with mean values and standard deviations (SD) reported for both pre-and post-testing.

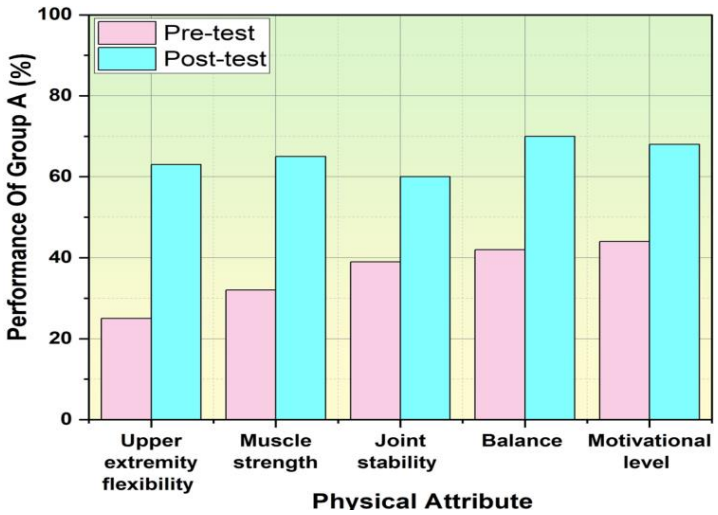


**Figure 2.** Performance of group A.

**Table 2** presents the pre- and post-training evaluation results for Group A, with each showing statistically significant p-values less than 0.0001. Upper extremity flexibility increased from (24.0 ± 3.5 to 26.5 ± 2.8), resulting in a *t*-value of 7.23 and indicating a highly significant change. Similarly, muscle strength improved from (30.0 ± 4.0 to 34.5 ± 4.5), joint stability from (17.5 ± 2.2 to 19.5 ± 1.8), balance from (15.0 ± 2.5 to 18.0 ± 2.0), and motivational level from (20.0 ± 3.0 to 24.0 ± 2.5), with each showing statistically significant *t*-values.

**Table 2.** Numerical findings of group A.

| Group | Physical attribute | $Pre\ (Mean \pm SD)$ | $Post\ (Mean \pm SD)$ | $t-value$ | $p-value$ |
|---|---|---|---|---|---|
| Group A | Upper extremity flexibility | 24.0 ± 3.5 | 26.5 ± 2.8 | 7.23 | <0.0001 |
| | Muscle strength | 30.0 ± 4.0 | 34.5 ± 4.5 | 7.68 | <0.0001 |
| | Joint stability | 17.5 ± 2.2 | 19.5 ± 1.8 | 7.14 | <0.0001 |
| | Balance | 15.0 ± 2.5 | 18.0 ± 2.0 | 6.40 | <0.0001 |
| | Motivational level | 20.0 ± 3.0 | 24.0 ± 2.5 | 7.15 | <0.0001 |

These results indicate that the martial arts training program had a substantial positive effect on all measured physical attributes in Group A participants.

### 4.1.2. Assessment of group B

**Table 3** displays the pre- and post-training evaluation results for Group B across five physical attributes. Upper extremity flexibility showed a slight increase

from (24.5 ± 3.2) to (25.0 ± 3.1), yielding a *p*-value of 0.524 and a *t*-value of 0.64, signifying that there is no important difference.

**Table 3. Numerical findings of group B.**

| Group | Physical Attribute | $Pre\ (Mean \pm SD)$ | $Post\ (Mean \pm SD)$ | $t-value$ | $p-value$ |
|---|---|---|---|---|---|
| Group B | Upper Extremity Flexibility | 24.5 ± 3.2 | 25.0 ± 3.1 | 0.64 | 0.524 |
| | Muscle Strength | 30.5 ± 3.9 | 32.0 ± 4.0 | 1.19 | 0.239 |
| | Joint Stability | 18.0 ± 2.1 | 18.5 ± 2.0 | 1.18 | 0.244 |
| | Balance | 15.5 ± 2.3 | 16.0 ± 2.1 | 1.12 | 0.267 |
| | Motivational Level | 19.5 ± 2.8 | 20.5 ± 2.6 | 1.06 | 0.301 |

Muscle strength increased from (30.5 ± 3.9) to (32.0 ± 4.0) with a $p-value$ of 0.239, and$t-value$ of 1.19, and joint stability from (18.0 ±2.1) to (18.5 ±2.0) with a $t-value$ of 1.18 and a $p-value$ of 0.244, balance from (15.5 ± 2.3)to (16.0 ± 2.1) with a $t-value$ of 1.12 and a $p-value$ of 0.267, and motivational level from (19.5 ± 2.8) to (20.5 ± 2.6) with a $p-value$ of 0.301 and$t-value$ of 1.06. **Figure 3** presents the pre- and post-training evaluation results for Group Bacross five physical attributes.

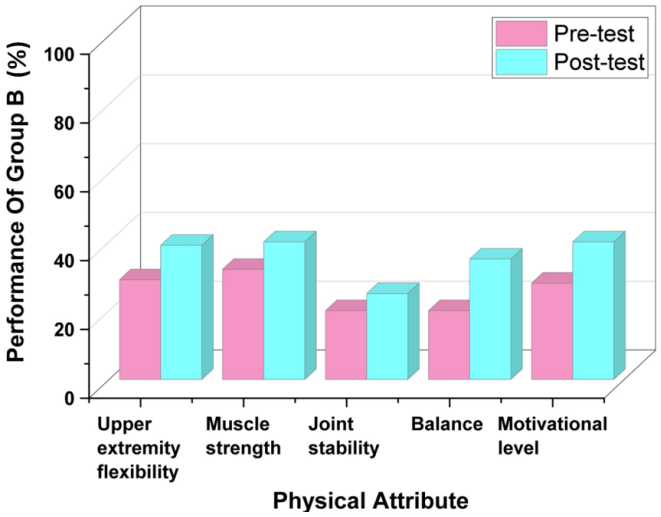


**Figure 3.** Performance of group B.

These results indicate that the standard sports training did not yield statistically significant improvements in any of the assessed physical attributes among participants in Group B.

The study found that martial arts training significantly improved physical attributes in Group A participants, while standard sports training did not yield significant improvements in any assessed physical attributes among Group B participants.

## 4.2. Evaluation of one-way ANOVA findings

One-way ANOVA is a statistical technique comparing means of five or more independent groups to determine significant differences, producing an $F-value$and

$p-value$. **Table 4** represents One-Way ANOVA results comparing pre- and post-training means for both groups A and B.

**Table 4.** Findings of one-way ANOVA.

| Physical Attribute | Group | $Pre$ ($Mean \pm SD$) | $Post$ ($Mean \pm SD$) | $F-value$ | $p-value$ |
|---|---|---|---|---|---|
| Upper extremity flexibility | Group A | 24.0 ± 3.5 | 26.5 ± 2.8 | 10.56 | 0.0011 |
| | Group B | 24.5 ± 3.2 | 25.0 ± 3.1 | | |
| Muscle strength | Group A | 30.0 ± 4.0 | 34.5 ± 4.5 | 15.34 | <0.0001 |
| | Group B | 30.5 ± 3.9 | 32.0 ± 4.0 | | |
| Joint stability | Group A | 17.5 ± 2.2 | 19.5 ± 1.8 | 8.92 | 0.0032 |
| | Group B | 18.0 ± 2.1 | 18.5 ± 2.0 | | |
| Balance | Group A | 20.0 ± 2.0 | 23.0 ± 1.5 | 9.10 | 0.0020 |
| | Group B | 19.5 ± 1.8 | 20.5 ± 1.9 | | |
| Motivational level | Group A | 75.0 ± 8.0 | 85.0 ± 7.5 | 12.50 | <0.0001 |
| | Group B | 73.0 ± 9.0 | 75.0 ± 8.0 | | |

Group A showed significant improvements across all attributes, with *F*-values ranging from 8.92 to 15.34 and corresponding $p-values < 0.05$, Upper Extremity Flexibility improved from a mean of (24.0 ± 3.5) to (26.5 ± 2.8), resulting in an *F*-value of 10.56 ($p$ = 0.0011). Compared to Group B exhibited minimal changes, as indicated by the absence of significant $F-values$ or $p-values$, highlighting the effectiveness of the martial arts training in Group A compared to the standard training provided to Group B. Overall, the results underscore the positive influence of martial arts training is on physical fitness attributes then motivational levels, emphasizing its value in enhancing these aspects in participants.

## 4.3. Performance of correlation analysis

Correlation analysis quantifies the relationship between physical attributes and training outcomes, identifying strong associations between these attributes and improved outcomes post-training. **Figure 4** presents the correlation analysis of the physical attributes, whose coefficients indicate the strength and direction of the relationships between these attributes.

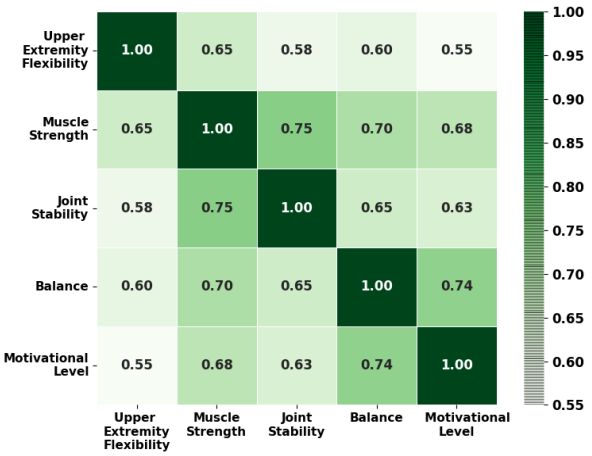


**Figure 4.** Correlation matrix.

The study identifies physical attributes that significantly predict overall performance, such as upper extremity flexibility and muscle strength gains, suggesting that enhancing flexibility can enhance muscle strength.

## 5. Discussion

The study finds that positive martial arts influence the training, particularly karate, in muscle strength then joint stability. In comparison, the participants in Group A had a significant enhancement in flexibility of the joint, balance, and muscular strength that are important elements in injury prevention and musculoskeletal health. Such observations give support to the notion that martial arts can be an appropriate training activity for improving the condition of musculoskeletal health, thus reducing the risk of sport-specific injuries due to its involvement of functional movement patterns and dynamic resistance. BMI, though comparable between groups, did not address the variation of body fat distribution and muscle mass. Additional body composition data, such as body fat percentage and lean muscle mass, would provide a more accurate understanding of the training effects on physical health and joint stability. Group A's improvements in muscle strength and joint stability are likely due to the dynamic and resistance-based nature of martial arts, which engage muscles and improve joint function through repetitive, functional movements. In contrast, Group B's lack of improvement could be attributed to factors such as insufficient training intensity, a lack of consistency, or a less structured approach to joint-specific exercises. Additionally, variations in recovery strategies, adherence to training schedules, and psychological motivation may have influenced Group B's outcomes.

## 6. Conclusion

Martial arts training enhances physical fitness, promotes musculoskeletal health, and reduces injury risks, particularly for young athletes, by improving flexibility, strength, and joint stability. The study found that martial arts training, specifically karate, significantly improves balance, motivational levels, muscle strength, and joint stability. Group A, which underwent karate training, demonstrated superior improvements in upper extremity flexibility, balance, muscle strength, motivational levels, and joint stability compared to Group B, which participated in standard sports training. The statistical analysis confirms these differences, with *t*-values and p-values indicating that the improvements in Group A were statistically significant. Moreover, the correlation analysis revealed moderate to strong positive relationships between upper extremity flexibility, muscle strength, balance, motivational levels, and joint stability. This suggests that as flexibility improves, there are corresponding increases in both muscle strength and joint stability, which are crucial for injury prevention and physical performance, particularly during growth periods in children.

### Limitations and future scope

This study is limited by its small sample size and lack of demographic diversity, which restrict the generalizability of the findings. Additionally, the short duration of the study does not allow for assessing long-term outcomes like sustained

improvements in muscle strength and joint stability. Future research should involve larger, more diverse populations, longer follow-up periods, and explore the influence of variables such as gender and baseline fitness levels to optimize training protocols.

**Author contributions:** Conceptualization, QL and XW (Xiaonan Wang); methodology, XW (Xin Wang); software, XW (Xin Wang); data curation, XW (Xiaonan Wang); writing—original draft preparation, QL; writing—review and editing, QL and XW (Xiaonan Wang); supervision, XW (Xin Wang). 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.

## Abbreviations

| | |
|---|---|
| AKD | Anterior knee displacement |
| ACL | Anterior cruciate ligament |
| ETT | Exceeding the tip |
| NETT | Not exceeding the tip |
| LTT | Less than the tip |
| MMA | Mixed martial arts |
| PNF | Proprioceptive neuromuscular facilitation |
| QoL | Quality of life |
| MATT | Martial arts traditional teaching |
| FA | Free activity group |
| MAST | Martial arts sensory education group |
| VSA | Vertical Stiffness Assessment |
| WNN | Wavelet neural network |
| EMG | Electromyography |

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