

Article

Upper-Limb Dynamic Stability and Functional Symmetry in Experienced Taekwon-Do Athletes

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Abstract

Combat sports are characterized by sport-specific asymmetrical movement patterns that may influence neuromuscular control, functional stability, and injury risk. Although lower-limb asymmetry has been widely investigated in taekwon-do experienced ITF taekwon-do practitioners, upper-limb functional symmetry remains insufficiently explored. Sixteen experienced male ITF taekwon-do practitioners underwent assessment of hand grip strength and upper-limb dynamic stability using the Upper Quarter Y-Balance Test (UQYBT). Reach distances in anterior (AP), posteromedial (PM), and posterolateral (PL) directions were analyzed together with composite symmetry indices. Inter-limb differences were evaluated using paired Student's *t*-tests, and associations between strength and dynamic stability variables were examined using Pearson's correlations. Significant inter-limb asymmetry was observed only in the posteromedial (PM) UQYBT direction, with higher values for the left upper limb ($p < 0.001$; $d_z = 1.34$). No significant inter-limb differences were observed for hand grip strength, anterior reach distance, posterolateral reach distance, or composite index values. Correlation analyses demonstrated weak-to-moderate and statistically non-significant relationships between hand grip strength and dynamic stability variables. Experienced taekwon-do athletes demonstrate movement-specific upper-limb asymmetry while maintaining relatively symmetrical overall dynamic stability and grip strength. The findings further suggest that upper-limb dynamic stability may depend more strongly on neuromuscular coordination and sport-specific motor control than on maximal grip strength alone. These findings suggest that asymmetry in taekwon-do may reflect a potential sport-specific adaptation rather than generalized neuromuscular dysfunction.

Keywords: taekwon-do; inter-limb asymmetry; dynamic stability; Upper Quarter Y-Balance Test; hand grip strength; neuromuscular control; combat sports; functional symmetry; upper extremity; sports biomechanics



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1. Introduction

Symmetry and asymmetry are fundamental characteristics of human movement and play an important role in sports performance, neuromuscular control, and injury prevention [1,2]. Although bilateral symmetry is generally considered advantageous for efficient movement execution, many sports induce functional asymmetries as an outcome of repetitive unilateral actions and sport-specific training adaptations. In athletic populations, inter-limb asymmetry may therefore reflect both beneficial functional specialization and

potential neuromuscular imbalance associated with impaired movement efficiency or increased injury susceptibility.

Combat sports are particularly characterized by asymmetrical movement patterns because athletes repeatedly adopt preferred stances, execute unilateral offensive techniques, and rely on dominant-side stabilization strategies [3–5]. Similar sport-specific asymmetrical adaptations have been reported across various combat sports, including taekwon-do [6,7], karate [8], judo [9], and Brazilian jiu-jitsu [10]. Repetitive unilateral technical actions, preferred fighting stances, and side-dominant movement strategies may contribute to long-term neuromuscular adaptations and inter-limb performance differences [11].

Among martial arts, taekwondo is considered a highly lateralized discipline that requires repetitive kicking movements, sudden changes in direction, postural control, and dynamic stability [6,12]. While lower-limb asymmetry in taekwon-do athletes has been widely investigated, substantially less attention has been devoted to upper-limb function, dynamic shoulder stability, and inter-limb asymmetry of the upper extremities [13]. Nevertheless, upper-limb stabilization plays an important role in maintaining the guard position, supporting balance recovery, absorbing impacts, and transmitting force effectively during offensive and defensive techniques, yet upper-limb asymmetry in taekwon-do remains poorly investigated compared with lower-limb function.

Dynamic upper-limb stability can be assessed using the Upper Quarter Y-Balance Test (UQYBT), a closed kinetic-chain test designed to evaluate shoulder mobility, neuromuscular control, trunk stability, and upper-extremity functional performance through multidirectional reaching tasks [14]. The UQYBT requires the athlete to maintain unilateral upper-limb support while reaching in the anterior, posteromedial, and posterolateral directions, thereby challenging dynamic stability at the limits of postural control. Previous research has demonstrated that the UQYBT is a reliable and reproducible assessment tool for evaluating upper-extremity function in athletic populations [15,16]. Moreover, the test has been widely used to identify movement asymmetries, monitor rehabilitation progress, and screen potential injury risk in athletes [16,17].

The Composite Index (CI), calculated from normalized reach distances across all testing directions, provides an overall indicator of upper-limb dynamic stability and functional performance [18]. Since reach distance is normalized to limb length, the UQYBT allows meaningful comparisons between individuals and between limbs [15]. Importantly, asymmetries identified during the UQYBT may reflect deficits in scapular control, shoulder stability, proprioception, trunk coordination, or neuromuscular efficiency. Some studies have also suggested that excessive asymmetry in specific reach directions may be associated with increased risk of injury [17,19].

Another commonly used indicator of upper-extremity function is hand grip strength, which reflects overall neuromuscular performance, muscle function, and upper-limb strength capacity [20,21]. Grip strength assessment is simple, reliable, inexpensive, and widely used in sports science and clinical practice as an indirect marker of general muscular fitness and functional capacity. In athletes, hand grip strength has been associated with upper-body strength, force production, sport performance, and neuromuscular readiness. In combat sports specifically, grip strength may contribute to stabilization efficiency, force transmission, defensive positioning, and upper-limb control during dynamic movements. Despite its practical importance, the relationship between grip strength and dynamic upper-limb stability in taekwon-do athletes remains insufficiently investigated.

In recent years, the evaluation of inter-limb asymmetry has gained increasing attention in sports biomechanics and performance research. Current evidence indicates that asymmetry should not always be interpreted as dysfunction because a certain degree of asymmetry may represent a sport-specific functional adaptation developed through long-term training

exposure. This perspective has been supported by recent reviews suggesting that the effects of inter-limb asymmetry on athletic performance are highly task- and sport-specific [22,23]. However, excessive asymmetry may negatively influence movement quality, mechanical efficiency, and injury resilience [1,24,25]. Although previous research in taekwon-do has primarily focused on lower-limb biomechanics, kicking performance, balance, and strength characteristics, studies examining upper-extremity neuromuscular function remain limited. Furthermore, existing investigations rarely combine assessments of dynamic upper-limb stability and hand grip strength within the same research framework. Consequently, there is still insufficient evidence regarding the relationships between upper-limb strength, dynamic stability performance, and inter-limb asymmetry in taekwon-do practitioners.

Despite the growing interest in inter-limb asymmetry in combat sports, most studies conducted in taekwon-do have focused on lower-limb performance, kicking biomechanics, balance, and strength characteristics. In contrast, upper-limb dynamic stability and functional symmetry have received considerably less attention, despite the important role of the upper extremities in maintaining guard position, postural stabilization, impact absorption, and force transmission during combat actions. Moreover, previous studies have rarely combined assessments of upper-limb dynamic stability and hand grip strength within a single research framework. Consequently, it remains unclear whether upper-limb strength capacity is associated with dynamic stability performance and inter-limb symmetry in experienced taekwon-do athletes.

Therefore, further investigation is needed to better understand the characteristics of upper-limb asymmetry and its association with dynamic stability and strength performance in taekwon-do athletes. The aim of the present study was to evaluate upper-limb dynamic stability and inter-limb asymmetry in experienced ITF taekwon-do practitioners and to determine whether hand grip strength is associated with dynamic stability performance.

The following research questions were formulated: (1) Do experienced taekwon-do athletes demonstrate inter-limb asymmetry in upper-limb dynamic stability and hand grip strength? (2) Is hand grip strength associated with upper-limb dynamic stability performance and asymmetry indices?

It was hypothesized that experienced taekwon-do athletes would demonstrate significant inter-limb asymmetry in selected UQYBT reach directions, whereas overall hand grip strength and Composite Index values would remain relatively symmetrical. Furthermore, hand grip strength was expected to demonstrate weak-to-moderate associations with upper-limb dynamic stability variables and asymmetry indices.

2. Materials and Methods

2.1. Study Group

The study included 16 male ITF taekwon-do practitioners who voluntarily participated in this cross-sectional investigation. At the time of data collection, all participants were active taekwon-do instructors who regularly practiced and taught ITF taekwon-do. In addition to their coaching responsibilities, they remained systematically engaged in training activities and continued to practice taekwon-do on a regular basis. Some participants were also actively involved in national and international competitions.

The participants represented a highly advanced level of expertise, holding master grades ranging from 1st to 8th Dan and possessing extensive taekwon-do training experience. All participants were right-handed and reported using their right hand for writing as well. The mean age of the athletes was 41.8 ± 7.3 years, the mean body mass was 87.4 ± 9.6 kg, the mean body height was 179.4 ± 7.9 cm, and the mean body mass index (BMI) was 27.2 ± 2.7 kg/m². Although the mean BMI was within the overweight range, the study group was heterogeneous with respect to body composition, including both par-

ticipants with mild obesity according to BMI classification and participants with elevated muscularity resulting from long-term taekwon-do training.

Eligibility criteria included: (1) male sex; (2) possession of at least a 1st Dan black belt rank; (3) a minimum of 10 years of regular taekwon-do training experience; and (4) active participation in training during the study period. Participants were excluded if they reported any musculoskeletal injury, neurological disorder, pain, or other medical condition that could affect upper-limb performance or interfere with the execution of the testing procedures.

None of the athletes reported injuries at the time of examination. Prior to the study, all participants were informed of its purpose and procedure and voluntarily agreed to participate. The study protocol complied with the ethical standards of the Declaration of Helsinki and was approved by the Ethics Committee of Jan Długosz University in Częstochowa (decision no. KE-O/4/2022). A priori sample size estimation was conducted using G*Power v. 3.1 (Heinrich Heine University Düsseldorf, Düsseldorf, Germany). For a paired-samples *t*-test, assuming a significance level of 0.05, a statistical power of 0.80, and a large effect size ($d = 0.80$) based on the expected inter-limb asymmetry in experienced athletes, the minimum required sample size was calculated to be 15 participants. Consequently, the inclusion of 16 taekwon-do practitioners satisfied the recommended sample size requirements for the present study.

2.2. Research Protocol

All measurements were performed during a single testing session in a sports laboratory under standardized conditions. Participants attended the testing session in their habitual training state and were asked to avoid strenuous physical exercise immediately before testing. No additional dietary or caffeine restrictions were imposed. Prior to testing, participants completed a standardized warm-up consisting of light aerobic exercise and dynamic upper-limb mobility exercises. Following the warm-up, two assessments were conducted: hand grip strength testing and the Upper Quarter Y-Balance Test (UQYBT).

Hand grip strength was assessed using a hydraulic hand dynamometer (Saehan Corporation, Model SH5001, Changwon, Republic of Korea). Measurements were obtained separately for the right and left hands. Participants were tested in a standing position, with the shoulder maintained in a neutral and adducted position alongside the trunk, the elbow flexed to 90° , the forearm in a neutral position, and the wrist positioned between 0° and 30° of extension. Although the assessment was performed in a standing position, upper-limb alignment followed the recommendations of the American Society of Hand Therapists (ASHT) [26], consistent with previously published protocols. Participants were instructed to avoid trunk movements, shoulder elevation, and compensatory actions of the contralateral upper limb while performing maximal voluntary contractions. Each contraction was sustained for 3 s. Three trials were completed for each hand, beginning with the right hand and followed by the left, with 10–15 s of rest between attempts. The highest value recorded for each limb was used for further analysis and expressed in kilograms [kg].

The Upper Quarter Y-Balance Test (UQYBT) was used to evaluate upper-extremity stability, mobility, and inter-limb functional symmetry. During the assessment, participants assumed a push-up position with their feet placed hip-width apart and both hands positioned on the center platform. While supporting body weight on one arm, participants reached with the contralateral arm in three directions—anterior (AP), posteromedial (PM), and posterolateral (PL)—by pushing the reach indicator as far as possible while maintaining balance and keeping the supporting hand in contact with the platform (Figure 1). Reach distances were attributed to the reaching limb. Therefore, when participants supported

their body weight on one upper limb, the reach distance obtained with the contralateral upper limb was recorded for the reaching limb and used for further analyses.

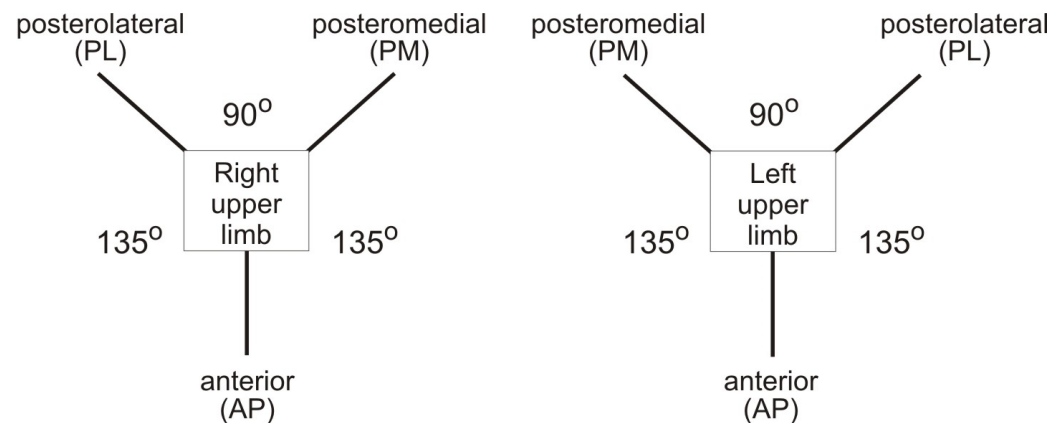


Figure 1. Upper Quarter Y-Balance Test (UQYBT): Reach directions relative to the supporting upper limb, including anterior (AP), posteromedial (PM), and posterolateral (PL) directions.

For the UQYBT, participants were tested using a standardized sequence. The right upper limb was assessed first, followed by the left upper limb. Within each limb, reach directions were performed in the order of AP, PM, and PL.

Each participant performed three successful trials in each reach direction for each upper limb. The greatest reach distance achieved in each direction was retained for further analysis. Reach distances were subsequently normalized to upper-limb length and expressed as a percentage of limb length according to the following equation [14]:

$$\text{Normalized reach distance [\%]} = \left(\frac{\text{reach distance}}{\text{upper limb length}} \right) \times 100$$

Short rest intervals were provided between consecutive trials and between testing of the two upper limbs to minimize fatigue; however, the exact duration of these intervals was not formally recorded. Trials were considered unsuccessful and repeated if the participant lost balance, removed or repositioned the supporting hand from the platform, lifted either foot from the floor, touched the floor with any body part other than the designated support points, demonstrated excessive body or trunk tilt that compromised the required push-up position, was unable to complete the reach movement in a controlled manner, or failed to return to the starting position following the reaching task.

Prior to testing, upper-limb length was measured with participants standing upright as the linear distance from the spinous process of the seventh cervical vertebra (C7) to the distal tip of the middle finger of the tested limb, with the shoulder abducted to 90°, the elbow fully extended, and the fingers extended [16]. This measurement was used to normalize reach distances and calculate composite performance indices.

A composite index (CI) was calculated separately for each upper limb using the following equations:

$$CI_{\text{left}} = \frac{AP + PM + PL}{3 \times \text{Left upper limb length}} \times 100; \quad CI_{\text{right}} = \frac{AP + PM + PL}{3 \times \text{Right upper limb length}} \times 100$$

where AP represents the anterior reach distance, PM the posteromedial reach distance, and PL the posterolateral reach distance.

The composite inter-limb symmetry index (*Sym_CI*) was calculated using the following formula:

$$Sym_CI = \frac{|CI_{left} - CI_{right}|}{\max(CI_{left}, CI_{right})} \times 100$$

Similarly, hand grip strength (*Grip_SI*) was calculated according to the following equation:

$$Grip_SI = \frac{|Grip_{left} - Grip_{right}|}{\max(Grip_{left}, Grip_{right})} \times 100$$

2.3. Statistical Analysis

Statistical analyses were performed using Python (version 3.11) with computational packages including SciPy (version 1.11.4). Data normality was assessed using the Shapiro–Wilk test. As all variables demonstrated a normal distribution ($p > 0.05$), parametric statistical methods were applied.

Inter-limb differences in hand grip strength, UQYBT reach distances, and Composite Indexes (*CI*) values were evaluated using paired Student's *t*-tests. Effect sizes were calculated using Cohen's *dz* and interpreted as trivial (<0.20), small (0.20 – 0.49), medium (0.50 – 0.79), and large (≥ 0.80) [27].

Associations between hand grip strength of both upper limbs, dynamic stability variables, and asymmetry indices were examined using Pearson's correlation coefficients (*r*). Correlation strength was interpreted as weak ($|r| < 0.30$), moderate (0.30 – 0.49), strong (0.50 – 0.69), and very strong (≥ 0.70) [28].

3. Results

3.1. Inter-Limb Differences in Hand Grip Strength and UQYBT Performance

Table 1 presents comparisons between the left and right upper limbs in hand grip strength and UQYBT performance among experienced taekwon-do practitioners. No significant inter-limb differences were observed for hand grip strength, UQYBT posterolateral (PL), anterior (AP), or the Composite Indexes ($p > 0.05$). However, a statistically significant difference was identified for UQYBT posteromedial (PM), with higher reach values recorded for the left upper limb compared with the right upper limb ($p < 0.001$). The effect size for this difference was large ($dz = 1.34$), indicating substantial inter-limb asymmetry in this movement direction. The remaining variables demonstrated trivial-to-moderate effect sizes.

Table 1. Inter-limb differences in hand grip strength, UQYBT reach distances, and Composite Index values presented as mean $\pm$ standard deviation, including *t*-test statistics, *p*-values, and Cohen's *dz* effect sizes. Statistically significant differences are indicated by *.

Variable	Left Upper Limb	Right Upper Limb	<i>t</i> -Test	<i>p</i> -Value	Cohen's <i>dz</i>
Hand Grip Strength [kg]	52.75 $\pm$ 6.53	53.81 $\pm$ 6.87	−0.93	0.368	0.23
UQYBT posteromedial (PM) [cm]	88.69 $\pm$ 7.53	83.19 $\pm$ 8.24	5.37	<0.001 *	−1.34
UQYBT posterolateral (PL) [cm]	66.06 $\pm$ 11.40	68.75 $\pm$ 11.93	−2.12	0.052	0.53
UQYBT anterior (AP) [cm]	114.81 $\pm$ 12.78	117.19 $\pm$ 11.90	−1.44	0.169	0.36
<i>CI</i> [%]	98.90 $\pm$ 8.02	98.73 $\pm$ 8.17	0.17	0.866	−0.04

As illustrated in Figure 2, experienced taekwon-do participants generally demonstrated greater UQYBT posteromedial (PM) reach distances with the left upper limb than with the right. Most paired observations showed a downward trend from the left to the

right side, indicating that the asymmetry was consistent across participants rather than being driven by a small number of extreme values. Although some individuals exhibited minimal differences or higher PM reach distances in the right limb, the overall pattern supported the significant inter-limb difference observed in Table 1.

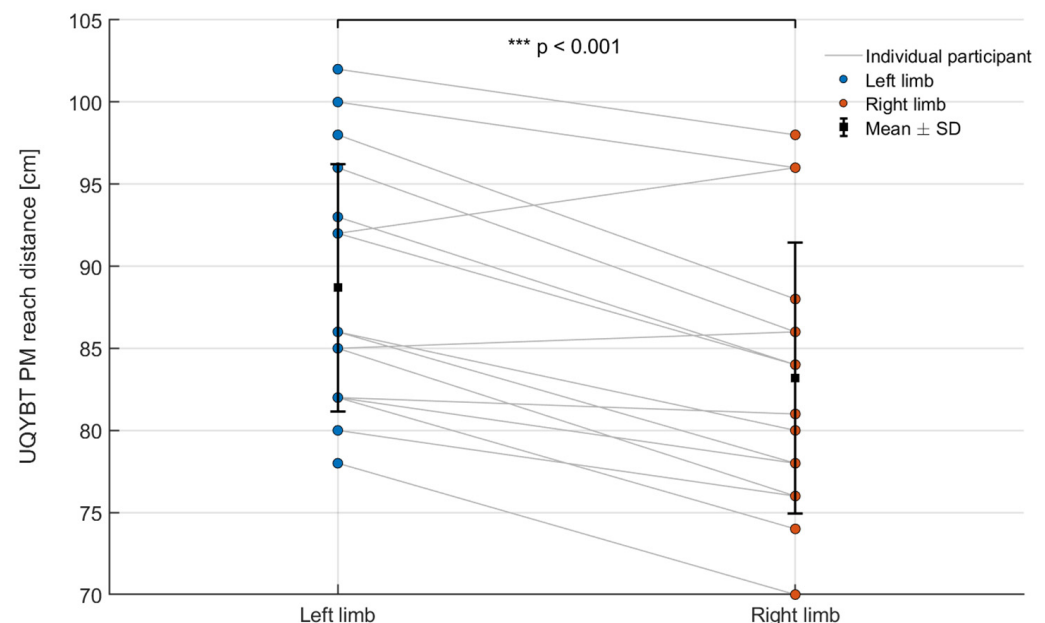


Figure 2. Paired connection plot illustrating individual inter-limb differences in UQYBT postero-medial (PM) reach distance. Grey lines connect values from the same participant, coloured circles represent individual observations, and black squares indicate mean $\pm$ standard deviation. A significant difference between limbs was observed ($*** p < 0.001$).

3.2. Relationships Between Hand Grip Strength and Dynamic Stability Variables

Table 2 presents correlations between hand grip strength, inter-limb symmetry, and upper-limb dynamic stability variables in experienced taekwon-do athletes. No statistically significant correlations were observed between hand grip strength and upper-limb dynamic stability variables in experienced taekwon-do athletes (all $p > 0.05$). Both right- and left-hand grip strength showed weak to moderate associations with the Composite Index (CI), anterior (AP), posteromedial (PM), and posterolateral (PL) reach distances; however, none of these relationships were statistically significant. The strongest, although still non-significant, association was found between right-hand grip strength and posterolateral reach distance of the right upper limb ($r = 0.422$; $p = 0.103$), indicating a moderate effect magnitude despite limited statistical power.

Table 2. Pearson correlation coefficients (r) and corresponding p -values ($p > 0.05$) for associations between hand grip strength, grip symmetry, and upper-limb dynamic stability variables in experienced taekwon-do athletes.

Variables	Right Upper Limb Pearson's Correlations (r), p -Value	Left Upper Limb Pearson's Correlations (r), p -Value
Grip strength vs. Composite Index (CI)	−0.102; 0.7080	−0.353; 0.180
Grip strength vs. Anterior reach distance (AP)	0.185; 0.4916	−0.011; 0.967
Grip strength vs. Posteromedial reach distance (PM)	0.033; 0.9042	−0.140; 0.604
Grip strength vs. Posterolateral reach distance (PL)	0.422; 0.1034	0.019; 0.943
Grip symmetry index (<i>Grip_SI</i>) vs. Composite symmetry index (<i>Sym_CI</i>): 0.036; 0.8945		

Additionally, no significant relationship was identified between the grip symmetry index (*Grip_SI*) and composite symmetry index (*Sym_CI*) ($r = 0.036$; $p = 0.895$).

Visual inspection of the scatter plots (Figure 3) did not reveal obvious nonlinear relationships or influential outliers that could disproportionately affect the reported correlation coefficients. Thus, the absence of statistically significant associations between hand grip strength, grip symmetry, and upper-limb dynamic stability variables was unlikely to be explained by a small number of extreme observations.

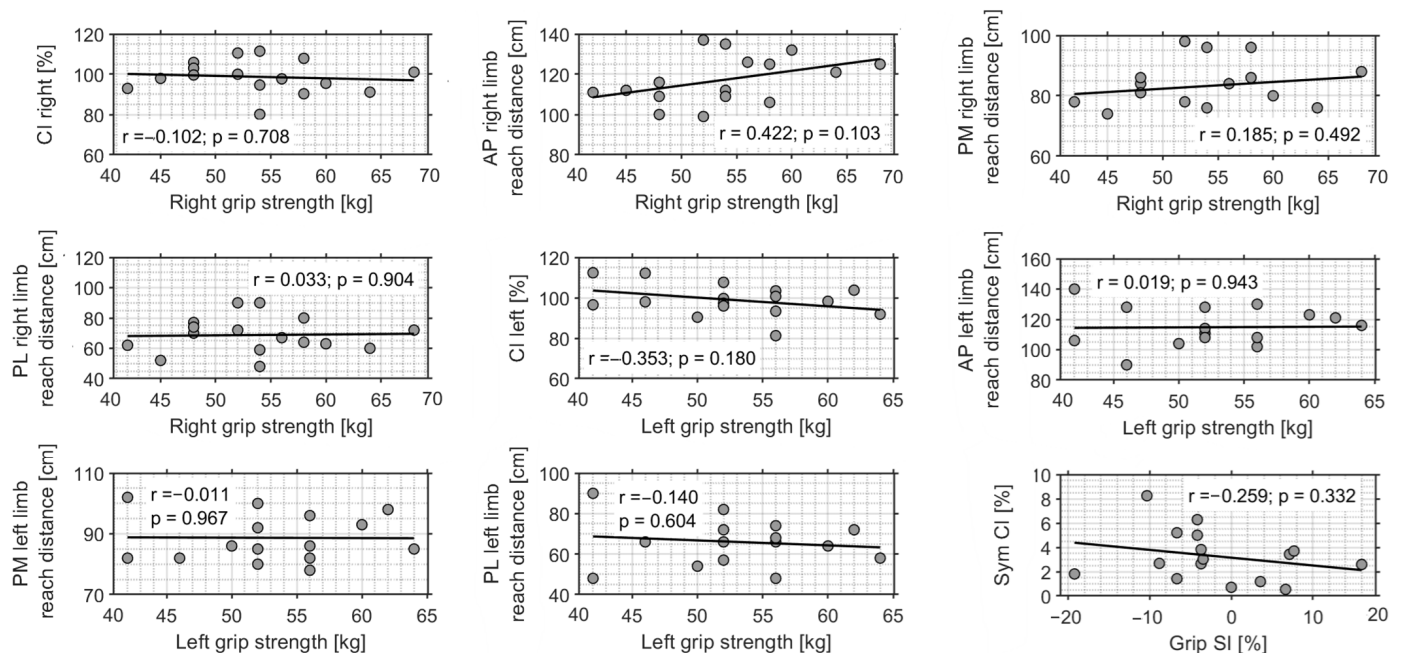


Figure 3. Scatter plots illustrating the relationships between hand grip strength, grip symmetry, and upper-limb dynamic stability variables in experienced taekwon-do athletes. Each point represents an individual participant. Solid black lines indicate least-squares regression lines, and Pearson's correlation coefficients (r) together with the corresponding p -values are presented within each panel. Red diamonds denote potential outliers identified based on regression residuals. Visual inspection of the plots did not reveal obvious nonlinear relationships or influential observations that could disproportionately affect the reported correlation coefficients, supporting the conclusion that no statistically significant associations were observed between hand grip strength, grip symmetry, and upper-limb dynamic stability variables.

3.3. Upper-Limb Dynamic Stability and Asymmetry Profiles

Figure 4 illustrates upper-limb dynamic stability and inter-limb asymmetry in experienced taekwon-do athletes. Panel A presents mean reach distances obtained in the UQYBT for both upper limbs across the three movement directions. Greater values for the left limb were observed in the posteromedial (PM) direction, whereas slightly higher reach distances for the right limb were identified in the anterior (AP) and posterolateral (PL) directions.

Panel B presents asymmetry values for individual UQYBT directions. Positive asymmetry values indicate superior performance of the left limb, while negative values reflect higher performance of the right limb. The greatest asymmetry was observed in the PM direction, accompanied by considerable inter-individual variability.

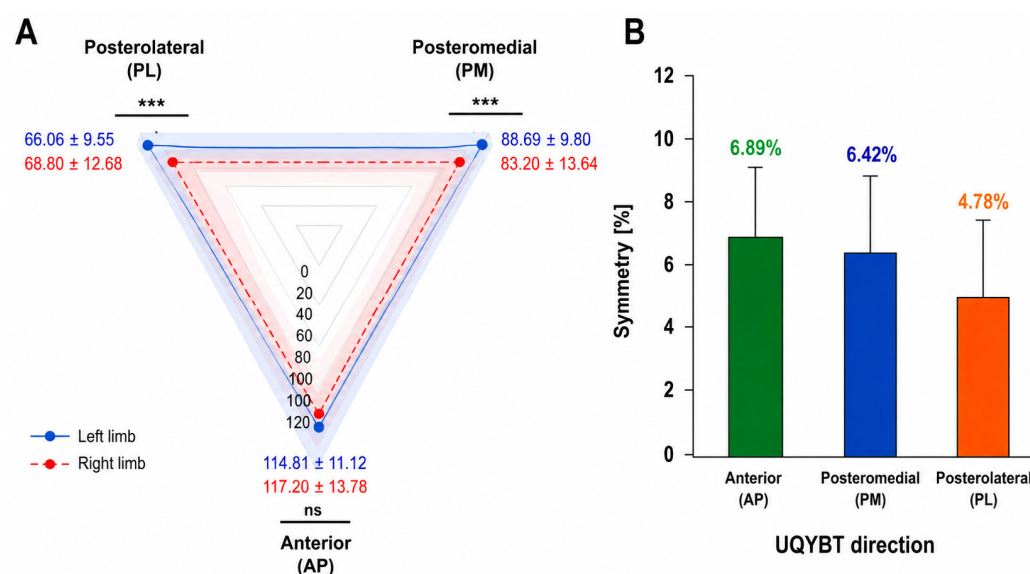


Figure 4. Upper-limb dynamic stability and inter-limb asymmetry in experienced taekwon-do practitioners. (A) Radar plot presenting mean $\pm$ SD reach distances obtained in the Upper Quarter Y-Balance Test (UQYBT) for the left and right limbs across the anterior (AP), posteromedial (PM), and posterolateral (PL) reach directions. Shaded areas represent standard deviations. p -values indicate the significance of inter-limb differences for each reach direction. (B) Inter-limb symmetry values [%] calculated for the anterior (AP), posteromedial (PM), and posterolateral (PL) reach directions. Error bars represent standard deviations. *** $p < 0.001$; ns, $p > 0.05$.

4. Discussion

The present study investigated upper-limb functional asymmetry and dynamic stability in experienced taekwon-do athletes using the Upper Quarter Y-Balance Test (UQYBT) and hand grip strength assessment. The main findings demonstrated selective inter-limb asymmetry in upper-limb dynamic stability, whereas overall hand grip strength and composite dynamic stability remained relatively symmetrical between limbs. Additionally, maximal grip strength was not significantly associated with dynamic stability performance or asymmetry indices.

4.1. Interpretation of Inter-Limb Asymmetry

One of the most important findings of the present study was the presence of movement-specific asymmetry in the posteromedial (PM) direction of the UQYBT. In contrast, no significant inter-limb differences were identified for the anterior (AP), posterolateral (PL), or Composite Index (CI) values. These findings suggest that experienced taekwon-do athletes develop selective sport-specific neuromuscular adaptations rather than generalized asymmetry across all movement tasks.

Taekwon-do is characterized by repetitive unilateral actions, asymmetrical fighting stances, and rapid changes in body position, which may contribute to the development of directional asymmetry. Repeated execution of offensive and defensive techniques may promote side-specific adaptations in neuromuscular coordination, postural stabilization, and closed kinetic chain control. Previous biomechanical analyses in taekwon-do athletes demonstrated differences in effective mass generation and movement execution between kicking techniques and athlete characteristics, supporting the presence of sport-specific functional adaptations [29]. Furthermore, studies conducted in combat sports have shown that dynamic technical actions are accompanied by specific muscle activation patterns and neuromuscular control strategies that may influence stability performance and inter-limb

coordination [30]. Similar sport-specific asymmetrical adaptations have been reported in athletes practicing handball, baseball, and other unilateral sports, where repetitive movement patterns contribute to inter-limb differences in upper-quarter mobility and stability [17,31].

Interestingly, despite the asymmetry identified in the PM direction, the Composite Index values remained symmetrical between limbs. This finding may indicate that athletes are capable of maintaining overall upper-limb functional balance despite directional differences in selected movement patterns. Such compensation mechanisms may potentially reflect long-term neuromuscular adaptation resulting from systematic training exposure.

Current evidence suggests that asymmetry should not always be interpreted as pathological dysfunction, particularly in highly trained athletes exposed to repetitive unilateral movement patterns. In highly trained athletes, asymmetrical movement strategies may represent functional sport-specific adaptations associated with technical specialization and repeated unilateral loading [16]. However, excessive asymmetry may still influence movement efficiency and potentially increase injury susceptibility [17].

4.2. Relationship Between Strength and Dynamic Stability

Another important observation of the present study was the absence of significant correlations between hand grip strength and dynamic stability performance. Neither maximal grip strength nor grip symmetry indices were significantly associated with Composite Index values or asymmetry measures.

These findings suggest that dynamic upper-limb stability in taekwon-do athletes depends primarily on neuromuscular coordination, proprioception, trunk stabilization, and shoulder control rather than isolated maximal force production. Previous studies in physically active and athletic populations have emphasized the importance of neuromuscular efficiency, reaction capacity, and sensorimotor control for functional movement performance and stability regulation [32,33]. Recent evidence further suggests that sport-specific performance and movement quality are strongly influenced by neuromuscular coordination patterns, which may be altered by fatigue and training load, highlighting the importance of coordination-related adaptations beyond isolated strength measures [34].

Although grip strength is commonly considered a general indicator of upper-extremity function, the UQYBT requires complex sensorimotor integration and closed kinetic chain stabilization abilities that may not directly depend on maximal strength capacity alone [35]. Interestingly, the relationships observed for the left upper limb were consistently negligible-to-weak, whereas the right upper limb demonstrated slightly stronger, although still statistically non-significant, associations with selected UQYBT variables. This may indicate a greater functional involvement of the dominant limb in sport-specific stabilization and movement control strategies developed through long-term taekwon-do practice.

The UQYBT has previously been identified as a reliable and reproducible tool for evaluating upper-extremity mobility, stability, and neuromuscular control in athletic populations [15]. Furthermore, the UQYBT may help identify movement asymmetries and potential injury risk in athletic populations [36].

The strongest relationship observed in the present study was the moderate association between grip strength and posterolateral (PL) reach performance; however, this relationship did not reach statistical significance. Importantly, this association was identified only for the right upper limb, while no comparable tendency was observed for the left limb. The relatively small sample size may have reduced statistical power and limited the detection of weaker associations. Therefore, future studies involving larger cohorts and additional biomechanical or electromyographic assessments are warranted.

4.3. Practical Applications

The present findings have several practical implications for coaches, physiotherapists, and strength and conditioning specialists working with taekwon-do athletes. First, the observed movement-specific asymmetry indicates that upper-limb functional screening may provide valuable information regarding sport-specific neuromuscular adaptations and movement strategies.

The Upper Quarter Y-Balance Test appears to be a useful tool for identifying directional asymmetry and monitoring upper-limb dynamic stability in combat sports athletes. Previous studies demonstrated high reliability of the UQYBT, with excellent test–retest reproducibility and strong practical applicability in athletic populations [15,37].

Monitoring inter-limb asymmetry may support individualized training planning, neuromuscular conditioning, and injury prevention strategies. Importantly, asymmetry should be interpreted cautiously because asymmetrical movement patterns are not always associated with dysfunction or elevated injury risk [17]. Since asymmetry in the present study was limited to a specific movement direction and was not accompanied by reduced overall stability or grip strength deficits, it may represent a functional adaptation rather than clinically relevant dysfunction.

Additionally, practitioners should avoid relying exclusively on hand grip strength when evaluating upper-limb function in taekwon-do athletes. Multidimensional assessment protocols combining strength, dynamic stability, neuromuscular control, and asymmetry analysis may provide a more comprehensive evaluation of athlete preparedness and functional performance.

4.4. Study Limitations

Several limitations of the present study should be acknowledged. First, the relatively small sample size limits the generalizability of the findings and may reduce statistical sensitivity for detecting weaker correlations. Second, hand dominance was self-reported rather than determined using a standardized laterality questionnaire. Another limitation is that sport-specific stance preference and dominant kicking side were not analyzed, although these variables may substantially influence upper-limb asymmetry patterns in taekwon-do athletes. Third, the cross-sectional design does not allow conclusions regarding causal relationships between strength and dynamic stability variables.

Furthermore, only selected measures of upper-limb function were included in the study. In particular, handgrip strength was used as a practical indicator of upper-extremity strength; however, it does not fully capture the contributions of other muscle groups involved in dynamic stabilization tasks and may have limited predictive value for complex athletic performance. Therefore, the observed lack of association between grip strength and UQYBT performance should be interpreted with caution. Future studies should incorporate additional assessments of upper-body strength, such as isometric shoulder strength measurements, pushing performance tests, or bench press evaluations, to provide a more comprehensive understanding of the relationship between strength and upper-limb dynamic stability. Additional biomechanical, electromyographic, and kinematic analyses could provide deeper insight into the neuromuscular mechanisms underlying asymmetry in taekwon-do athletes. Future studies should also include female athletes and compare athletes representing different training levels and combat sport disciplines.

5. Conclusions

Despite these limitations, the present study contributes to the growing body of literature concerning asymmetry and neuromuscular adaptations in combat sports. The findings indicate that experienced taekwon-do athletes demonstrate selective upper-limb

asymmetry primarily in the posteromedial UQYBT direction while maintaining relatively symmetrical overall dynamic stability and hand grip strength.

These results support the concept that asymmetry in trained athletes may reflect functional sport-specific adaptation rather than generalized neuromuscular imbalance.

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Informed Consent Statement: Informed consent for participation was obtained from all subjects involved in the study.

Data Availability Statement: The dataset supporting the findings of this study is publicly available in the RepOD repository [26].

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