

Active range of motion in the hip joint and the ability to maintain balance in young judo athletes: A study with eyes open

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Abstract

Introduction with Problem Statement and Approach: Judo is an Olympic combat sport demanding high levels of neuromuscular coordination and joint mobility. While the biomechanical relationship between lower limb flexibility and postural control is documented in adults, there is a notable gap regarding the coordinative profiles of prepubescent children. To address this problem, this observational cross-sectional study aimed to examine the correlation between the active range of motion (AROM) of the hip joint and postural stability in young judo athletes, focusing on how specific mobility patterns influence balance during early sports specialization. **Material and Methods:** The sample consisted of 29 male judokas aged 7–14 years (mean age 9.5 ± 2.27) with at least one year of consistent training experience. All participants declared right-side dominance. Hip AROM was measured bilaterally using a universal goniometer for flexion, extension, abduction, adduction, and rotation, adhering to standardized clinical assessment protocols. Postural stability was evaluated on a CQStab2P stabilometric platform during a 30-second quiet standing task with eyes open, focusing on the displacement of the center of pressure (COP). **Results:** Significant correlations were observed between hip mobility and balance metrics, occurring primarily in the left (non-dominant) lower limb in the frontal plane. The direction of these relationships differed significantly: a greater left hip abduction range was associated with improved stability (lower sway amplitude), whereas an increased left hip adduction range was related to reduced postural stability. The right lower limb showed almost no significant impact on balance parameters. **Discussion:** These findings indicate the early presence of marked functional asymmetry in young judo athletes. This phenomenon likely stems from the dominant role of the left limb as the primary weight-bearing "supporting leg" during the *kuzushi* and *tsukuri* phases of right-sided technical actions (throws), compounded by a general lack of bilateral training emphasis. This specific biomechanical loading adapts the limbs to different functional tasks, fundamentally linking support leg mobility to overall balance. **Conclusions:** Addressing these mobility-related stability deficits is crucial for optimizing motor development and preventing future injuries. The results highlight the necessity of incorporating targeted physiotherapeutic and conditioning exercises designed to strengthen the eccentric control of the adductor muscles. Furthermore, coaches should implement strategies that promote bilateral motor proficiency to mitigate the effects of unilateral dominance. By balancing hip mobility and enhancing neuromuscular control, practitioners can improve the foundational balance required for competitive performance.

Key Words: Stabilometry, functional asymmetry, Center of Pressure (CoP), neuromuscular control, grappling, young athletes.

Introduction

According to data from the Central Statistical Office (Główny Urząd Statystyczny, 2023) regarding physical culture, in 2022, combat sports were practiced by 13% of active individuals in Poland, with judo and karate being the most popular disciplines. Judo is an Olympic combat sport where competition takes place in strict divisions based on age, gender, and weight categories. In light of the official rules of the International Judo Federation (International Judo Federation, 2025), competition at the international level begins at the age of 16 (Cadet category). However, as indicated by Garcia et al. (2009), the training process is often initiated much earlier, as early as the age of 4. This means that young adepts undergo a multi-year preparatory period shaping their motor skills before entering the phase of championship competition.

Technical actions in judo, particularly throwing techniques (*Nage-waza*), require a highly coordinated kinematic chain. The execution of a throw is traditionally divided into three phases: unbalancing the opponent (*Kuzushi*), fitting into the throw (*Tsukuri*), and the final execution (*Kake*) (Sacripanti, 2024). During the *Tsukuri* phase, the athlete must rapidly lower their center of gravity below the opponent's center of gravity while simultaneously rotating their trunk and pelvis. This explosive movement is heavily dependent on the optimal mobility of the hip joints, both in terms of flexion and internal/external rotation. A deficit in hip Active Range of Motion (AROM) can limit the mechanical efficiency of the throw and force compensatory movements in adjacent structures, particularly the lumbar spine.

Competitive judo training requires athletes to have a high level of motor abilities, such as speed, strength, and endurance (Pocceco et al., 2012). The specificity of the discipline forces the maintenance of proper body posture and above-average mobility in the joints of the entire kinematic chain (Almeida et al., 2012). Range of Motion (ROM) is defined as the angular distance and direction that a joint can move between flexed and extended positions (Kent, 2006). Particular attention should be paid to the hip joint, which transfers body weight from the trunk to the lower limbs and enables movements reaching up to 140° of flexion and up to 30° of extension (Zaghloul & Elalfy, 2018). Epidemiological analyses indicate that the areas most exposed to injuries are the lower spine and the shoulder joint (Bromley et al., 2018), i.e., structures directly functionally adjacent to the hip joint. This suggests a key role of the hip in force transmission, which is confirmed by reports on limb injuries during the Olympic Games (Engebretsen et al., 2013) and analyses of injury rates in young judokas (Carvalho et al., 2018).

Furthermore, despite the general recommendation for symmetrical technical training, competitive judo inherently promotes functional asymmetry. Athletes usually develop a preferred side for executing their signature throws (*tokui-waza*), which leads to unequal biomechanical loading on the right and left sides of the body (Chapelle & D'Hondt, 2025). Over time, this unilateral repetitive loading can induce morphological and functional adaptations, potentially leading to differences in joint mobility and neuromuscular control between the dominant and non-dominant lower limbs.

Maintaining balance is crucial for minimizing the risk of injuries and increasing combat effectiveness (Tak et al., 2020). Balance is defined as the ability to maintain the body in a vertical position while controlling sway (Ragnarsdóttir, 1996). In judo, these parameters are inextricably linked to effectiveness (Jaworski et al., 2022). It has been shown that judo training increases tolerance to balance disturbances (Maśliński et al., 2017) and affects lower limb strength (Walaszek et al., 2017). Furthermore, strengthening core muscles translates into better movement control (Martins et al., 2019).

Understanding these mechanisms is particularly important in young practitioners. The prepubescent period (around 9-10 years of age) is considered a critical window for motor development, characterized by high plasticity of the central nervous system and the rapid development of postural control (Boubaker et al., 2023). Recent systematic reviews confirm that regular judo training significantly accelerates the holistic motor development of children, providing superior benefits in postural alignment and balance compared to non-training peers (Kons et al., 2025). From a practical perspective, identifying the relationship between hip AROM and postural stability in prepubescent judokas has crucial implications for coaching and injury prevention strategies. If a significant correlation is established, strength and conditioning coaches could implement targeted hip mobility protocols into standard warm-up routines to safely enhance balance and, consequently, throwing effectiveness. Furthermore, baseline AROM and stabilometric assessments could serve as a valuable early screening tool. Physiotherapists could use these accessible, non-invasive methods to identify young athletes at risk of lower back or lower extremity overload injuries before they manifest clinically during the transition to elite competition levels.

Despite the recognized importance of postural control and joint mobility in combat sports, the existing literature predominantly focuses on adult elite athletes or adolescent populations. There is a notable gap regarding the specific biomechanical and coordinative profiles of prepubescent children during the initial stages of judo training. This research is necessary to establish whether structural joint capabilities, such as functional asymmetries or range of motion limitations, already dictate balance capabilities in young practitioners. To address this problem and fill the identified gap, an observational cross-sectional study was designed. The research method involved evaluating the Active Range of Motion (AROM) of the hip joint using standardized clinical goniometry and assessing postural stability via a precise stabilometric platform. The aim of this study was to analyze the correlations between the Active Range of Motion (AROM) in the hip joint and the level of balance in young judokas. The authors formulated two research hypotheses: H1: Dynamic range of motion in the hip joint significantly affects the level of balance. H2: There will be no lower limb dominance affecting hip joint mobility.

Materials and Methods

Study Design and Participants

An observational, cross-sectional study was conducted to evaluate the relationship between hip joint mobility and postural stability in young athletes. The measurements were carried out on a single day, December 6, 2025, at one of the sports clubs in the Greater Poland Voivodeship, Poland.

Initially, a cohort of 45 children (11 girls and 34 boys) was recruited for the study. However, to ensure the homogeneity and credibility of the resulting data, the female participants were excluded, as their subgroup was too small to yield statistically robust gender comparisons. Furthermore, several male participants were excluded due to incomplete datasets (e.g., opting out during the testing procedure). Ultimately, the final study group consisted of 29 male judo athletes.

The mean age of the subjects was 9.5 years (SD = 2.27, range: 7–14 years), mean body height was 140.62 cm (SD = 17.35), and body mass was 35.43 kg (SD = 13.15). The inclusion criteria for the study group were: (1) active participation in judo training for at least one full year, (2) chronological age between 7 and 14

years, and (3) declaration of the right leg as the dominant lower limb (assessed by asking the child which leg they would use to kick a ball). Subjects were excluded if they had a history of musculoskeletal injuries in the lower limbs or spine within the last six months, uncorrected visual impairments, or any diagnosed neurological disorders affecting balance. The authors obtained approval from the Bioethics Committee at the Poznan University of Medical Sciences (No. 456/25, issued on 12 June 2025). Due to the underage status of the participants, written informed consent was obtained from their parents or legal guardians prior to the commencement of the study, in accordance with the Declaration of Helsinki.

Instruments and Measures

Basic anthropometric measurements (body height and mass) were collected using a standard stadiometer and a certified medical scale before the main testing phase.

Active Range of Motion (AROM)

The dynamic mobility of the hip joint was measured using a standard universal goniometer (Clarkson, 2000). To minimize inter-rater variability and measurement error, all goniometric assessments were performed by the same experienced researcher. Measurements were taken for both lower limbs in the sagittal, frontal, and transverse planes, recording the exact angles for extension (fixed knee), flexion (fixed knee), abduction, adduction, and internal/external rotation. This rigorous multi-positional approach was applied because recent biomechanical analyses indicate that measurement position, alongside limb dominance, significantly affects the ultimate values of hip rotation and mobility parameters (Kozinc et al., 2022).

Postural Stability

Postural control was assessed using the CQStab2P stabilometric platform (CQ Elektronik System, Poland). The device recorded the Center of Pressure (COP) displacement using six integrated force sensors. Based on the acquired data, a comprehensive set of stabilometric parameters was extracted for analysis, including: total Sway Path [mm], Sway Path in the Antero-Posterior (A-P) and Medio-Lateral (M-L) planes [mm], Mean Amplitude (total, A-P, and M-L) [mm], Sway Area [mm²], the Sway Path to Sway Area ratio [1/mm], and the Number of deviations in the A-P and M-L directions.

Experimental Procedure

All measurements were conducted under strictly controlled environmental conditions. Participants wore standard sports attire and performed all stabilometric tests barefoot to eliminate the influence of footwear on somatosensory feedback. Before the measurement, subjects were rested and had explicitly not performed any physical warm-up (Yamamoto et al., 2018).

The experimental session for each participant began with the AROM assessment. Measurements were taken in three positions: flexion (supine position), extension (prone position), and external/internal rotation (sitting on a chair with lower legs hanging freely). Following the goniometric assessment, participants proceeded to the stabilometric platform. The measurement lasted exactly 30 seconds in a free-standing position (arbitrary foot placement, not forced), with eyes open. The platform was placed 10 cm from the wall, and subjects were instructed to remain as still as possible, focusing their gaze on a point in front of them.

Statistical Analysis

Statistical analysis was performed using standard statistical software Statistica 13.3. Statistical analysis included the calculation of mean (M), median (Mdn), standard deviation (SD), minimum, and maximum values. The Shapiro-Wilk test was used to analyze the normality of data distribution. Due to the nature of the data distribution, the relationship between specific hip ranges of motion and all aforementioned postural stability parameters was analyzed using Spearman's rank correlation. The following scale for correlation strength was adopted: $0 < r_s \leq 0.2$ – no relationship; $0.2 < r_s \leq 0.4$ – low correlation; $0.4 < r_s \leq 0.7$ – moderate correlation; $0.7 < r_s \leq 0.9$ – strong correlation; $r_s > 0.9$ – very strong correlation. The level of statistical significance was set at $p < 0.05$.

Results

The descriptive characteristics of hip joint mobility and postural stability parameters for the study group ($N = 29$) are summarized in Table 1. The mean Sway Path length was 440.55 ± 143.12 mm, and the Sway Area was 571.66 ± 380.88 mm². Hip flexion in the sagittal plane reached $69.59^\circ \pm 13.24^\circ$ for the right side and $67.90^\circ \pm 13.54^\circ$ for the left side. Correlation analysis revealed that the majority of statistically significant relationships involved the left (non-dominant) lower limb in the frontal plane. Left Hip Adduction (LHA D-F) demonstrated moderate positive correlations with Mean Amplitude Antero-Posterior ($r_s = 0.45$, $p < 0.05$) and Sway Path ($r_s = 0.41$, $p < 0.05$). Additionally, LHA D-F showed low positive correlations with Sway Path Antero-Posterior ($r_s = 0.38$), Sway Path Medio-Lateral ($r_s = 0.40$), Mean Amplitude ($r_s = 0.40$), and Sway Area ($r_s = 0.38$) (all $p < 0.05$). Left Hip Abduction (LHA B-F) was moderately and negatively correlated with Mean Amplitude Antero-Posterior ($r_s = -0.47$, $p < 0.05$) and Mean Amplitude ($r_s = -0.44$, $p < 0.05$), while showing a low positive correlation with the Path/Area Ratio ($r_s = 0.39$, $p < 0.05$).

Regarding the right lower limb, the only significant relationship was a low negative correlation between Right Hip Abduction (RHA B-F) and Mean Amplitude Antero-Posterior ($r_s = -0.39$, $p < 0.05$). No significant correlations were observed for hip flexion, extension, or internal/external rotation in either limb in relation to the analyzed stabilometric parameters ($p > 0.05$) (Table 2).

Table 1. Descriptive statistics of hip range of motion and postural stability parameters

Variable	M	Mdn	Min	Max	SD	W	p
Right Hip Extension - Sagittal (fixed knee) [°]	20.86	20	10	32	5.5	0.96	0.3332
Right Hip Flexion (Fixed knee) - Sagittal [°]	69.59	70	35	96	13.24	0.97	0.5127
Left Hip Extension - Sagittal (Fixed knee) [°]	19.38	20	12	31	4.86	0.88	0.0029
Left Hip Flexion - Sagittal (Fixed knee) [°]	67.9	70	40	95	13.54	0.97	0.5665
Right Hip Abduction - Frontal [°]	46.31	45	25	85	12.28	0.91	0.0183
Right Hip Adduction - Frontal [°]	22.31	20	10	45	9.13	0.92	0.025
Left Hip Abduction - Frontal [°]	45.24	40	20	80	12.27	0.93	0.0681
Left Hip Adduction - Frontal [°]	22	20	10	40	8.86	0.9	0.0107
Right Hip External Rotation [°]	35	40	20	45	6.68	0.84	0.0004
Right Hip Internal Rotation [°]	36.79	35	30	46	5.6	0.87	0.0022
Left Hip External Rotation [°]	35.86	35	20	45	6.13	0.9	0.0125
Left Hip Internal Rotation [°]	35.35	35	30	50	4.95	0.87	0.0017
Sway Path [mm]	440.55	429	190	761	143.12	0.97	0.5155
Sway Path Antero-Posterior - [mm]	298.14	285	133	497	87.23	0.98	0.861
Sway Path Medio-lateral -[mm]	257.52	246	106	588	102.14	0.92	0.0249
Mean amplitude [mm]	3.83	3.8	1.8	6.5	1.32	0.96	0.3412
Mean amplitude Antero-Posterior [mm]	2.97	2.9	1.2	5.8	1.02	0.96	0.3324
Mean amplitude Medio- Lateral [mm]	1.81	1.7	0.6	3.9	0.95	0.91	0.0163
Sway area - [mm ²]	571.66	468	121	1639	380.88	0.87	0.0019
Sway Path Sway area [1/mm]	0.96	0.85	0.46	1.91	0.37	0.93	0.0564
Number of deviation in Antero-Posterior	20.79	21	7	47	9.08	0.95	0.1965
Number of deviation in Medio-Lateral	28.62	32	5	54	14.08	0.95	0.2121

Note: M – Mean; Mdn – Median; Min – Minimum; Max – Maximum; SD – Standard Deviation; W – Shapiro-Wilk test statistic; p – statistical significance, Statistically significant values ($p < 0.05$) indicating non-normal distribution are marked in bold.

Table 2. Spearman's rank correlation between hip range of motion and stabilometric parameters

Variable	RHE-S	RHF-S	RHAB-F	RHAD-F	RHER	RHIR	LHE-S	LHF-S	LHAB-F	LHAD-F	LHER	LHIR
Sway Path	-0.02	0.17	-0.17	0.31	-0.07	0.32	-0.02	-0.06	-0.23	0.41	-0.06	0.22
Sway Path A-P	-0.07	0.11	-0.13	0.25	-0.14	0.34	-0.08	-0.14	-0.18	0.38	-0.13	0.26
Sway Path M-L	0.07	0.18	-0.11	0.32	-0.05	0.34	0.02	-0.02	-0.17	0.40	-0.05	0.24
Mean Amp.	-0.25	0.18	-0.30	0.31	0.01	0.14	-0.32	0.15	-0.44	0.40	0.04	0.06
Mean Amp. A-P	-0.39	0.19	-0.39	0.37	0.07	0.05	-0.40	0.09	-0.47	0.45	0.06	-0.03
Mean Amp. M-L	-0.06	0.15	-0.12	0.23	-0.04	0.25	-0.14	0.16	-0.21	0.28	0.03	0.16

Sway Area	-0.13	0.17	-0.23	0.28	-0.02	0.25	-0.21	0.07	-0.30	0.38	0.02	0.15
Path/Area Ratio	0.19	-0.17	0.29	-0.27	0.02	-0.14	0.28	-0.16	0.39	-0.36	-0.02	-0.09
Deviations A-P	0.28	-0.19	0.31	-0.03	-0.20	0.33	0.35	-0.16	0.19	-0.05	0.06	0.17
Deviations M-L	0.17	0.17	-0.17	0.10	0.01	0.14	0.26	-0.04	-0.12	0.04	0.01	-0.04

Note: Statistically significant correlations ($p < 0.05$) are marked in bold.

RHE-S - Right Hip Extension - Sagittal (fixed knee), RHF-S - Right Hip Flexion (Fixed knee) - Sagittal, RHAB-F - Right Hip Abduction – Frontal, RHADD-F - Right Hip Adduction - Frontal, RHEP - Right Hip External Rotation, RHIR - Right Hip Internal Rotation, LHE-S - Left Hip Extension - Sagittal (Fixed knee), LHF-S - Left Hip Flexion - Sagittal (Fixed knee), LHAB-F - Left Hip Abduction – Frontal, LHAD-F - Left Hip Adduction – Frontal, LHER - Left Hip External Rotation, LHIR - Left Hip Internal Rotation

Discussion

The primary purpose of this study was to examine the relationship between the active range of motion (AROM) in the hip joint and the ability to maintain static balance among young judo athletes. The analysis of the obtained data showed that the first hypothesis (H1), assuming a significant influence of the dynamic range of hip motion on balance, was partially confirmed. Statistically significant correlations were found, but they were isolated strictly to the frontal plane (abduction and adduction). It was noted that a greater range of abduction in the left hip joint correlates with enhanced postural stability (reflected by a lower sway amplitude). It can be inferred that hip abductors play a vital role in dynamic pelvic stabilization. Conversely, a distinctly opposite relationship was observed in the case of left hip adduction: a greater range of adduction motion was associated with an increase in stabilometric sway parameters. This critical finding suggests that excessive passive mobility in this direction, without adequate eccentric strength, may indicate weaker neuromuscular control of the pelvic girdle, directly translating into decreased balance performance. Considering that the left lower limb exhibited statistically significant correlations across multiple stabilometric parameters, while the right leg showed almost no significant impact on postural control, the second research hypothesis (H2)—assuming no lower limb dominance affecting hip joint mobility—must be rejected.

This observed disproportion strongly suggests the early emergence of functional asymmetry. While balance in healthy, non-training individuals typically shows no significant limb dominance (Paillard & Noé, 2021), our findings provide concrete evidence that the unilateral nature of judo technical specialization disrupts this equilibrium even at the initial stages of training (7-14 years of age). This phenomenon can be explicitly explained through the biomechanics of the throw. All participants declared the right side as their dominant, preferred side for executing attacks. Consequently, during the critical phases of the throw—*kuzushi* (unbalancing) and *tsukuri* (fitting in)—it is the left leg that acts as the primary (support leg). As indicated by recent research (Tirp et al., 2014; Chapelle & D'Hondt, 2025), the repetitive execution of signature throws (*tokui-waza*) on a preferred side neurologically adapts the limbs to highly specialized tasks: the left leg becomes the main pillar responsible for bearing body weight and stabilizing the Center of Pressure (COP), while the right leg executes the dynamic, sweeping action. These observations are highly consistent with Lyu et al. (2026), who demonstrated that repetitive unilateral gripping and throwing demands in youth judokas create distinct morphological asymmetries directly linked to sport-specific performance. Furthermore, as highlighted by Arboix-Alió et al. (2025), monitoring such inter-limb functional asymmetries is currently a priority in sports science due to their strong correlation with both performance deficits and elevated injury risks. This distinct biomechanical division effectively explains why stabilization among young judokas is strictly determined by the specific hip mechanics of the support leg, and not by generalized, bilateral joint mobility.

Previous studies generally state that judo training stimulates overall postural control (Maśliński et al., 2017; Jaworski et al., 2022). Importantly, studies indicate that a key factor influencing mobility and the quality of technique execution is training experience (Brito et al., 2025). Our results significantly refine these broad observations, bringing a new level of specificity to the current body of knowledge. Based on our results, practical recommendations should be directed toward judo coaches and motor coaches. Allowing early functional specialization (resulting in support leg dominance) to progress unchecked in prepubescent athletes could lead to unilateral overload injuries. Bearing in mind the critical developmental age of the subjects, coaches should mandate bilateral technical training (practicing throws on both the right and left sides equally) during the initial years of practice. Furthermore, targeted, unilateral strength training focusing on the eccentric control of the adductors and abductors of the non-dominant leg should be implemented into standard warm-up protocols to optimize stability and mitigate the observed asymmetries. Modern motor guidelines for combat sports and team sports emphasize that maintaining an optimal strength ratio of the adductor complex is critical for pelvic stabilization and the prevention of severe overuse injuries (Moreno-Pérez et al., 2021; Guan et al., 2022).

Limitations

When interpreting the obtained results, certain methodological limitations must be taken into account. First, the sample size was relatively small ($N=29$), which limits the possibility of broad, population-wide generalization of the conclusions. Second, the subjects were aged 7 to 14 years. This wide bracket indicates considerable heterogeneity in terms of biological development and ontogeny, which could have inherently influenced the baseline variability of the stabilometric results. Furthermore, the lack of a control group consisting of non-training peers prevents an unequivocal determination of the extent to which the specific patterns of balance control are the direct result of judo training, as opposed to natural, developmental predispositions.

Future directions

The conducted research serves as a foundational step for further analysis in the field of young and adolescent combat sports biomechanics. Expanding the study cohort and incorporating a cross-sectional control group would be justified to allow for a more comprehensive assessment. A key direction for future experimental research is verifying the specific role of the lower limb adductor muscles. It would be highly valuable to conduct longitudinal intervention studies checking whether the implementation of targeted training—specifically strengthening the eccentric control of the adductors—will actively reduce COP sway in young athletes. Additionally, future protocols should incorporate standardized functional tests (e.g., single-leg hop tests) to objectively determine the lead and support leg, rather than relying solely on self-declaration. Finally, striving for strict standardization of stabilometric measurement procedures in accordance with international consensus guidelines (Scoppa et al., 2013) is imperative to enable reliable comparisons across different sports institutions and global populations.

Conclusions

The present study provides evidence that the active range of motion (AROM) in the hip joint is significantly associated with static postural stability in prepubescent judo athletes. A key finding of this research is the pronounced functional asymmetry observed at an early stage of sports specialization. Unlike the general youth population, young judokas demonstrate a clear left-limb dominance in balance regulation. The theoretical contribution of this study lies in identifying the biomechanical origin of this asymmetry: the role of the left leg as the primary, weight-bearing support limb during the *kuzushi* and *tsukuri* phases of preferred right-sided throws. This suggests that unilateral, repetitive technical loading influences neuromuscular control and postural stability long before athletes reach elite competitive levels.

The practical implications of these findings are highly relevant for sports scientists, physiotherapists, and coaching staff involved in youth athletic development. While traditional judo training for youth emphasizes general motor development, our results indicate that without targeted interventions, the natural tendency toward unilateral throw execution may foster mobility-related stability deficits, particularly involving the adductor and abductor muscles of the support leg. To address this, it is recommended that sports academies implement a pedagogical shift toward bilateral technical training during the foundational years. Furthermore, strength and conditioning professionals should incorporate specialized, preventative warm-up protocols focused on the eccentric control and strength of the hip adductors in the non-dominant leg. These practices are essential for optimizing the mechanical efficiency of throws and mitigating long-term structural overloads and asymmetrical injuries.

Ultimately, this research emphasizes the need for a refined approach to monitoring and managing early specialization in combat sports. The sports science community should transition from generic balance assessments to highly specific, lateralized functional screenings. Future longitudinal studies are warranted to evaluate how targeted eccentric conditioning of the support limb's adductors affects Center of Pressure (COP) sway over a training macrocycle. By recognizing and actively managing these early asymmetrical adaptations, practitioners can establish safer and more scientifically grounded developmental pathways for young athletes.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors did not use AI and AI-assisted technologies in the writing process.

Conflicts of interest The authors declare no conflict of interest.

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