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ANALYSIS OF DYNAMIC BALANCE PARAMETERS IN YOUNG JUDOKAS

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Abstract: *This study evaluated dynamic balance in female judokas using the Sensamove Miniboard. Parameters included overall performance, dynamic lateral balance (DLB), vertical balance (DVB) and average deviations. Average performance was 78.67 % for DLB and 83.87 % for DVB, indicating superior vertical stability. The largest deviations occurred in the back-inside position, with the highest variability in left-side deviation. DLB correlated significantly with overall performance (R = 0.593, p = 0.017), whereas DVB did not (R = –0.038, p = 0.892). A t-test confirmed significant DLB–DVB differences. Targeted training to enhance lateral stability, especially backward control, is recommended to optimize postural balance.*

Key words: *lateral balance, vertical balance, performance, deviations, statistical analysis.*

1. Introduction

Dynamic balance is an essential component of athletic performance, particularly in combat sports such as judo, where athletes must maintain postural stability while executing rapid and forceful movements [1], [12], [16]. The ability to control one’s center of mass during offensive and defensive maneuvers can significantly influence technical execution, injury prevention and overall competitive success [19].

Judo training inherently involves movements that enhance proprioception, neuromuscular coordination, and balance control [15], [17]. Several studies highlight the positive impact of judo practice on both static and dynamic balance in young athletes [9], [16]. It was shown that regular participation in judo improves postural control, motor skills and lower limb strength, all of which contribute to enhanced balance capabilities [22]. Furthermore, elite-level youth judokas exhibit superior dynamic balance and

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coping skills, consistent with international competitive performance [21].

In comparison with other combat sports, such as wrestling and Brazilian jiu-jitsu, judo practitioners demonstrate specific balance adaptations due to the emphasis that this sport gives on throws, grips and falls [4], [20]. These adaptations involve neuromuscular responses that enhance postural stability and reactivity, reducing the risk of lower limb injuries [3], [10], [11], [18].

Furthermore, training methodologies incorporating neurofeedback and proprioceptive exercises have been suggested as effective tools for optimizing dynamic balance in judokas [13].

Given the importance of balance control in judo, recent research has focused on assessing the developmental aspects of dynamic balance in young practitioners. Studies have investigated how training experience, competitive level and anthropometric characteristics influence postural stability [8]. Also, factors such as foot arch structure and asymmetries in limb control have been identified as potential determinants of balance performance in young judokas [7].

In this context, assessing dynamic balance is essential for understanding postural adaptation mechanisms and for identifying effective training strategies in youth athletes.

Analyzing these parameters contributes both to the optimization of technical-tactical performance and to the development of injury-prevention programs tailored to the specific requirements of judo.

This study aims to analyze the parameters of dynamic balance in young judokas, considering the influence of training experience, sport-specific demands and neuromuscular adaptations. By examining key balance indicators, the research tries to provide important insights into performance optimization and injury prevention strategies in youth judo development.

2. Methods

The study was conducted in February 2025, to assess the dynamic balance in female judokas, members of the national junior team, using the Sensamove Miniboard platform (duration: 20 seconds, maximum tilt angle: 10°). The analyzed parameters included overall performance, lateral balance (front-back inside), vertical balance (left-right inside) and average deviations.

Dynamic balance analysis was performed using descriptive and correlational statistical methods in the KyPlot program. Mean values, coefficient of variation (CV%), mean deviations and other relevant statistical indicators were calculated, such as the confidence level of the mean (95% Confidence Interval), quartile deviation (Q Dev.), Pearson correlation coefficient (R), Student's t-test and statistical significance level (P, $p<0.05$).

3. Results

Table 1 presents the descriptive and correlation analysis of the dynamic balance parameters, highlighting the mean values, coefficient of variation (CV%), mean deviations, confidence level of the mean (CLM 0.95) and standard deviations (Q Dev.). There are also shown the correlation coefficients (R), **t** values and statistical significance level (P) for the dynamic lateral balance (DLB) and the dynamic vertical balance (DVB).

Descriptive and correlation analysis of the dynamic balance indices Table 1

Parameters		Balance	Mean	CV(%)	Mean dev.	CLM (0.95)	Q Dev.	R	t	P
Perf. (%)		DLB	78.67	12.68	8.67	5.52	6.75	0.593	2.66*	0.017
		DVB	83.87	12.02	8.60	5.58	8.25			
Inside	front	DLB	36.27	22.36	6.34	4.49	4.00	-0.038	0.139	0.892
(%)	left	DVB	47.67	25.75	10.86	6.79	8.00			
Inside	back	DLB	42.13	29.42	10.13	6.86	7.25	0.115	0.42	0.684
(%)	right	DVB	36.2	32.95	10.17	6.61	6.50			
Front, avg. dev. (deg.)		DLB	1.59	28.32	0.37	0.25	0.27	0.506	2.11	0.054
		DVB	4.33	24.05	0.78	0.57	0.40			
Back, avg. dev. (deg.)		DLB	-1.49	29.61	0.38	0.24	0.33	0.439	1.76	0.101
		DVB	-4.13	17.97	0.59	0.41	0.48			
Left, avg. dev. (deg.)		DLB	-3.73	23.71	0.76	0.49	0.56	0.222	0.821	0.426
		DVB	-1.39	30.92	0.35	0.24	0.28			
Right, avg. dev. (deg.)		DLB	3.93	22.08	0.74	0.48	0.48	0.491	2.03	0.063
		DVB	1.21	41.33	0.42	0.27	0.25			

Notes: DLB – dynamic lateral balance; DVB – dynamic vertical balance; *p< 0.05

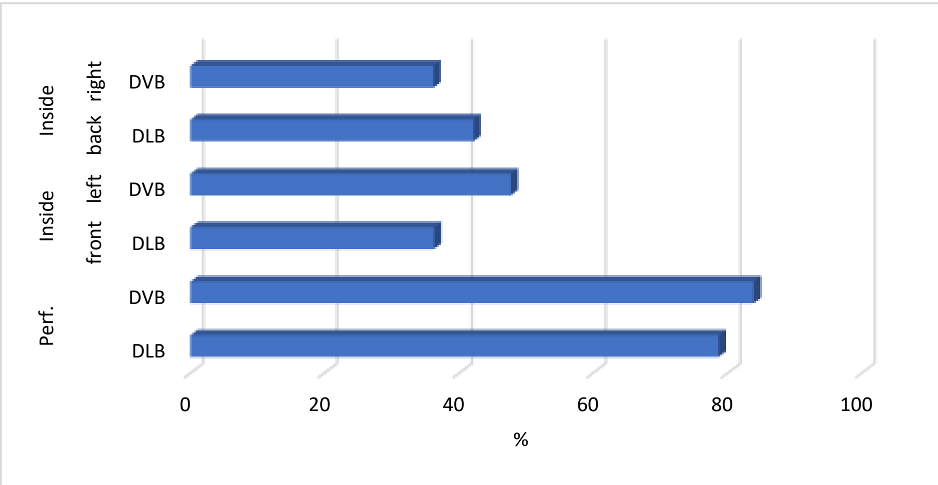

Fig. 1. *Performance and inside position of the dynamic balance*

The results presented in Table 1 and Figure 1 showed an average performance of 78.67% for the dynamic lateral balance (DLB) and 83.87% for the dynamic vertical balance (DVB), suggesting better stability in the vertical direction. The largest deviations were found in the back inside position (42.13% for DLB, 36.2% for DVB), while the coefficient of variation was higher for the left average deviation, indicating an increased variability.

Correlation analysis revealed a significant correlation between DLB and overall performance (R = 0.593*, p = 0.017), whereas DVB did not significantly influence performance

(R = -0.038, p = 0.892). The t-test indicated significant differences between DLB and DVB (t = 2.66, p = 0.017).

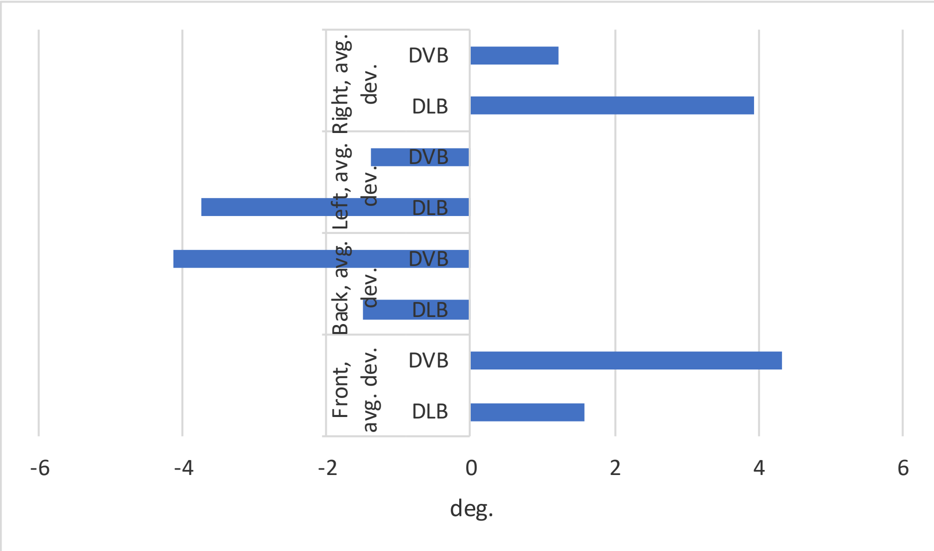

Fig. 2. *Average deviation of the dynamic balance*

Figure 2 shows the mean deviations (in degrees), revealing a greater tendency toward oscillation for the dynamic vertical balance (DVB) in frontal plane (4.33° vs. 1.59° for the dynamic lateral balance, DLB) and in posterior plane (-4.13° vs. -1.49°), reflecting a larger amplitude of movement in vertical direction. The highest coefficients of variation were observed for the right-side average deviation in DVB (41.33 %) and for the left-side average deviation in DLB (23.71 %), highlighting areas of increased directional variability.

Directional analyses identified moderate but statistically non-significant correlations (p > 0.05) between frontal deviations and overall performance (R ≈ 0.50, p = 0.054 for DLB), as well as between lateral deviations and performance (R ≈ 0.49, p = 0.063 for DLB). This fact suggests a potential influence of fronto-lateral control on overall postural stability.

In comparative terms, the athletes demonstrated better vertical stability; however, overall performance depended significantly on lateral balance. The greater variability observed in vertical deviations indicates that targeted exercises aimed at enhancing lateral control may bring greater benefits for optimizing dynamic balance and overall performance.

4. Discussion

The aim of this study was to analyze the lateral and vertical dynamic balance in athletes and determine their influence on performance. The results highlight the importance of developing lateral balance as a key factor in optimizing motor performance. Based on these findings, it is recommended to integrate specific lateral stabilization exercises into training programs to reduce postural variations and improve balance control in competitive situations. These conclusions are supported by previous studies that emphasize differences in static and dynamic balance based on gender and type of sport practiced [2], [5].

The present findings highlight several key aspects of dynamic balance control that guarantee careful interpretation in the context of motor performance and postural regulation. First, the higher mean performance in dynamic vertical balance (DVB) compared with dynamic lateral balance (DLB) suggests that the athletes have superior stability in the vertical plane. This is consistent with previous evidence indicating that vertical postural adjustments rely more heavily on well-trained vestibular and proprioceptive mechanisms, which may be more effectively stimulated through regular athletic training. Nevertheless, the significant relationship between DLB and overall performance ($R = 0.593$, $p = 0.017$) underscores the functional importance of lateral balance for sport-specific tasks. Many sport movements, including directional changes, rapid accelerations and decelerations, require fine lateral control, making this aspect a critical determinant of performance. This proves that the study participants have better stability in the vertical plane, which may indicate a biomechanical adaptation specific to the requirements of the analyzed sport discipline. These observations align with research emphasizing the importance of dynamic stabilization training in improving lower limb biomechanics [14].

The greater oscillation amplitudes recorded for DVB in both the frontal (4.33°) and posterior (-4.13°) planes, compared with DLB, indicate that while vertical stability is maintained at a high average level, it is also subject to larger instantaneous deviations. This pattern may reflect the dynamic demands placed on the vertical control system, where micro-adjustments are frequent and necessary for maintaining equilibrium under varying perturbations.

The deviation analysis shows that the highest variations were recorded in the back inside position (42.13% for DLB and 36.2% for DVB), which may reflect greater difficulty in maintaining balance in this direction, possibly due to the postural strategies used or specific neuromuscular demands. Additionally, the high coefficient of variation for left average deviation indicates increased variability, suggesting a postural asymmetry that could influence balance control.

Although directional correlations between frontal and lateral deviations with performance were only moderate and failed to reach statistical significance ($p > 0.05$), the effect sizes ($R \approx 0.50$) reflect a practical relevance. The data imply that improved control in fronto-lateral movements may contribute significantly to overall dynamic stability, even if the current sample size limited statistical power. From an applied perspective, these tendencies justify targeted training aimed at enhancing the integration of lateral and anterior–posterior control mechanisms.

The correlational analysis revealed a significant association between DLB and overall performance ($R = 0.593$, $p = 0.017$), highlighting that better lateral balance directly contributes to stability and efficiency in sport-specific movements. On the other hand, DVB did not show a significant influence on overall performance ($R = -0.038$, $p = 0.892$), indicating that vertical stability is not a major determining factor in this context. The t-test results confirmed significant differences between DLB and DVB ($t = 2.66$, $p = 0.017$), indicating the relevance of lateral balance in relation to the motor demands of the analyzed athletes. These findings are consistent with the specialized literature, which emphasizes that balance differences can be influenced by the specificity of the sport practiced and the postural strategies adopted [2], [5], [14].

In comparative terms, the results prove that overall sports performance depends more on lateral than on vertical balance, despite the latter showing better average stability. This apparent paradox highlights that lateral balance may be more functionally specific to the requirements of dynamic sport actions. Consequently, training programs focused on increasing lateral stability—for example, through perturbation-based balance drills, side-to-side hopping, and unstable-surface exercises—are likely to provide greater gains in performance than aiming solely at vertical balance enhancement.

Taking together, these findings reinforce the concept that dynamic balance is a multi-dimensional construct, in which the quality of lateral control plays a decisive role in competitive settings. Future research should explore longitudinal interventions to confirm whether targeted lateral-balance training translates into measurable improvements in sport-specific performance and injury prevention.

5. Conclusions

Dynamic lateral balance plays a crucial role in optimizing motor performance, as better stability in the lateral plane contributes to improved movement efficiency and control in sports. Training programs should incorporate specific exercises to enhance lateral stability.

Athletes demonstrate greater stability in the vertical plane compared to the lateral plane, proving a natural biomechanical adaptation. However, the significant differences between the two suggest that lateral balance requires more targeted development in training.

Postural asymmetries and increased variability in specific movement directions point out the need for individualized balance training. Reducing these imbalances through specialized exercises can lead to better neuromuscular coordination and overall stability.

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