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Lateral Dominance In Strength And Stability Among Higher Education Students

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Abstract: *Lateral dominance influences motor performance in various physical tasks, with the dominant side typically demonstrating superior strength capabilities. This study investigated differences between dominant and non-dominant sides in handgrip strength and single leg stability among first-year university students to understand how lateral dominance manifests across different motor control systems. Twenty-nine healthy higher education students (15 male and 14 female; height 172.6±8.8 cm; weight 69.2±9.6 kg; age 20.5±1.9 years) were recruited from a first-year physiotherapy university class. All subjects were right leg and hand dominant. Students underwent handgrip strength testing and single leg stability assessments for both dominant and non-dominant sides. Handgrip strength measured maximum force production, while single leg tests measured sway path length and oscillation area during 10 seconds of single leg standing. Paired t-test analysis compared dominant and non-dominant sides with significance set at $p<0.05$. Dominant handgrip force production was significantly higher compared to non-dominant (40.5±10.6 kg vs 39.0±10.3 kg; $p=0.019$), but no differences were measured between sides for single leg stability. Sway path length was similar between dominant and non-dominant sides (32.4±9.8 cm vs 31.8±14.5 cm; $p=0.808$), as was oscillation area (22.4±16.6 cm^2 vs 16.7±19.4 cm^2; $p=0.160$). The findings demonstrate that lateral dominance significantly affects handgrip strength but not single leg stability in young university students. These results suggest that dominance patterns may be task-specific and that training programs should consider bilateral development for balance while addressing potential asymmetries in strength.*
Keywords: *handgrip strength, lateral dominance, postural stability, single leg stance, university students.*

1. INTRODUCTION

Lateral dominance represents a fundamental characteristic of human motor behavior, with most individuals demonstrating preferential use of one side of the body for skilled movements. This phenomenon extends beyond simple handedness to encompass complex motor tasks involving strength, coordination, and postural control [1]. The neural mechanisms underlying lateral dominance involve complex interactions between cortical and subcortical structures, with the contralateral hemisphere typically exhibiting greater activation during dominant limb movements. Recent neuroimaging studies have revealed that dominance patterns are associated with asymmetric activation in primary motor cortex, supplementary motor area, and cerebellum, suggesting a distributed neural network governing lateral preferences. Understanding how dominance manifests across different motor systems is crucial for developing effective training and rehabilitation programs, particularly in young adults transitioning to university life.

Research has consistently demonstrated superior performance of the dominant side in strength-related tasks, with handgrip strength serving as a reliable indicator of overall muscular function and general health status [2]. Wind et al. demonstrated that grip strength correlates significantly with total muscle strength across different age groups, establishing it as a valid proxy measure for overall muscular capacity. The dominant hand typically exhibits 5-15% greater force production compared to the non-dominant side in healthy populations. This asymmetry emerges early in development and persists throughout the lifespan, influenced by both genetic predisposition and environmental factors including task-specific practice and cultural preferences.

Recent systematic review by Szaflik et al. [11] has further validated handgrip strength as a comprehensive indicator of functional performance, emphasizing its clinical relevance beyond simple force production.

However, the relationship between dominance and postural control systems appears more complex, with conflicting evidence regarding bilateral differences in balance performance [3]. Alammari and colleagues recently demonstrated that contralateral sensory input can significantly influence single-leg stance stability, suggesting that postural control may rely more heavily on bilateral integration and compensatory mechanisms that minimize dominance effects.

The neuromuscular adaptations associated with lateral dominance extend beyond simple force production differences. Histological studies have demonstrated variations in muscle fiber composition between dominant and non-dominant limbs, with the dominant side typically showing greater proportion of type II fibers conducive to rapid force development. Additionally, corticospinal excitability differs between hemispheres, with lower motor threshold and higher motor evoked potential amplitudes observed for dominant limb representations.

These neurophysiological asymmetries contribute to the complex manifestation of dominance across different motor tasks. Migliaccio et al. [8] demonstrated differential muscle activation patterns between skill levels during vibration training, suggesting that neuromuscular adaptations to external stimuli vary based on baseline motor competence and dominance patterns.

University students represent a unique population experiencing significant lifestyle transitions that may impact their physical fitness and motor control capabilities [4]. Kljajević and colleagues' systematic review revealed concerning trends in physical activity levels among university students, with significant declines observed during the transition to higher education. The sedentary nature of academic life, combined with reduced structured physical activity, can lead to changes in neuromuscular function and postural control. Academic stress, irregular sleep patterns, and dietary changes further compound these effects, potentially altering motor performance patterns established during adolescence.

Deforche et al. [9] documented substantial changes in weight, physical activity, and dietary patterns during the transition to university, with particular vulnerability in maintaining structured exercise routines. Understanding baseline dominance patterns in this population is essential for designing appropriate intervention strategies that account for the specific challenges faced by university students. Single leg stance represents a fundamental motor skill requiring integration of multiple sensory systems including visual, vestibular, and proprioceptive inputs. The complexity of maintaining upright posture on one leg involves continuous adjustments at multiple joints, with ankle strategies predominating in stable conditions and hip strategies emerging with increased perturbation. Promsri et al. [1] revealed that lower limb dominance significantly influences postural control strategies during single-leg stance, with distinct neuromuscular patterns observed between dominant and non-dominant limbs. While some studies suggest dominant leg superiority in dynamic tasks, static balance performance may not follow the same dominance patterns observed in strength measures.

This discrepancy highlights the need for task-specific analysis of dominance effects and suggests that different motor control strategies may govern various aspects of human movement. The assessment of postural stability has evolved considerably with technological advances, moving from simple clinical tests to sophisticated biomechanical analyses. Force platform technology enables quantification of center of pressure dynamics, providing insights into the complex interplay between sensory feedback and motor output during balance tasks. Padulo et al. [6] validated innovative assessment methodologies for isometric strength testing, demonstrating the importance of standardized, reliable measurement protocols in detecting bilateral differences.

These objective measures have revealed subtle bilateral differences not apparent through observational assessment, emphasizing the importance of instrumented evaluation in understanding dominance effects. The integration of wearable technologies, as reviewed by Migliaccio et al. [7], offers new opportunities for continuous monitoring of motor performance and detection of marginal gains in athletic populations, with potential applications for assessing dominance patterns in daily activities.

The purpose of this investigation was to examine lateral dominance patterns in both strength and stability measures among first-year university students, providing insight into how motor dominance manifests across different functional systems in this population. This study aims to contribute to the growing body of evidence regarding task-specific dominance effects and their implications for targeted training interventions.

2. METHODS

2.1Participants: Twenty-nine healthy higher education students (15 males, 14 females; height 172.6±8.8 cm; weight 69.2±9.6 kg; age 20.5±1.9 years) were recruited from a first-year physiotherapy university class. All participants were confirmed as right-hand and right-leg dominant through standardized dominance questionnaires based on the Edinburgh Handedness Inventory and Waterloo Footedness Questionnaire. Dominance determination involved multiple criteria including preferred hand for writing, throwing, and tool use, as well as preferred leg for kicking, hopping, and single-leg balance recovery. The laterality quotient was calculated for each participant, with scores >40 confirming right-side dominance. Inclusion criteria required absence of musculoskeletal injuries in the preceding 12 months and no neurological conditions affecting balance or coordination. Participants maintained regular physical activity levels typical of university students, with no specialized athletic training that might influence bilateral motor patterns. The recruitment process considered the findings of Stodden et al. [10] regarding motor skill proficiency barriers in young adults, ensuring participants represented typical university-level motor competence. Exclusion criteria included history of lower extremity surgery, vestibular disorders, uncorrected visual impairments, and current use of medications affecting balance or neuromuscular function.

2.2Testing Protocol: Students underwent comprehensive fitness assessments following standardized protocols established in previous research:

a. *Handgrip Strength Assessment:* Maximum isometric handgrip strength was measured using a calibrated digital dynamometer (Takei Digital Grip Strength Dynamometer, T.K.K.5401, Japan) following protocols validated in recent systematic reviews [11]. Participants maintained a seated position with the arm at 90° elbow flexion, wrist in neutral position, and shoulder adducted and neutrally rotated. The testing position was standardized according to American Society of Hand Therapists recommendations to ensure measurement reliability. The dynamometer handle was adjusted to accommodate individual hand size, ensuring optimal grip position at the second metacarpophalangeal joint. Three maximal voluntary contractions were performed for each hand with 60-second rest intervals, and the highest value was recorded for analysis. This protocol aligns with recommendations from Wind et al. [2] for accurate assessment of grip strength as an indicator of total muscle strength. Verbal encouragement was provided consistently across all trials to ensure maximal effort, using standardized phrases to maintain testing consistency. The testing sequence alternated between hands to minimize fatigue effects, with the starting hand randomized across participants.

b. *Single* Leg *Stability Testing:* Postural stability was assessed during 10-second single leg stance trials using force platform technology (AMTI AccuSway Plus, Advanced Mechanical Technology Inc., USA) sampling at 100 Hz, following methodologies similar to those employed by Promsri et al. [1]. The force platform was calibrated before each testing session according to manufacturer specifications, with verification of accuracy using known weights. Participants stood barefoot with hands placed on hips, maintaining single leg stance with eyes open while focusing on a target positioned at eye level 3 meters away. The standardized visual target consisted of a 5 cm black circle on white background to ensure consistent visual input across participants. The non-stance leg was maintained at approximately 90° knee flexion without contact with the stance leg, following protocols described by Alammari et al. [3] for single-leg stance assessment. Foot position was standardized using platform markings to ensure consistent placement across trials, with the great toe aligned to a reference line and heel position marked for reproducibility.

Two primary outcome measures were recorded: sway path length (total distance of center of pressure displacement) and oscillation area (elliptical area encompassing 95% of center of pressure data points). Secondary measures included mean velocity, anterior-posterior and medial-lateral displacement ranges, and frequency domain parameters. Three trials were performed for each leg with 30-second rest between trials and 2-minute rest between legs to prevent fatigue.

Failed trials, defined as loss of balance requiring foot touchdown, excessive arm movement (>45° from starting position), or opening of the eyes during eyes-closed conditions, were repeated after additional rest. Data processing involved fourth-order Butterworth low-pass filtering at 10 Hz cutoff frequency, with the first and last seconds of each trial excluded from analysis to eliminate transient effects.

- **Testing Environment and Procedures:** All assessments were conducted in a controlled laboratory environment at consistent temperature (21±2°C) and humidity conditions (45-55% relative humidity), recognizing the potential influence of environmental factors on performance. Testing order was randomized between participants using a computer-generated sequence to minimize learning effects and systematic bias. A standardized warm-up consisting of 5 minutes light walking on a treadmill at self-selected pace, followed by dynamic stretching focusing on lower extremity muscle groups (gastrocnemius, hamstrings, quadriceps, hip flexors), was performed prior to testing. The warm-up protocol incorporated elements from Russo et al. [5] regarding the importance of posterior chain flexibility for optimal motor performance. Participants wore standardized athletic clothing (shorts and t-shirt) and were instructed to avoid caffeine consumption for 4 hours and vigorous exercise for 24 hours before testing. Testing sessions were scheduled between 9:00 AM and 12:00 PM to control for circadian rhythm effects on neuromuscular performance. Hydration status was monitored using urine specific gravity, with values between 1.010-1.020 considered acceptable for testing.

2.3Statistical Analysis: Descriptive statistics (mean ± standard deviation) were calculated for all measures. Data distribution was assessed using Shapiro-Wilk tests, Q-Q plots, and examination of skewness and kurtosis values. Paired t-tests were used to compare dominant versus non-dominant side performance for normally distributed variables, with Wilcoxon signed-rank tests employed for non-normal distributions. Effect sizes (Cohen's d) were calculated to determine the magnitude of differences, with interpretations of small (0.2-0.49), medium (0.5-0.79), and large (≥0.8) effects. Statistical significance was set at $p<0.05$, with Bonferroni corrections applied for multiple comparisons where appropriate. All analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY) and confirmed using R statistical software (version 4.1.0) for robustness. Pearson correlation coefficients were calculated to examine relationships between strength asymmetry and balance performance parameters. Additionally, a symmetry index was calculated as [(dominant-nondominant)/((dominant+nondominant)/2) × 100] to quantify the percentage difference between sides, following recommendations for bilateral comparison studies. Intraclass correlation coefficients (ICC 3,1) were calculated to assess test-retest reliability for all measures, with values >0.75 considered excellent, 0.40-0.75 moderate, and <0.40 poor reliability.

3. RESULTS

Significant bilateral differences were observed in handgrip strength but not in postural stability measures (Table I). Dominant handgrip strength was significantly greater than non-dominant strength (40.5±10.6 kg vs 39.0±10.3 kg; p=0.019), representing a 3.8% difference with moderate effect size (d=0.45). This finding confirms the expected dominance pattern for strength measures in university students, aligning with previous research [2,11]. Individual analysis revealed that 72% of participants demonstrated higher strength in their dominant hand, while 28% showed either equivalent or reversed patterns, highlighting individual variability in dominance expression. The symmetry index for handgrip strength averaged 3.7±8.2%, with values ranging from -15.3% to 18.6%, indicating substantial inter-individual variation in bilateral strength relationships.

Gender-stratified analysis revealed interesting patterns consistent with known sex differences in muscle strength. Males showed slightly greater absolute asymmetry (4.2±7.9%) compared to females (3.1±8.5%), though this difference was not statistically significant (p=0.724). The absolute handgrip strength values showed expected gender differences, with males averaging 48.3±6.8 kg (dominant) and 46.5±6.4 kg (non-dominant), while females averaged 32.1±5.2 kg (dominant) and 30.9±5.0 kg (non-dominant). These values align with normative data for university-aged populations and support the use of handgrip strength as a valid indicator of overall muscular function [11].

Conversely, no significant differences were found between dominant and non-dominant legs for either postural stability measure, supporting the findings of recent balance studies [1,3]. Sway path length showed nearly identical values between sides (32.4±9.8 cm vs 31.8±14.5 cm; p=0.808), with minimal effect size (d=0.05). Similarly, oscillation area demonstrated no significant bilateral difference (22.4±16.6 cm^2 vs 16.7±19.4 cm^2; p=0.160) despite the non-dominant leg showing slightly smaller values. The trend toward better stability on the non-dominant leg, though not statistically significant, may reflect compensatory adaptations or different motor control strategies between limbs as suggested by Promsri et al. [1]. Analysis of secondary balance measures revealed similar patterns, with mean velocity showing no significant difference (3.2±1.0 cm/s vs 3.1±1.4 cm/s; p=0.771) between dominant and non-dominant legs.

Frequency domain analysis of postural sway revealed interesting patterns not captured by traditional measures. The median frequency of sway was similar between limbs (0.28±0.08 Hz dominant vs 0.29±0.09 Hz non-dominant; p=0.642), suggesting comparable neuromuscular control strategies. However, power

spectral density analysis showed slightly higher low-frequency content (<0.5 Hz) in the dominant leg, potentially indicating greater reliance on visual and vestibular inputs, while the non-dominant leg showed higher high-frequency content (>1 Hz), suggesting enhanced proprioceptive contributions.
The coefficient of variation for handgrip strength was relatively low for both sides (26.2% dominant, 26.4% non-dominant), indicating consistent measurement reliability. Test-retest reliability analysis showed excellent ICC values for handgrip strength (ICC=0.94 dominant, 0.93 non-dominant). Postural stability measures showed higher variability, particularly for oscillation area (74.1% dominant, 116.2% non-dominant), reflecting the complex nature of balance control and individual differences in postural strategies. This high variability suggests that factors beyond simple dominance, such as previous injury history, physical activity patterns, and individual motor control strategies, may influence postural stability performance.
Correlation analysis revealed no significant relationship between handgrip strength asymmetry and balance performance asymmetry (r=0.08, p=0.674), suggesting that dominance effects in strength and postural control represent independent phenomena. This finding aligns with the concept of task-specific dominance expression and supports differential assessment approaches for various motor capabilities. Additional correlational analyses showed weak relationships between anthropometric variables and asymmetry indices, with height showing the strongest correlation with balance asymmetry (r=0.21, p=0.271), though this did not reach statistical significance.

Table 1: Bilateral Comparison of Strength and Stability Measures

Parameter	**Dominant Side**	**Non-Dominant Side**	**p-value**	**Effect Size (d)**
Handgrip Strength (kg)	40.5 ± 10.6	39.0 ± 10.3	0.019*	0.45
Sway Path Length (cm)	32.4 ± 9.8	31.8 ± 14.5	0.808	0.05
Oscillation Area (cm^2)	22.4 ± 16.6	16.7 ± 19.4	0.160	0.32

*p<0.05; Data presented as mean ± standard deviation

The coefficient of variation for handgrip strength was relatively low for both sides (26.2% dominant, 26.4% non-dominant), indicating consistent measurement reliability. Postural stability measures showed higher variability, particularly for oscillation area (74.1% dominant, 116.2% non-dominant), reflecting the complex nature of balance control and individual differences in postural strategies. This high variability suggests that factors beyond simple dominance, such as previous injury history, physical activity patterns, and individual motor control strategies, may influence postural stability performance.

4. Conclusions

The observed bilateral asymmetry in handgrip strength aligns with extensive literature documenting dominance effects in force production tasks [2,11]. The 3.8% difference falls at the lower end of the typical 5-15% range, possibly reflecting university students' predominantly bilateral daily activities. Static single-leg stance may not provide sufficient challenge to reveal bilateral differences that might emerge during dynamic assessments. Alammari et al. [3] demonstrated that additional sensory input can significantly alter single-leg stance performance, suggesting our protocol may not have adequately challenged sensory integration systems. Our findings support the dynamic dominance hypothesis, positing that each hemisphere/limb system has developed specialized control capabilities. Migliaccio et al. [8] provided additional support through their work on differential muscle activation patterns during vibration training. The high variability in postural stability measures reflects individual differences in control strategies and the influence of lifestyle factors documented by Kljajević et al. [4] and Deforche et al. [9]. Advanced technologies reviewed by Migliaccio et al. [7] offer promising avenues for more sensitive bilateral difference detection.

Limitations: The small sample size limited statistical power (0.82 for handgrip, 0.31 for balance). The homogeneous sample of physiotherapy students with higher physical literacy may limit generalizability [10]. Dynamic balance tasks or fatigue protocols might reveal differences not apparent in static conditions. The influence of posterior chain flexibility [5] was not assessed. The cross-sectional design prevents assessment of how dominance patterns change over time. Technical limitations include the 10-second balance trial duration and absence of electromyographic assessment.

Practical Applications: Strength training programs should emphasize non-dominant limb development to address observed asymmetry. Handgrip strength asymmetry can serve as a screening tool, as supported by

Szaflik et al. [11]. Technology-based assessment tools [7] may provide sensitive detection of bilateral differences. Preventive programs should address strength and balance components independently. Russo et al. [5] suggest that addressing posterior chain flexibility could enhance both strength and balance performance.
Sport-specific applications should consider differential dominance patterns. The concept of marginal gains [7] suggests that addressing small asymmetries could improve overall performance. Implementation strategies should include regular bilateral assessment [6,11], targeted interventions for significant asymmetries, and education about bilateral motor development.
Future Directions: Longitudinal studies should track dominance patterns throughout university education. Advanced assessment technologies could reveal subtle dominance effects. Investigation of training intervention effects on bilateral symmetry would inform program design. Cross-cultural studies could examine environmental influences on dominance development.
This investigation reveals task-specific lateral dominance patterns, with significant handgrip strength asymmetries but bilateral postural stability symmetry. The 3.8% strength advantage confirms motor dominance in force production [2,11], while absent balance effects suggest symmetric postural control development [1,3].
These findings support comprehensive approaches recognizing distinct neural control mechanisms [8]. Modern technological approaches [7] may detect subtle bilateral differences. The skill-dependent responses suggest training adaptations vary with motor demands [10]. Future interventions should consider individual differences, particularly given university lifestyle challenges [4,9].
The findings emphasize comprehensive assessment approaches evaluating multiple motor functions. Validated assessment methods [6] and handgrip strength understanding [11] provide the foundation for effective screening and intervention programs in university populations.

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