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Initial study on Hand Grip Asymmetry in Lebanese Adults: An Advanced Model Integrating Maximal and Explosive Strength

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ABSTRACT

This study introduces a refined model of hand grip asymmetry tailored to the Lebanese population, incorporating both maximal strength (F_{max}) and explosive strength (RFD_{max}). Unlike previous models that primarily focused on maximal strength, this dual-parameter approach provides a more comprehensive assessment of hand grip asymmetry, offering insights into functional health and injury risk. Given the absence of prior data on this population, the model establishes baseline asymmetry thresholds to support clinical evaluations and performance assessments. A total of 393 healthy adults (241 males, 152 females) from various Lebanese regions underwent hand grip assessments measuring F_{max} and $RFD_{max}$for both the dominant (DH) and non-dominant hands (NDH). Asymmetry levels were computed separately for handgrip strength and handgrip explosive strength, and participants were classified into four asymmetry groups: low (0–10%), moderate (10.1–20%), high (20.1–30%), and very high (>30%) based on asymmetry percentage thresholds. Results indicated that males demonstrated approximately 44% greater hand grip strength (F_{max}) and 47% higher RFD_{max} than females across both hands ($p < 0.001$). A dominant hand advantage was observed, with a 6.9% higher Fmax in males and a 7.9% difference in females ($p < 0.001$). While overall asymmetry did not differ significantly between genders, females exhibited slightly higher asymmetry in RFD_{max}. Notably, explosive strength asymmetry was more pronounced than maximal strength asymmetry, suggesting it may serve as a stronger indicator of neuromuscular control and injury risk. This model serves as a key reference for understanding hand grip asymmetry in the Lebanese population, establishing normative benchmarks that may aid in health risk identification and functional assessments. Future research should explore age-related trends and cross-population comparisons to further evaluate the impact of hand grip asymmetry on performance and health outcomes.

Keywords: hand grip strength (HGS); health risk assessment; asymmetry levels; biomarkers in muscular asymmetry; population-specific model

INTRODUCTION

Symmetry in limbs, defined as differences in size, shape, or function between two corresponding limbs, can stem from factors like genetic predispositions, developmental anomalies, injuries, or certain medical conditions affecting growth and muscle development (Gutnik et al., 2015; Bardo et al., 2021). While minor asymmetry may have little impact on daily activities, significant discrepancies can impair mobility and overall physical performance (McGrath et al., 2022). Limb strength differences, often between the dominant and non-dominant sides, critically influence physical capabilities. These differences may result from habitual use of one side or conditions that weaken one limb (McGrath et al., 2022). Addressing such imbalances is vital to prevent compensatory movements that can strain other body parts, increasing injury risk.

Hand grip strength (HGS) asymmetry, specifically, refers to the variance in strength between the dominant hand (DH) and non-dominant hand (NDH), which can affect a range of daily tasks, from basic functions like opening jars to complex athletic movements (McGrath et al., 2022). Research has identified HGS asymmetry as a potential biomarker in health assessments due to its associations with risks like morbidity, cognitive decline, mortality, and fall risk. Recent studies have applied percentage-based classifications of asymmetry (e.g., ≥10%, ≥20%, ≥30%) to evaluate health risk thresholds, providing a standardized approach for categorizing asymmetry severity in population studies (McGrath et al., 2021). Studies indicate that a 10% increase in HGS asymmetry correlates with a 1.21-fold higher risk for conditions such as hypertension, diabetes, and cardiovascular disease (McGrath et al., 2020). Additionally, older adults with HGS asymmetry face increased cognitive impairment risks, such as motoric cognitive risk syndrome and other neurodegenerative conditions (Abudukelimu et al., 2024; Peng et al., 2024).

Furthermore, the coexistence of low HGS and asymmetry heightens all-cause mortality risk, especially among those with abdominal obesity, linking these imbalances to poorer health outcomes (Wang et al., 2024). Asymmetric HGS has also been associated with a higher incidence of falls, particularly among individuals with significant strength differences between hands (Baek et al., 2023). These findings highlight the importance of including both HGS strength and asymmetry in health assessments, providing critical insights into functional health and well-being. However, most studies on HGS asymmetry focus only on maximal force (F_{max}), neglecting the role of explosive strength (RFD_{max}), which may offer unique insights (Aeles et al., 2022).

Currently, no data exist on hand grip asymmetry within the Lebanese population, making it difficult to assess whether an individual's asymmetry level signifies health complications or falls within a healthy range. Additionally, studies have rarely assessed asymmetry using multiple HGS parameters. This study aims to develop an enhanced model of hand grip asymmetry for the Lebanese adult population, incorporating both maximal hand grip strength and explosive strength parameters. By expanding the traditional assessment to include explosive strength asymmetry, this model provides a more comprehensive approach to identifying acceptable versus potentially harmful asymmetry levels, specifically adapted to a demographic for which no prior data on hand grip asymmetry exist.

METHOD

Participants

A total of 393 healthy adult participants were recruited for this study, including 241 males and 152 females from diverse training backgrounds and regions throughout Lebanon. Their basic characteristics are presented in Table 1. Each participant provided written informed consent, and the study received ethical approval from the Antonine University Ethical Committee (Code 413, Ref No. 1675-2023). Eligibility criteria required participants to be free from limb injuries and hormonal disorders. To ensure test reliability and validity, participants were also instructed to abstain from intense physical activity for 48 hours before testing and to fast for at least 1.5 hours. This study was conducted in compliance with the Declaration of Helsinki (Christie, 2000).

Table 1. Participant characteristics by gender among the Lebanese population

Variable	Mean ± SD (Males n = 241)	Mean ± SD (Females n =152)
Age (years)	32.18 ± 13.95	32.52 ± 14.54
Body Height (cm)	177.34 ± 7.39	163.60 ± 6.03
Body Mass (kg)	82.80 ± 14.50	64.58 ± 12.23
Body Mass Index (kg/m²)	26.32 ± 3.99	24.14 ± 4.48
Weekly Training Time (minutes)	310.71 ± 358.31	224.98 ± 289.73

Additionally, 363 participants identified their right hand as the dominant hand, while 30 identified their left hand as dominant. Among the males, 220 were right-handed, and 21 were left-handed; for females, 143 were right-handed, and 9 were left-handed.

Anthropometric measurements

Physical assessments were conducted at the university's Laboratory of the 3S: Sport, Santé, Société (L3S), following standardized procedures. A qualified nutritionist measured body mass (BM) and additional body composition variables using Bioelectrical Impedance Analysis (BIA, i30, Mediana, Korea). Although body composition variables were recorded for future research, only body mass data are relevant to the present study. Height (BH) was measured with a portable digital height scale (Campry, China), and body mass index (BMI) was calculated based on these measures (Andraos et al., 2024).

Testing Procedure

The handgrip isometric test protocol was conducted according to standardized procedures using a calibrated handgrip device (Sports Medical Solution, Belgrade, Serbia). Participants were seated upright with one arm extended holding the device, as outlined in prior studies (Dopsaj et al., 2019; Dopsaj et al., 2022). This handgrip test has demonstrated high reliability in previous research, with intraclass correlation coefficients reported between 0.938 and 0.977 for $F_{max,}$ and 0.903 to 0.971 for RFD_{max} (Marković et al., 2018).

Before testing, participants received verbal instructions and performed two practice trials with each hand. Dominant hand was identified through a brief questionnaire prior to testing. For the main test, participants were instructed to exert maximum force on the device for at least 2 seconds following a signal, with verbal encouragement provided. Tests for both dominant and non-dominant hands were conducted twice in random order, with a 1-minute rest interval between trials. During each test, participants kept their arms by their sides, with the tested arm slightly abducted.

F_{max} and RFD_{max} values were recorded using a laptop computer, with F_{max} representing the peak muscle force achieved. RFD_{max} was calculated as the steepest slope of the force-time curve. The onset of contraction was identified when the first derivative of the force-time curve rose above baseline by 3% of the peak value. The strain gauge connected to the force reader had a precision of ± 0.1 N, and data were sampled at 500 Hz, with filtering applied prior to calculating RFD_{max}. Data were processed and analyzed using a dedicated isometric measurement software-hardware system (Sports Medical Solutions Isometrics, ver. 3.4.0).

Variables

In this study, the primary variables assessed were hand grip strength (HGS) and hand grip explosive strength (HGES). HGS was measured as the maximal force (F_{max}) produced by both the dominant hand (DH) and non-dominant hand (NDH), while HGES was evaluated through the maximal rate of force development (RFD_{max}) in both hands. Asymmetry between DH and NDH was calculated for both F_{max} and RFD_{max}, producing the asymmetry ratio as an additional variable, which allowed categorization into four levels: low, moderate, high, and very high asymmetry, as outlined by McGrath et al. (2021). Additionally, descriptive anthropometric variables were recorded, including age, body height (BH), body mass (BM), and body mass index (BMI), to characterize the population and allow for gender comparisons.

Statistical analysis

Descriptive statistics, including mean (M) and standard deviation (SD), were computed for all anthropometric measurements and key hand grip parameters (HGS and HGES) to assess central tendency and data dispersion. Additionally, 95% confidence intervals (CIs) for the mean were calculated to determine the range of significant values.

A core component of this study involved calculating asymmetry levels, following the methodology of McGrath et al. (2021). The asymmetry percentage was computed using the formula:

Asymmetry%: $(DH-NDH)/NDH \times 100$

To classify participants into four asymmetry levels (low, moderate, high, and very high), we applied two separate classification methods: one based on HGS and another based on handgrip explosive strength HGES.

For handgrip strength asymmetry, low asymmetry was defined as 0–10%, moderate asymmetry as 10.1–20%, high asymmetry as 20.1–30%, and very high asymmetry as greater than 30%.

Similarly, for handgrip explosive strength asymmetry, low asymmetry was classified as 0–10%, moderate asymmetry as 10.1–20%, high asymmetry as 20.1–30%, and very high asymmetry as greater than 30%.

These classifications ensure a standardized approach to defining asymmetry levels based on both strength and explosive strength measurements.

A dependent t-test was performed to compare HGS and HGES values between the dominant hand (DH) and non-dominant hand (NDH) within each sex, determining whether within-subject differences were statistically significant.

To examine gender differences in HGS, HGES, and their asymmetry indices, a multivariate analysis of variance (MANOVA) was performed. To analyze differences in HGS and HGES across asymmetry levels within each sex, the Kruskal–Wallis test was used, as the data were not normally distributed. When the Kruskal–Wallis test revealed statistically significant group differences, post-hoc pairwise comparisons were performed using Mann–Whitney U tests with Bonferroni correction to identify which asymmetry levels differed significantly from one another. These results are presented in Figure 1 (HGS) and Figure 2 (HGES), with asterisks denoting levels of significance for both gender.

The combined maximal force (F_{max}_SUM) and maximal rate of force development (RFD_{max}_SUM) were derived by summing the dominant hand (DH) and non-dominant hand (NDH) values for each respective parameter:

F_{max}_SUM was calculated as F_{max} (DH) + F_{max} (NDH), and RFD_{max}_SUM was computed as RFD_{max} (DH) + RFD_{max} (NDH). All statistical analyses were conducted using SPSS Statistics 26.0 (IBM Corp, Armonk, NY) and Microsoft Excel 2016. Significance levels were set at $p < 0.05$.

RESULTS

In this study, we analyzed the distribution of hand grip strength (HGS) and hand grip explosive strength (HGES) between the dominant hand (DH) and non-dominant hand (NDH) among participants. Our findings revealed distinct patterns in strength asymmetry across individuals. Regarding HGS, 7 participants showed equal strength in both DH and NDH. In comparison, 295 participants exhibited greater strength in the DH, whereas 91 showed stronger NDH. For HGES, only one participant demonstrated equal explosiveness between DH and NDH. Meanwhile, 288 participants had a more explosive DH, and 104 exhibited a more explosive NDH.

Table 2. Comparison of Hand Grip Maximum Force and Rate of Force Development in the Lebanese Population according to gender

Variable	Males (n=241) Mean ± SD	Females (n=152) Mean ± SD	Difference between Male & Female in F_{max} & RFD_{max} in %	p-value
Dominant HG F_{max} (N)	492.37 ± 87.27	273.73 ± 54.46	44.40%	0.000
Non-Dominant HG F_{max} (N)	460.58 ± 89.45	253.63 ± 56.15	44.93%	0.000
Dominant HG RFD_{max} (N/s)	2984.52 ± 675.52	1587.34 ± 460.37	46.81%	0.000
Non-Dominant HG RFD_{max} (N/s)	2779.59 ± 690.63	1466.76 ± 457.28	47.23%	0.000

The results in Table 2 indicate significant differences in hand grip strength (HGS) parameters between males and females in the Lebanese population. Males demonstrated higher maximum force (F_{max}) and rate of force development (RFD_{max}) in both the dominant and non-dominant hands compared to females.

For the dominant hand, the mean F_{max} was 492.37 ± 87.27 N in males and 273.73 ± 54.46 N in females ($p < 0.001$). The non-dominant hand showed a mean F_{max} of 460.58 ± 89.45 N for males and 253.63 ± 56.15 N for females ($p < 0.001$).

In terms of RFD_{max}, males reached 2984.52 ± 675.52 N/s in the dominant hand and 2779.59 ± 690.63 N/s in the non-dominant hand, while females had 1587.34 ± 460.37 N/s and 1466.76 ± 457.28 N/s, respectively. These findings indicate that males exhibited significantly greater force generation and rate of force application across both hands (all $p < 0.001$).

Table 3. Dependent t-test analysis of dominant and non-dominant hand grip strength and explosive strength in Lebanese males and females (Mean ± SD)

Variables	Dominant HG	Non-Dominant HG	Difference %	p-value
Male HG F_{max} (N)	492.37 ± 87.27	460.58 ± 89.45	6.9	0.000
Female HG F_{max} (N)	273.73 ± 54.46	253.63 ± 56.15	7.92	0.000
Male HG RFD_{max} (N/s)	2984.52 ± 675.52	2779.59 ± 690.63	6.86	0.000
Female HG RFD_{max} (N/s)	1587.34 ± 460.37	1466.76 ± 457.28	7.60	0.000

Note: HG= Hand grip; F_{max} = Maximum Force; RFD_{max} = Maximum Rate of Force Development

The results in Table 3 present the comparison of hand grip strength (F_{max}) and rate of force development (RFD_{max}) between the dominant and non-dominant hands in Lebanese males and females. The analysis shows a significant difference in both parameters for each gender.

In males, the mean F_{max} was 492.37 ± 87.27 N for the DH and 460.58 ± 89.45 N for NDH, with a significant difference ($p < 0.001$). Similarly, females exhibited a mean F_{max} of 273.73 ± 54.46 N in the DH and 253.63 ± 56.15 N in the NDH, also showing a significant difference ($p < 0.001$).

For RFD_{max}, males demonstrated 2984.52 ± 675.52 N/s in the DH compared to 2779.59 ± 690.63 N/s in the NDH, with a significant difference ($p < 0.001$). In females, the RFD_{max} was 1587.34 ± 460.37 N/s for the DH and 1466.76 ± 457.28 N/s for the NDH, with a similar significant difference ($p < 0.001$).

These findings suggest that both males and females exhibit higher HGS and HGES in the DH compared to the NDH.

Table 4. Multivariate Analysis of Variance (MANOVA) of Handgrip Strength (HGS) and Handgrip Explosive Strength (HGES) Asymmetry Between Males and Females (Mean ± SD)

Variable	Male (%)	Female (%)	Difference between Males and Females (%)	p-value
HGS Asymmetry	9.89 ± 7.47	10.21 ± 7.7	3.13	0.685
HGES Asymmetry	11.79 ± 9.42	13.13 ± 9.95	10.2	0.177

Table 4 shows the comparison of handgrip strength HGS and HGES asymmetry indices between males and females. The analysis indicates no significant differences between genders for both HGS asymmetry (males: 9.89 ± 7.47%, females: 10.21 ± 7.7%, $p = 0.685$) and HGES asymmetry (males: 11.79 ± 9.42%, females: 13.13 ± 9.95%, $p = 0.177$). These results suggest similar levels of asymmetry in handgrip performance across both groups.

Table 5. Sample Size Distribution by Handgrip Strength Asymmetry Levels and Handgrip explosive strength in Males and Females in the Lebanese Population

Variable	Category	Low Asymmetry (0–10%)	Moderate Asymmetry (10.1%–20%)	High Asymmetry (20.1%–30%)	Very High Asymmetry (>30%)
F_{max}		**Male**			
	Sample Size (n= 241)	n=138 (57.26 %)	n=83 (34.44 %)	n=16 (6.64 %)	n=4 (1.66 %)
		Female			
	Sample Size (n=152)	n=88 (57.89 %)	n=49 (32.24 %)	n=13 (8.55 %)	n=2 (1.32 %)
$RFDmax_{max}$		**Male**			
	Sample Size (n= 241)	n=122 (50.62 %)	n=74 (30.7 %)	n=30 (12.45 %)	n=15 (6.22 %)
		Female			
	Sample Size (n=152)	n=67 (44.07%)	n=57 (37.5 %)	n=18 (11.84%)	n=10 (6.57 %)

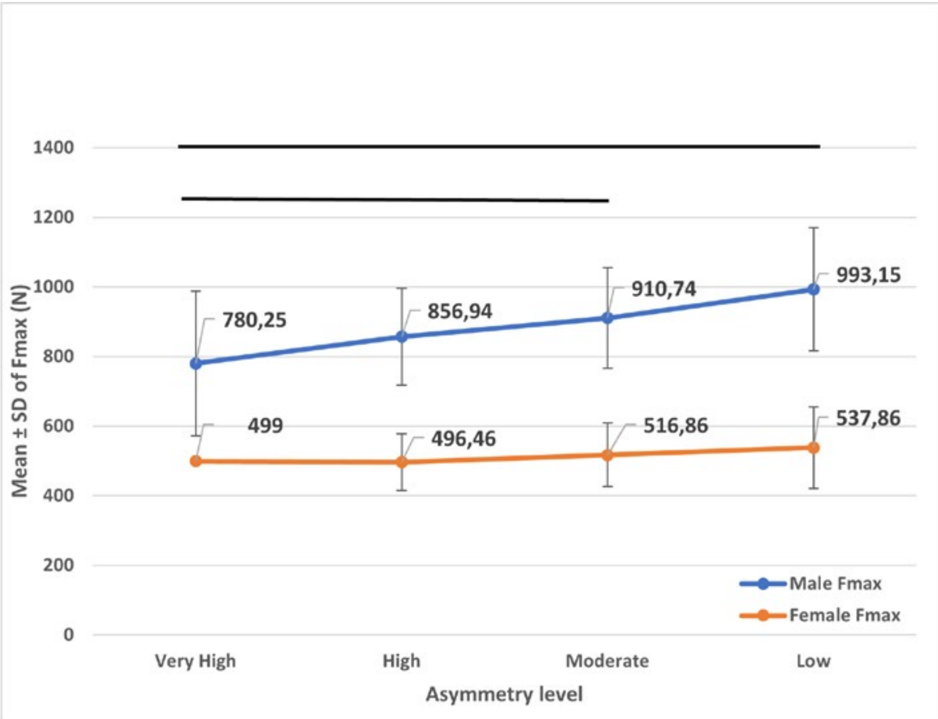
Table 5 presents the sample size distribution of males and females across different levels of HGS and HGES asymmetry. In both sexes, the majority of participants exhibited low asymmetry (0-10%), with 57.26% of males and 57.89% of females for HGS, and 50.62% of males and 44.07% of females for HGES. As asymmetry increased, the sample sizes progressively decreased, with the very high asymmetry category (>30%) having the fewest participants (≤6.57% in all cases).

To further examine how asymmetry levels relate to handgrip strength and explosive strength, Figures 1 and 2 illustrate the mean values of maximal HGS and HGES, respectively, across asymmetry categories for males and females.

Figure 1 illustrates the comparison of mean maximal HGS across different asymmetry levels in males and females. In males, significant differences ($p < 0.01$) were observed between the Very High and Moderate asymmetry groups, as well as between the Very High and Low asymmetry groups. No significant differences were found among females across asymmetry levels.

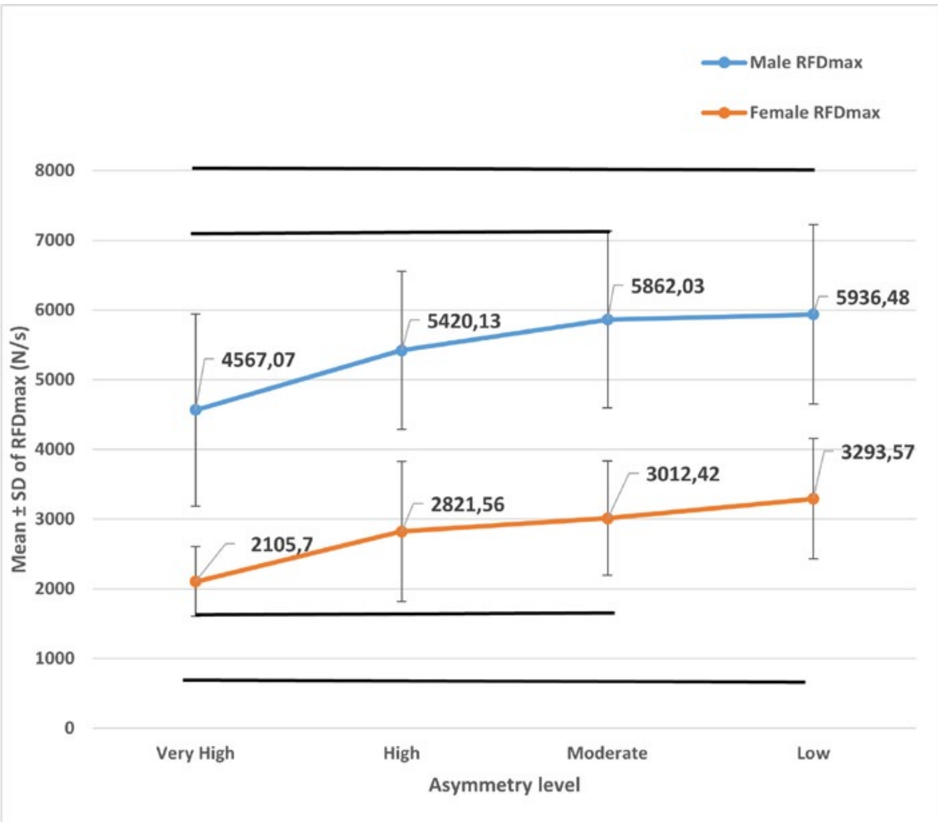
Figure 2 presents the mean of HGES across the same asymmetry levels. Similar to HGS, significant differences ($p < 0.01$) were found in males between the Very High and Moderate asymmetry groups and between the Very High and Low asymmetry groups. Additionally, in females, significant differences ($p < 0.01$) were also observed between the Very High and Moderate asymmetry groups, as well as between the Very High and Low asymmetry groups, indicating that explosive strength asymmetry follows a similar trend in both sexes.

Figure 1. Comparison of mean hand grip strength across hand grip asymmetry levels in males and females of the Lebanese population using the Kruskal-Wallis test



* p < 0.05, ** p < 0.01

Figure 2. Comparison of mean hand grip explosive strength across hand grip asymmetry levels in males and females of the Lebanese population using the Kruskal-Wallis test



* p < 0.05, ** p < 0.01

DISCUSSION

This study presents an advanced model of hand grip strength (HGS) and hand grip explosive strength (HGES) asymmetry, specifically adapted to the Lebanese population. By integrating both maximal strength (F_{max}) and explosive strength (RFD_{max}), and categorizing asymmetry into four levels (low, moderate, high, and very high), this model offers a comprehensive framework for assessing functional imbalance and potential health risks.

Consistent with existing literature, males demonstrated significantly higher HGS and HGES values compared to females, with approximately 44 % greater F_{max} and 47 % higher RFD_{max} (Table 2). These findings align with studies by Dopsaj et al. (2022), Perna et al. (2016), and Giuriato et al. (2024), which attribute such gender differences to greater muscle cross-sectional area and enhanced neuromuscular efficiency in males.

The comparison between dominant and non-dominant hands (Table 3) revealed statistically significant asymmetry in both strength and explosiveness for males and females. Males exhibited a 6.9 % difference in F_{max}, while females showed a slightly higher difference of 7.92 %. A similar pattern was observed in RFD_{max}, suggesting a general trend where the dominant side is stronger and more explosive. Although males had higher absolute force values, females demonstrated slightly higher asymmetry in HGES (Table 4), with an average of 13.13 % compared to 11.79 % in males.

This slightly higher HGES asymmetry in females may be influenced by lifestyle differences in daily physical activities. Men, in general, tend to perform more explosive movements during everyday tasks—such as lifting a heavy load quickly from the floor, pushing objects forcefully, or throwing items with speed—compared to women. These types of actions require rapid force production and are more commonly encountered in male daily routines. In contrast, women are less likely to engage in such high-intensity, explosive activities and may seek assistance when faced with similar tasks. As a result, the demand for explosive force may be lower in females, contributing to more balanced force output between limbs and slightly lower functional asymmetry.

Figure 1 and Figure 2 further illustrate the functional consequences of high asymmetry levels. In males, both HGS and HGES showed significant reductions in the very high asymmetry group when compared to the low and moderate groups ($p < 0.01$). This indicates that excessive asymmetry is associated with diminished physical performance. In females, HGS differences were not statistically significant, possibly due to the limited number of participants in the very high group ($n = 2$). However, HGES did show significant reductions in the very high asymmetry group, suggesting that explosive strength asymmetry may be a more sensitive indicator of neuromuscular imbalance, even in populations with overall lower strength levels.

These results align partially with previous research. While studies such as Bailey et al. (2015) reported greater asymmetry in lower-body tasks among females, our findings suggest that upper-body asymmetry patterns may differ. The biomechanical and neuromuscular demands of upper-limb function appear to vary by sex, likely due to differences in daily physical activity patterns and movement habits.

Table 5 shows that the majority of Lebanese participants fell into the low asymmetry category for both HGS and HGES. Specifically, 57.26 % of males and 57.89 % of females were classified as having low HGS asymmetry, while 50.62 % of males and 44.07 % of females fell into the same category for HGES. This distribution aligns with similar studies in other populations (McGrath et al., 2021; Bardo et al., 2021), suggesting that low asymmetry is common in the general population. However, moderate-to-high asymmetry levels, although less frequent, are clinically significant, as previous research links them to higher risks of falls, impaired gait, and decreased neuromuscular performance (Baek et al., 2023; McGrath et al., 2022).

Notably, HGES asymmetry was more widespread than HGS asymmetry, with a higher number of participants in the moderate, high, and very high categories. This may indicate that explosive strength is more sensitive to neuromuscular differences or less consistently trained or used in daily life. Given that explosive strength reflects rapid motor unit recruitment and synchronization, it may serve as a more accurate biomarker of neuromuscular function than static maximal strength alone.

Practical Implications

This assessment model is relevant not only for athletes but also for the general population. For the general public, evaluating both F_{max} and RFD_{max} asymmetry provides early detection of neuromuscular imbalances that could increase the risk of falls or functional decline. For athletes, identifying moderate to very high asymmetry can help predict injury risk and inform training adjustments. Regular assessments using this dual-parameter model can guide targeted interventions—such as bilateral strength training or neuromuscular re-education—to correct imbalances and prevent injury. Thus, the model serves as both a diagnostic tool and a foundation for personalized, evidence-based training and rehabilitation strategies.

LIMITATIONS

This study has several limitations. First, the distribution of participants across asymmetry categories was uneven, with very few individuals in the highest asymmetry group (e.g., n = 4 for HGS), limiting the statistical power of comparisons. Second, only healthy adults were included, excluding older adults, individuals with motor disorders, or those undergoing rehabilitation, which may limit generalizability. Lastly, the cross-sectional design prevents conclusions about causal relationships. Future research should focus on longitudinal studies to examine age-related trends in asymmetry, and on expanding sample sizes in extreme categories to improve precision and generalizability.

CONCLUSION

This study develops an advanced model for evaluating hand grip strength HGS and HGES asymmetry in the Lebanese population, integrating both F_{max} and RFD_{max} as key parameters. This dual approach marks a significant advancement over previous models that relied solely on maximal strength, offering a more comprehensive assessment of hand grip asymmetry. By categorizing asymmetry into four distinct levels, this model provides practical insights into potential health risks, setting a valuable baseline for identifying injury and fall risks within this demographic.

Beyond serving as a reference for the Lebanese population, this model presents a standardized framework adaptable to other populations, fostering comparative studies on asymmetry and its implications for functional health outcomes.

Future research should explore age-specific trends in asymmetry, determining whether strength, explosive strength, or both change with age. Additionally, expanding sample sizes, particularly in the very high asymmetry category, and validating this model across diverse populations could enhance its applicability and precision.

Ultimately, this model serves as a valuable tool for health practitioners, aiding in the assessment of asymmetry-related risks and informing preventive interventions to reduce functional imbalances and injury risks. Its findings contribute to a broader understanding of hand grip asymmetry and its role in health risk assessment.

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