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Effect of Shoulder Posture and Gripping Frequency on Hand Grip Strength among Malaysian Female Young Adults

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ABSTRACT

Hand grip strength (HGS) is a key biomechanical metric informing the design of tools, equipment, and manual tasks in industrial settings. Effective human centred design requires understanding of how posture and task demand affect muscular performance and fatigue. Although HGS is well-researched, few studies have explored the combined effects of shoulder posture and gripping frequency, especially among females who are often underrepresented in strength data. This study investigates the effects of shoulder posture and gripping frequency on maximal HGS among healthy Malaysian female young adults. A repeated measures experimental design was employed involving 60 participants. Participants performed maximum voluntary grip trials under eight conditions: two shoulder postures (180° overhead, 90° front-facing) and four gripping frequencies (baseline, infrequent, occasional, frequent). Maximum grip strength was measured using a calibrated Jamar hydraulic dynamometer. A two-way repeated measures ANOVA was conducted to evaluate the effects. Significant main effects were found for both shoulder posture ($F(1,60) = 32.99$, $p < .001$) and gripping frequency ($F(3,180) = 396.99$, $p < .001$), with higher HGS recorded at 180° posture and progressively lower values with increasing gripping frequency. Post hoc analyses confirmed a consistent and significant decline in HGS across all frequency levels ($p < .001$). Both elevated shoulder posture and increased gripping repetition significantly reduce HGS, underscoring the need to consider these factors in the engineering design of tools and manual tasks. These findings contribute to the application of ergonomic principles in early-stage design decisions, aligning with the Prevention through Design (PtD) philosophy to improve worker safety.

Keywords: Hand grip strength; endurance; gripping; overhead posture

INTRODUCTION

Hand grip strength (HGS) is a widely used measure in biomechanics and occupational ergonomics to assess upper limb functionality, musculoskeletal performance, and fatigue under various task constraints. It has been established as a reliable indicator for overall muscle strength, functional capacity, and even long-term health outcomes in occupational populations (Kaczorowska et al. 2025; Kothari et al. 2024; Vaishya et al. 2024). Several studies have highlighted that HGS is sensitive to a variety of postural conditions, suggesting that workplace configuration can significantly influence physical capability and fatigue rates during manual tasks (Alam & Mukhtar 2022; Bashir et al. 2018; Kattel et al. 1996). In engineering design contexts, particularly those involving manual tools and repetitive forceful exertions, consideration of physical grip configurations and HGS elements in tool design process can directly influence biomechanical load on the end users (Halim et al. 2019; Radwin 2007)

The role of upper limb posture, particularly shoulder elevation, in modulating grip strength has drawn considerable interest in literature. Prior research has demonstrated that maximal HGS may be affected in different positions of shoulder positions. The synergistic muscles of back and shoulder to concurrently coactivate when shoulders are at certain angles may result in biomechanical advantage (Parvatikar and Mukkannavar, 2009; Kattel et al. 1996; Su et al. 1994). These findings are especially relevant in industrial and engineering work environments where overhead work or elevated tool use is common. In addition, frequent or repetitive gripping can accelerate muscular fatigue and diminish grip performance over time (Sonne et al. 2015). Despite these insights, few studies have jointly examined the interaction between shoulder posture and gripping frequency in a controlled experimental setting. This limits the development of predictive ergonomic guidelines applicable to real-world task design where both static and dynamic factors coexist.

From an engineering design perspective, the integration of ergonomic principles during early stages of workplace or tool design is central to the Prevention through Design (PtD) philosophy. PtD, as advocated by organizations like National Institute of Occupational Safet and Health (NIOSH), promotes the elimination or mitigation of occupational risks by embedding human-centered considerations into equipment, tasks, and workspace layout before deployment (Zerges & Giles, 2008; Cavalcanti et al. 2022). The concept of PtD has also been embedded in the recent Occupational Safety And Health (Construction Work) (Design And Management) Regulations 2024, emphasizing the duties of designers especially in pre-construction phase to consider the general principles of prevention and eliminate or minimize foreseeable risks during the design phase (DOSH 2024).

In the context of manual tool design and operation, hand grip strength (HGS) data plays a critical role in optimizing handle orientation, grip posture, and repetitive force cycles to minimize strain on the musculoskeletal system. However, current ergonomics literature still lacks comprehensive empirical evidence linking shoulder posture and repetitive gripping to measurable reductions in grip strength—particularly among young female populations. Despite their growing representation in physically demanding occupations, young women remain significantly underrepresented in strength-related ergonomic studies (Alam & Mukhtar, 2022; Barnard et al. 2021; Eryiğit & Uğurlu, 2019; Bashir et al. 2018). This underrepresentation not only limits the generalizability of existing findings but also hinders efforts to develop inclusive and ergonomically sound designs. Prioritizing empirical data collection from this demographic is essential to ensure that tools and workstations are tailored to accommodate a diverse workforce, thereby enhancing usability, safety, and long-term occupational health outcomes.

Therefore, the objective of the present study is to investigate how shoulder posture and gripping frequency influence maximum HGS among healthy young adult females. By examining the main and interaction effects of these two factors, this study aims to provide engineering-relevant ergonomic evidence to inform safe task repetition limits and optimize tool positioning. The findings are expected to contribute to data-driven ergonomic design, especially in sectors requiring repetitive manual exertions such as manufacturing, healthcare, and field maintenance operations.

METHODOLOGY

STUDY DESIGN

This study employed a repeated measure experimental design to characterize hand grip strength patterns due to different shoulder postures and grip frequency. The independent variables were shoulder postures at 2 treatment levels [a) 180 degree and b) 90 degree] and gripping frequency at 4 treatments level [a) baseline – 1 maximum grip at maximum voluntary contraction, b) infrequent – 1 grip per 5 minute, c) occasional – 1 grip per 3 minute, and d) frequent – 1 grip per 30 second]. These gripping frequencies are extracted from definition set in one of the established design industrial guideline documents for manufacturing equipment (SEMI, 2024). Ethical approval was obtained from the Center of Research and Innovation Management, Universiti Teknikal Malaysia Melaka (approval reference number UTeM.11.02/500-25/1/4 Jilid 3(4)).

PARTICIPANTS

A total of 60 healthy female young adults aged between 20 to 29 years were voluntarily recruited for this study, through convenience sampling method. Inclusion criteria included no musculoskeletal, neurological, or cardiovascular disorders, and no recent upper limb injuries. Individuals with any upper limb condition affecting hand function were excluded.

DATA COLLECTION PROTOCOL

Each participant was given a consent form, and a briefing of the tasks to be performed upon arrival. Testing was performed with participants sitting upright, forearm in neutral position, and wrist position without ulnar or radial deviation. Participants were allowed to do test trials prior to actual data collection. Upon readiness, each participant was asked to do a combination of 8 (4 x 2 design) maximum voluntary hand grip strength trials. Each participant was asked to grip a power drill and hold the trigger for 5 seconds. At the end of each trial, hand grip strength was measured using a calibrated Jamar Hydraulic Hand Dynamometer (Sammons Preston, USA). Standardized verbal encouragement was given during each trial. The order of trails was randomized for each participant to minimize bias from cumulative fatigue. Each trial lasts for 15 minutes. A minimum of 2 minutes rest break were given between each trial.

FIGURE 1. Different shoulder posture conditions a) 90° degree front facing shoulder posture (left) and b) 180° overhead shoulder posture (right)

DATA PROCESSING AND ANALYSIS

All data were checked for completeness and accuracy prior to analysis. Each participant's hand grip strength (HGS) readings across eight experimental conditions—combinations of two shoulder postures (180° overhead, 90° front facing) and four levels of grip frequency (baseline, infrequent, occasional, frequent)—were organized into a structured dataset for statistical evaluation. Descriptive statistics were computed to summarize mean, standard deviation, minimum, and maximum HGS values for each condition. Data normality was assessed using the Shapiro–Wilk test. While most conditions showed non-significant results ($p > .05$), suggesting normal distribution, the 90° baseline condition approached the threshold for significance ($p = .06$). Given the absence of extreme values and consistent boxplot distributions, the data were considered appropriate for parametric analysis. A two-way repeated measures analysis of variance (RM-ANOVA) was conducted to assess the within-subject effects of shoulder posture and grip frequency on hand grip strength. The assumption of sphericity was examined using Mauchly's test. When sphericity was violated, as in the case of the frequency factor and its interaction with posture, Greenhouse–Geisser corrections were applied to adjust the degrees of freedom and ensure valid inference. Post hoc pairwise comparisons were performed using Bonferroni corrections to further examine significant main effects. All analyses were conducted using JASP statistical software (Version 0.19.3, Netherlands) with an alpha level of .05 set as the threshold for statistical significance.

RESULTS AND DISCUSSION

DESCRIPTIVE STATISTICS

Descriptive analyses were conducted to summarize the characteristics of hand grip strength among participants for each experimental condition. A consistent pattern of decreasing grip strength was observed as the frequency of repetitions increased, under both postural conditions. Under the 180° overhead shoulder posture, the highest mean HGS was recorded at the baseline condition (Mean = 24.97 kg, SD = 2.58), gradually decreasing through infrequent (Mean = 24.15 kg, SD = 2.70), occasional (Mean = 22.85 kg, SD = 2.92), and reaching the lowest value at frequent gripping (Mean = 20.28 kg, SD = 2.74). Similarly, in the 90° front facing shoulder posture, the baseline condition recorded a mean HGS of 23.58 kg (SD = 2.62), which progressively decreased with each increase in frequency level: infrequent (Mean = 22.98 kg, SD = 3.05), occasional (Mean = 21.67 kg, SD = 3.24), and frequent (Mean = 19.02 kg, SD = 2.97). Descriptive statistics of data are summarized in Table 1.

The range of values across all conditions was reasonable, with no extreme deviations. Minimum and maximum grip strengths range from 13 kg to 32 kg across all measurements. This spread suggests moderate inter-individual variability in grip strength capacity. The distribution of data was assessed using the Shapiro-Wilk test for normality. All conditions returned non-significant p-values ($p > 0.05$), indicating that the assumption of normality was reasonably met.

TABLE 1. Descriptive statistics of hand grip strength data

Experimental Conditions	Mean	Std. Deviation	P-value of Shapiro-Wilk	Minimum	Maximum
180_Baseline	24.97	2.58	0.06	18.00	32.00
180_infrequent	24.15	2.70	0.07	18.00	30.00
180_occasional	22.85	2.92	0.13	16.00	29.00
180_frequent	20.28	2.74	0.16	14.00	26.00
90_Baseline	23.58	2.62	0.06	17.00	30.00
90_infrequent	22.98	3.05	0.20	16.00	32.00
90_occasional	21.67	3.24	0.51	14.00	30.00
90_frequent	19.02	2.97	0.24	13.00	28.00

STATISTICAL ANALYSIS

A two-way repeated measures ANOVA was conducted to evaluate the effects of shoulder posture (180° overhead vs. 90° front facing) and grip frequency (Baseline, Infrequent, Occasional, Frequent) on maximum hand grip strength (HGS). Mauchly's test indicated that the assumption of sphericity was not met for the frequency factor, therefore degrees of freedom were corrected using the Greenhouse–Geisser estimate.

The analysis revealed a significant main effect of posture, $F(1, 60) = 32.99$, $p < .001$, partial $\eta^2 = .078$, indicating that grip strength differed between postures. On average, participants exhibited significantly higher HGS in the overhead (180°) posture compared to the front (90°) posture. There was also a highly significant main effect of grip frequency, $F(3, 180) = 396.99$, $p < .001$, partial $\eta^2 = .619$, reflecting a progressive decline in grip strength as the number of repetitions increased. This large size effect suggests that muscular fatigue substantially influenced performance, with frequent gripping resulting in the lowest strength measurements. The interaction between posture and frequency was not significant, $F(3, 180) = 0.331$, $p = .803$, partial $\eta^2 < .001$. This indicates that although posture and frequency independently influenced grip strength, the pattern of fatigue was similar regardless of arm elevation.

A descriptive plot summarizing the consistent pattern of decreasing grip strength was observed as the frequency of repetitions increased, under both postural conditions, as shown in Figure 2. Across all frequency levels, participants exhibited higher grip strength in the 180° overhead posture compared to the 90° front posture, as indicated by consistently higher plotted values. Despite this difference, the parallel decline of both lines suggests a uniform fatigue pattern across postures, which aligns with the non-significant interaction effect between posture and frequency found in the repeated measures ANOVA.

TABLE 1. Within subject effects comparing independent variables

Cases	Sum of Squares	df	Mean Square	F	p	η²	ω²
Posture	190.771	1	190.771	32.986	< .001	0.078	0.049
Residuals	347.002	60	5.783				
Frequency	1518.92	3	506.307	396.994	< .001	0.619	0.304
Residuals	229.563	180	1.275				
Posture - Frequency	0.914	3	0.305	0.331	0.803	3.725×10-4	0
Residuals	165.622	180	0.92				

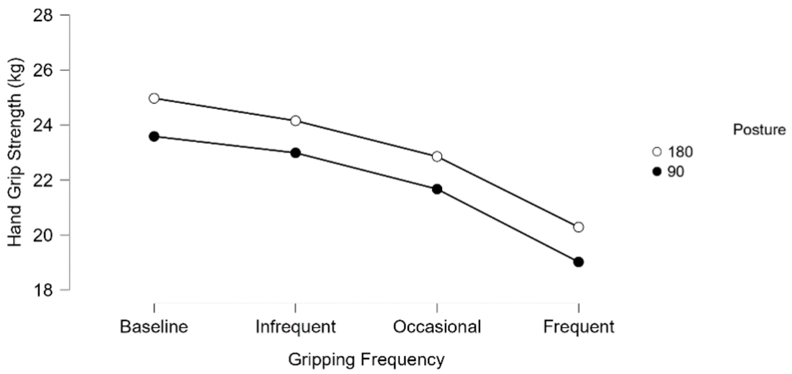

FIGURE 2. Descriptive plot of HGS in different frequency and shoulder postures

Post hoc pairwise comparisons were conducted using Bonferroni corrections to further examine the significant main effects of posture and frequency observed in the repeated measures ANOVA, as shown in Table 3. For posture, participants exhibited significantly greater hand grip strength in the 180° overhead posture compared to the 90° front posture across all levels of frequency, $t(60) = 5.74$, $p < .001$. The mean difference was 1.25 kg, indicating a consistent performance advantage when gripping in the overhead position. Regarding gripping frequency, all pairwise comparisons between the four frequency levels were statistically significant ($p < .001$), indicating a progressive decline in grip strength as repetition increased. Compared to baseline, strength was reduced by 0.71 kg in the infrequent condition, 2.02 kg in the occasional condition, and 4.62 kg in the frequent condition.

Each successive increase in frequency level also resulted in a significant drop: from infrequent to occasional (1.31 kg), from infrequent to frequent (3.92 kg), and from occasional to frequent (2.61 kg). These results reflect a robust fatigue effect, with substantial reductions in strength occurring as the number of repetitions increased.

The present study investigated the effects of shoulder posture and gripping frequency on hand grip strength (HGS) among healthy female young adults. The findings revealed that both shoulder posture and gripping frequency significantly influence HGS, with higher strength observed in the 180° overhead posture compared to the 90° front-facing posture. Additionally, a progressive decline in grip strength was noted with increasing gripping frequency, indicating the presence of muscular fatigue.

TABLE 3. Post Hoc Tests

		Mean Difference	SE	df	t	p-value
180	90	1.25	0.218	60	5.743	< .001

Note: Results are averaged over the levels of: Frequency

		Mean Difference	SE	df	t	p-value bonf
Baseline	Infrequent	0.707	0.129	60	5.495	< .001
	Occasional	2.016	0.18	60	11.227	< .001
	Frequent	4.624	0.16	60	28.882	< .001
Infrequent	Occasional	1.308	0.108	60	12.064	< .001
	Frequent	3.917	0.14	60	27.909	< .001
Occasional	Frequent	2.608	0.14	60	18.656	< .001

Note: Results are averaged over the levels of posture

DISCUSSION

The finding that HGS was greater in the overhead (180°) posture aligns with recent studies showing that shoulder position affects muscle activation and grip force. Bashir et al. (2020) reported that grip strength varies with upper-limb posture, emphasizing the role of shoulder positioning. Similarly, Alam and Mukhtar (2022) found significant effects of shoulder posture on grip strength, while Parvatikar and Mukkannavar (2009) observed highest grip strength at 180° flexion—comparable to the current setup. Notably, this may be attributed to the co-activation of key upper limb muscles, including the deltoid, upper trapezius, serratus anterior, and rotator cuff muscles, which collectively work to stabilize the glenohumeral joint during overhead postures. This stability potentially enhances the efficiency of force transmission down the arm and into the forearm flexors that are directly responsible for gripping action.

The observed decline in grip strength with increased gripping frequency supports existing evidence that repetitive exertions induce muscle fatigue. Fernandes (2015) showed that peripheral fatigue reduces grip force during sustained handgrip tests. Sonne et al. (2015) further emphasized the role of force time-history in fatigue accumulation, and Yung et al. (2012) highlighted how intermittent contractions influence fatigue and force capacity. These studies suggest that both task duration and repetition should be considered to prevent fatigue-related performance drops. The lack of significant interaction between posture and frequency suggests independent effects on HGS. This indicates that addressing either factor—posture or repetition—can mitigate fatigue without compounding effects. Palmerud et al. (1996) showed that gripping increases shoulder muscle activity, while Ekşioğlu (2006) reported that optimal work-rest cycles differ with shoulder posture, further supporting their independent roles. Collectively, these findings reinforce the need to consider task design parameters, including the gripping duration, frequency, and intensity, to prevent fatigue-related performance declines.

From a design perspective, these findings offer practical implications. McDowell et al. (2012) emphasized the need to characterize grip parameters to optimize tool and handle design. Halim et al. (2019) found that handle orientation, in addition to diameter and length, significantly affects grip strength. Poor orientation can lead to awkward postures and reduced performance. Matuszek and Drobina (2018) also noted that handle placement relative to tools or surfaces impacts worker comfort and safety. The current findings confirm that shoulder posture and gripping frequency are key considerations in tool and task placement. This study also addresses a gap in ergonomic research by focusing on healthy young females, a group often underrepresented in strength data. Alam and Mukhtar (2022) emphasized gender-based differences in grip strength and endurance, advocating for gender-responsive ergonomic design. Bylund and Burstrom (2006) recommended integrating gender-specific considerations in machine design, while Incel et al. (2002) highlighted the importance of including women in grip strength studies for broader applicability.

CONCLUSION

This study demonstrated that both shoulder posture and gripping frequency significantly influence hand grip strength among healthy female young adults. Participants exhibited higher grip strength in the 180° overhead posture compared to the 90° front posture, suggesting that maximal grip performance may not always be compromised in elevated arm positions. Additionally, grip strength declined progressively as gripping frequency increased, confirming the presence of fatigue effects associated with repeated exertions. The results highlight the importance of considering both biomechanical posture and task frequency when developing ergonomic guidelines to minimize fatigue and preserve performance in manual handling and tool use.

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DECLARATION OF COMPETING INTEREST

None.

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