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Exploring the Neuromuscular Physiology of Handgrip Dynamometry in Saudi Young Adults: A Cross-Sectional Study of Peak Force, Sustained Effort, and Sex Differences

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ABSTRACT

Background: Handgrip dynamometry is a rapid, portable measure of integrated neuromuscular performance, but peak force and sustained effort may describe distinct capacities. This study assessed categorical handgrip force and endurance in Saudi young adults and examined their associations with sex and Body Mass Index (BMI).

Methods: This cross-sectional study included 310 Saudi young adults. Age, sex, BMI category, bilateral grip-strength level, and endurance duration during 70% effort were recorded. Associations were evaluated using Pearson chi-square, likelihood-ratio, and linear-by-linear association tests.

Results: The sample included 172 males (55.5%) and 138 females (44.5%). Level I (lowest) grip strength was reported for 58.7% of the right hands and 62.3% of the left hands; 47.1% of participants had intermediate endurance duration (7–17 s). Sex was associated with right- and left-hand grip-strength categories (both $p < 0.001$) and endurance category ($p = 0.006$), whereas the BMI association was not statistically significant ($p = 0.056$).

Conclusion: In this cross-sectional sample, categorical grip strength and endurance varied by sex. Assessment of both peak-force and sustained-effort domains, interpreted with sex-specific reference values and a standardized protocol, may strengthen physiological interpretation.

Keywords: Handgrip Strength; Handgrip Dynamometry; Neuromuscular Function; Muscle Endurance; Exercise Physiology; Saudi Adults

Abbreviations: BMI: Body Mass Index

Introduction

Handgrip dynamometry is a portable, low-cost assessment that is increasingly used to characterize muscle function in clinical, community, and research settings. The force recorded during a maximal voluntary contraction is the mechanical output of voluntary neural drive, motor-unit recruitment and discharge, excitation–contraction coupling, forearm-muscle capacity, and task engagement [1,2]. Recent reviews also emphasize that its interpretation depends on a clearly standardized measurement protocol and appropriate population-specific reference values [3-5]. A single peak value does not fully describe handgrip performance. Force–time analyses identify phases of rapid force rise, maximal force attainment, force maintenance, and fatigue development. During sustained isometric work, fatigue-related changes in force control reflect both neural and peripheral processes, including local perfusion and metabolic stress [6-8]. Consequently, peak grip force and the duration of a sustained contraction should be interpreted as related, but distinct, physiological domains. Young adulthood is an important period for describing neuromuscular capacity because handgrip performance varies with sex, anthropometry, laterality, and habitual activity [9]. In Saudi Arabia, policies promoting physical activity and participation in sport heighten the relevance of practical assessments that can support exercise counselling and health surveillance [10-12].

International evidence also indicates that absolute handgrip performance should be interpreted using sex- and population-specific data rather than a single universal threshold [13]. Although prior work has described sex-related differences in muscular strength and the contribution of body composition in university populations [14], limited information is available on the combined interpretation of categorical bilateral peak-force and sustained-effort measurements in Saudi young adults. This study therefore aimed to describe bilateral handgrip-strength and endurance categories in Saudi young adults and to examine their associations with sex and BMI. The study's contribution is an exploratory two-domain description of peak-force and sustained-effort performance within the available categorical dataset.

Materials and Methods

Study Design and Participants

This cross-sectional study analysed data from 310 Saudi young adults. The analytical sample comprised 172 males and 138 females.

Study Size

The analysis included all 310 participants reported in the supplied dataset summary.

Eligibility Criteria

Ethical Considerations

Anthropometric Assessment

Body weight and standing height were assessed to calculate BMI. BMI was calculated as body weight in kilograms divided by height in metres squared (kg/m2). BMI was used as a body-size indicator; it does not directly quantify muscle mass or adiposity.

Handgrip Strength and Endurance Assessment

Bilateral handgrip strength was assessed using a digital dynamometer. The source manuscript states that a standardized protocol was used. Because posture, grip span, trial number, rest interval, and device characteristics affect handgrip values, these procedural details should be reported to permit reproducibility [4,15-17].

Study Variables and Operational Definitions

(Table 1)

Table 1: Study Variables, Operational Definitions, and Analytical Role.

Variable	Definition	Analytical role
Age group	Participant age grouped as ≤20 years, 21–22 years, or ≥23 years.	Descriptive / categorical predictor
Sex	Male or female, as reported in the source dataset summary.	Categorical predictor
BMI	Body weight (kg) / height^2 (m^2); BMI category cut-points require confirmation.	Body-size context / categorical predictor
Right- and left-hand grip strength	Digital-dynamometer performance categorized as Level I (lowest), Level II (middle), or Level III (highest).	Peak-force domain
Endurance duration	Duration maintained at 70% effort, categorized as short (<7 s), intermediate (7–17 s), or extended (>17 s).	Sustained-effort domain

Note: BMI = Body Mass Index. The derivation and justification of grip-level and endurance categories must be confirmed from the original protocol before submission.

Statistical Analysis

Descriptive results are reported as counts and percentages where supplied. Pearson chi-square, likelihood-ratio, and linear-by-linear association tests were used to examine associations between demographic variables, categorical grip-strength levels, and endurance categories. Statistical significance was set at $p < 0.05$.

Results

Participant Profile

The study included 310 Saudi young adults: 172 males (55.5%) and 138 females (44.5%). Age groups were ≤20 years (27.4%), 21–22 years (30.3%), and ≥23 years (42.3%). The most common BMI category was normal BMI (52.3%), followed by overweight (29.0%), obese (12.9%), and underweight (5.8%). Thus, the sample contained a slightly higher proportion of males and a predominantly normal-BMI profile (Table 2), Figure 1.

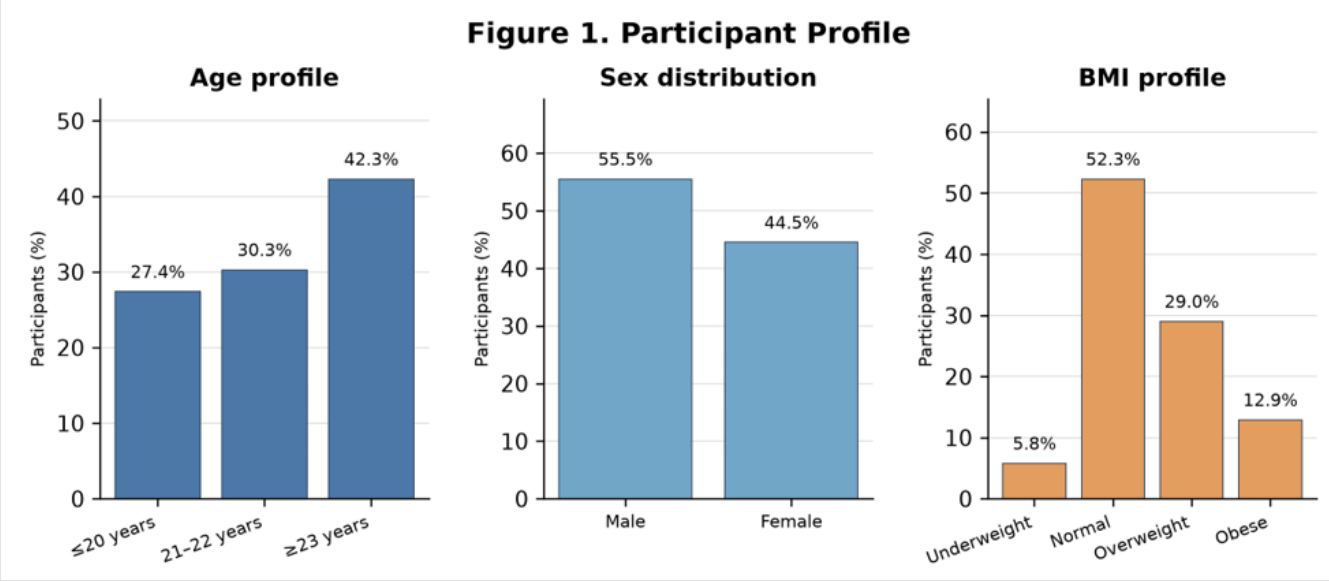


Figure 1: Participant Profile by age group, sex, and BMI category. Values are Percentages of the Full Cohort (N = 310).

Table 2: Reported Demographic and BMI-Category Profile (N = 310).

Characteristic	Category	Reported value
Sex	Male	172 (55.5%)
	Female	138 (44.5%)
Age group	≤20 years	27.40%
	21–22 years	30.30%
	≥23 years	42.30%
BMI category	Underweight	5.80%
	Normal	52.30%
	Overweight	29.00%
	Obese	12.90%

Note: BMI = Body Mass Index. Counts for age and BMI categories were not supplied in the manuscript summary and should be verified from the source dataset before submission.

Grip Strength and Endurance Duration

For both hands, Level I (lowest) grip strength was the most frequently reported category: 58.7% for the right hand and 62.3% for the left hand. Level II represented 36.1% and 32.6% of right- and left-hand observations, respectively, and Level III represented 5.2% for both hands. Endurance duration during 70% effort was most often intermediate (7–17 s; 47.1%), followed by short duration (<7 s; 36.1%) and extended duration (>17 s; 16.8%). These distributions show that the available categorical data were concentrated in the lowest grip category and the intermediate endurance category (Table 3) & Figures 2&3.

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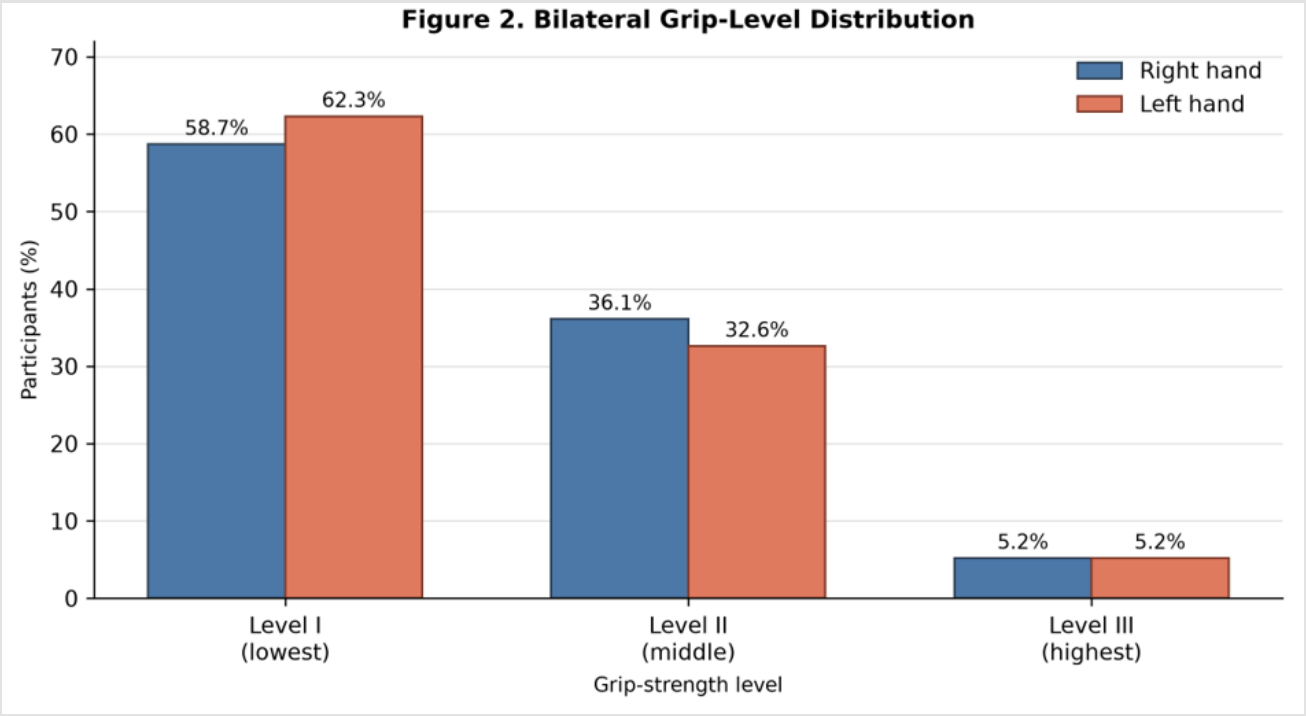


Figure 2: Bilateral Grip-Strength Level Distribution. Values represent the percentage of the full cohort in each reported category. Editable source chart: Handgrip_Dynamometry_Editable_Figures.xlsx.

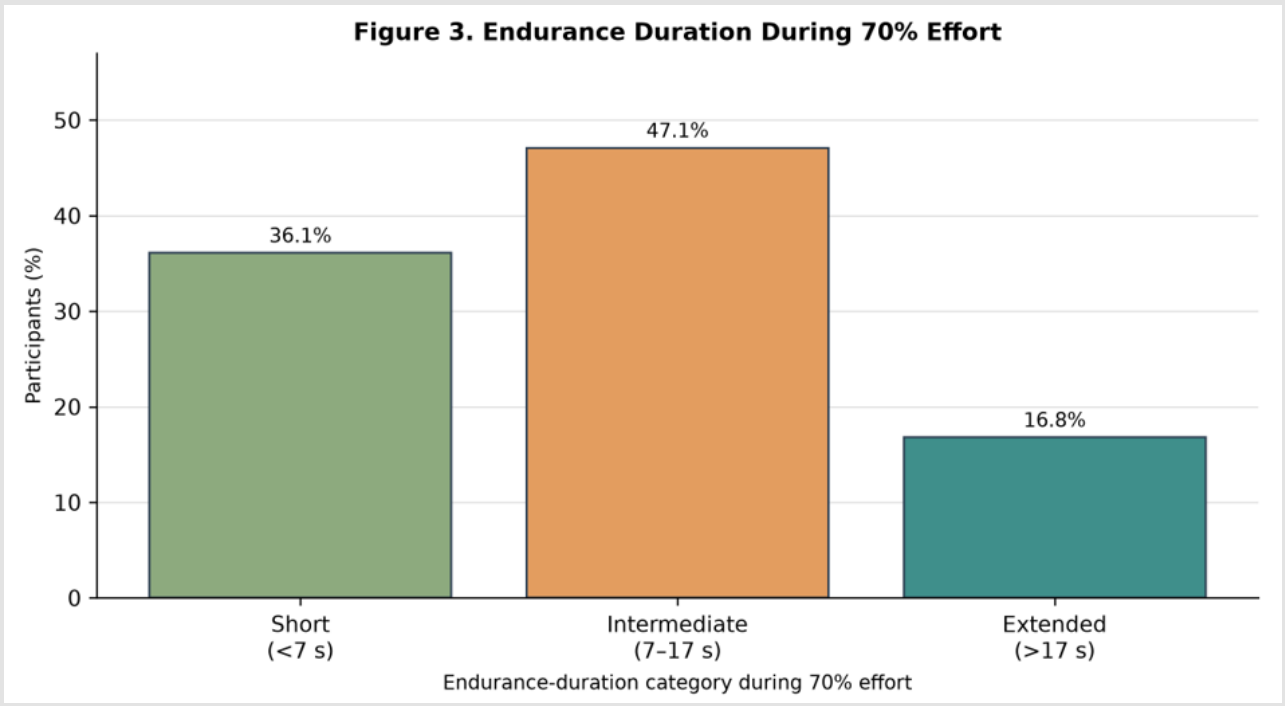


Figure 3: Endurance-Duration Category During 70% effort. Values represent the percentage of the full cohort. Editable source chart: Handgrip_Dynamometry_Editable_Figures.xlsx.

Table 3: Reported Distribution of Bilateral Grip-Strength Levels and Endurance Duration.

Measure	Category	Reported value
Right-hand grip strength	Level I (lowest)	58.70%
	Level II (middle)	36.10%
	Level III (highest)	5.20%
Left-hand grip strength	Level I (lowest)	62.30%
	Level II (middle)	32.60%
	Level III (highest)	5.20%
Endurance duration at 70% effort	Short (<7 s)	36.10%
	Intermediate (7–17 s)	47.10%
	Extended (>17 s)	16.80%

Note: Level I = lowest grip-strength category; Level II = middle category; Level III = highest category. Category thresholds and the derivation of the 70% effort target require confirmation from the original protocol.

Sex Differences and Categorical Associations

Sex was significantly associated with right-hand grip-strength category ($p < 0.001$), left-hand grip-strength category ($p < 0.001$), and endurance-duration category ($p = 0.006$). The source summary indicated that males were more frequently represented in the middle/highest grip categories, whereas females were more frequently represented in the lowest categories. In contrast, the reported association between BMI category and performance was borderline and did not reach the prespecified significance level ($p = 0.056$). These results demonstrate associations within a cross-sectional categorical analysis and should not be interpreted as causal effects (Table 4).

Table 4: Reported Categorical Association Results.

Association	Reported interpretation	p value
Sex × right-hand grip-strength level	Statistically significant association	$p < 0.001$
Sex × left-hand grip-strength level	Statistically significant association	$p < 0.001$
Sex × endurance-duration category	Statistically significant association	$p = 0.006$
BMI category × performance	Borderline, not statistically significant	$p = 0.056$

Note: Exact chi-square or likelihood-ratio statistics, degrees of freedom, effect sizes, confidence intervals, and complete contingency tables were not available in the supplied files. These should be added from the original statistical output before submission.

Discussion

This cross-sectional analysis describes a two-domain perspective on handgrip performance in Saudi young adults: bilateral categorical grip strength as a peak-force domain and duration at 70% effort as a sustained-effort domain. The principal finding was that sex was associated with both bilateral grip-strength category and endurance category, whereas the reported BMI association did not reach statistical significance. These findings should be interpreted as categorical associations rather than estimates of individual force capacity or causal mechanisms. The sex-related pattern in grip-strength category is consistent with evidence that absolute muscular strength and handgrip performance differ by sex and are influenced by body composition and anthropometry. International reviews recommend population-specific, sex-specific interpretation rather than universal thresholds [13], and a recent study of university students similarly reported sex differences in strength with relevant body-composition context [14]. The significant association between sex and endurance category extends the interpretation beyond a single maximal grip measurement. Sustained isometric force depends on the maintenance of neural drive and force control as well as peripheral processes such as local oxygen delivery, metabolite accumulation, and fatigue development [6-8,18]. However, no force–time curves, electromyography, muscle oxygenation data, or direct muscle-mass measures were available in the present dataset; any physiological explanation must therefore remain cautious.

Future studies should report continuous endurance time and force-decay data so that the relation between peak force and fatigue resistance can be examined quantitatively. BMI provided general body-size context but did not show a statistically significant association with performance in the reported categorical analysis. This is unsurprising because BMI does not distinguish fat mass from fat-free mass and cannot account for hand size, forearm morphology, or training status. Direct body-composition assessment would enable more informative analyses of lean mass and relative handgrip strength [9,14]. The findings have potential practical relevance for exercise prescription, sports medicine, and clinical screening. Handgrip dynamometry can provide a pragmatic component of routine functional assessment when testing conditions are standardized [3-5,15]. In young adults, low categorical performance should not be treated as a diagnosis; rather, it may prompt a broader assessment of training history, physical activity, nutritional status, musculoskeletal symptoms, and body composition. In the Saudi context, this approach aligns with broader efforts to promote physical activity and physical fitness [10-12].

Strengths and Limitations

A strength of this study is its inclusion of both bilateral grip-strength categories and sustained-effort duration in a Saudi young adult sample. The analysis also presents sex-stratified interpretation as a central consideration. Several limitations must be acknowledged. The cross-sectional design precludes causal inference. The available data were categorical and did not permit analysis of raw grip force, median values, interquartile ranges, confidence intervals, correlation coefficients, or effect sizes. Direct body-composition measurement and physical-activity assessment were not reported. In addition,

study setting, recruitment procedures, sample-size rationale, eligibility criteria, and complete measurement protocol details require completion before submission. If recruitment occurred at one centre, limited generalizability should be explicitly acknowledged.

Future Directions

Future research should use longitudinal and multicentre designs, collect raw force–time data, define a standardized dynamometer protocol, and include objective measures of muscle mass, hand dimensions, and physical activity. These data would allow sex-specific and body-size-adjusted reference equations, effect-size estimation, and a clearer assessment of the relation between peak force and fatigue resistance.

Conclusion

In this cross-sectional sample of Saudi young adults, sex was significantly associated with categorical bilateral grip strength and endurance duration, whereas the reported BMI association was not statistically significant. The findings support assessment of both peak-force and sustained-effort domains, interpreted with a standardized protocol and sex-specific reference values. They do not establish causality. Longitudinal, multicentre studies with raw force data, body-composition measures, and physical-activity assessment are needed to strengthen clinical and exercise-physiology interpretation.

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