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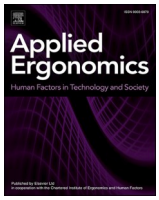

Grip strength of law enforcement officers and its implications

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ABSTRACT

Grip strength (GS) plays a vital role for law enforcement officers (LEOs). This study aimed to establish a baseline for LEO GS, compare it with the general population, determine the correlation between LEO GS and body dimensions, and evaluate the implications for occupational performance. A total of 756 male and 218 female LEOs from across the U.S. participated in the study. On average, male LEOs exhibit stronger GS (49.53 kg) than female officers (32.14 kg). Significant differences between LEOs and the general population were observed. GS correlated with hand breadth, hand length, stature, and bideltoid breadth. Approximately 26%–46% of males and 5%–39% of females were identified as being at risk of health, fit, or occupational performance based on their measured GS. Enhancing GS training or avoiding implementing heavy equipment (such as pistols with heavy trigger weight), could improve officer occupational performance, safety, or health.

1. Introduction

Grip strength (GS) serves as a predictor of overall body strength and muscular endurance, with significant health, safety, and occupational implications. In gerontology, GS has been linked to various health indicators, including mobility, cognitive function, and heart health (WebMD, 2023; Vaishya et al., 2024). Within the occupations, GS is indicative of upper arm muscular capacity and overall physical strength (Zaccagni et al., 2020; Wang et al., 2018), playing a crucial role in effective job performance and reducing the risk of injuries in certain tasks, such as manual lifting, valve operation, and machine maneuvering (Eksioglu, 2016). For instance, male manual workers were found to have a GS 12.4% stronger (average of 51.6 kg) than male office workers (45.2 kg) (Saremi and Rostamzadeh, 2019).

1.1. Normative data of grip strength

In addition to occupational effects (Saremi and Rostamzadeh, 2019), various factors contribute to GS capacity, including age (Werle et al., 2009), anthropometry (Wu et al., 2009; Clerke et al., 2005; Hone and McCullough, 2012), hand dominance (Schlüssel, dos Anjos, de Vasconcellos, and Kac, 2008; Bardo et al., 2022), and sex (Li et al., 2010; Bardo et al., 2022; Nicolay and Walker, 2005).

The American College of Sports Medicine (ACSM) guidelines for exercise testing and prescription reported normative data of general population by five categories of GS: Excellent, Very Good, Good, Fair, and Poor, using a combined strength data of right and left hands (ACSM, 2017; Shaw, 2024). Good GS (i.e., average values) for men is defined as 90–97 kg for age 15–19 years, 95–103 kg for age 20–39 years, 88–96 kg for age 40–49 years, 84–91 kg for age 50–59 years, and 84–90 kg for age 60–69 years. For women, good GS (i.e., average values) is outlined as 53–59 kg for age 15–19 years, 58–62 kg for age 20–39 years, 54–60 kg for age 40–49 years, 49–53 kg for age 50–59 years, and 45–47 kg for age 60–69 years. These values are to be divided by two when comparing to GS data of single measurement (typically the dominant hand) reported in the literature. In gerontology, for the aged 65 years and older population, a GS (dominant hand) of 26–32 kg is categorized as Intermediate, and less than 26 kg as Weak in men; while in women, 16–20 kg was classified as Intermediate, and less than 16 kg as Weak (Alley et al., 2014).

1.2. Grip strength of law enforcement officers and knowledge gaps

In law enforcement professions, GS is a potential health and fit indicator and is crucial for numerous tasks, including handling confrontations, operating firearms, moving obstacles, and conducting rescues (Effective Fitness, 2023). While previous studies have provided detailed grip strength data for various occupations, such as athletes, manual workers, and office workers (Zaggelidis, 2016; Josty et al., 1997; Saremi and Rostamzadeh, 2019), limited information is available regarding the

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GS of national law enforcement officers (LEOs). In sectional and regional studies, grip strength has been identified as a factor impacting officers' ability to pass the standard police pistol qualification (PPQ) (Brown et al., 2021) or maintain shooting accuracy (Rodd et al., 2008; Copay and Charles 2001). Hand grip strengths ranging from 36.36 kg to 56.82 kg have been determined as necessary to achieve approximately 85% and 90% scores on the PPQ when a heavy trigger weight (i.e., 3.64–5.45 kg) is used (n = 118), surpassing the average GS of female officers (35.23 kg; n = 32) (Brown et al., 2021).

Given the occupational task or performance demand, conducting a large-scale national stratified study on officer GS, along with hand and body anthropometry, would be invaluable for national law enforcement entities. This study could provide insights into the current status of LEO GS and facilitate the development of control measures to enhance officer safety and well-being. These control measures might include: (1) recommending GS benchmarks for individuals in the general population seeking to join the law enforcement workforce, (2) establishing training objectives for enhancing GS among current law enforcement personnel, and (3) adjusting optimal GS requirements for LEO equipment, such as firearm trigger designs to accommodate the diverse LEO population.

1.3. Objective

The objectives of this study were as follows:

1. Establish a national database of LEO grip strength for each age bracket within each sex group, aiming to set a baseline for advancing LEO protection and well-being.
2. Compare the difference in grip strength between LEOs and the general population as a reference for individuals preparing to join the LEO workforce.
3. Identify the correlation between grip strength and body dimensions (such as stature, body weight, body mass index, hand breadth, hand length, chest circumference, and chest breadth) among LEOs for future equipment design and work simulation applications.
4. Assess the physical and health risks faced by LEOs and identify potential control measures in duty activities, such as triggering a firearm, moving a barrier, and rescuing a person, based on grip strength capacity.

It was hypothesized that:

1. LEO grip strengths vary among age and sex groups.
2. LEOs exhibit larger grip strength compared to the general population.
3. The correlation (r) between grip strength and LEO body dimensions is strong, falling within the range of $0.5 \leq r < 0.7$.
4. More than 10% LEOs have GS levels classified as "at risk" for health or occupational activities (i.e., at the Poor or Fair level of the Excellent-Very Good-Good-Fair-and-Poor scoring system) and are at risk of scoring 85% or less on the projected police pistol qualification (PPQ) score when a heavy trigger weight (i.e., 3.64–5.45 kg) is used.

2. Methods

2.1. Participants

A total of 756 male and 218 female active-duty law enforcement officers (LEOs) participated in the study. They were recruited from 12 LEO stations and training centers across U.S. regions. Participants were selected based on the geographic density of racial/ethnic distributions, as derived from the 2010 U.S. Census (U.S. Census Bureau, 2012), which was the most current data available at the time of project scientific and ethical reviews. There were 714,000 LEOs in the U.S. at the time. The study aimed to recruit 1000 participants, with a detailed rationale and sampling plan outlined in Hsiao et al. (2021), and the stratified sample aimed to represent national LEO distributions in age and ethnicity (Table 1). The research protocol was approved by the National Institute for Occupational Safety and Health (NIOSH) Institutional Review Board (IRB #14-DSR-02XP).

2.2. Procedure

This study on LEO GS was part of a broader national LEO anthropometry investigation. LEOs participated in data collection at one of 12 study sites across the United States over a 25-month period from 2018 to 2020 (Hsiao et al., 2021). Prior to participation, LEOs provided consent to be involved in the study. They then completed a demographic data form, capturing information such as sex, age, and race/ethnicity. Following this, participants' body dimensions, encompassing 39 measurements and five three-dimensional body scans were collected (Hsiao et al., 2021). This paper presents LEO GS data alongside demographic information and data on nine body dimensions relevant to GS: age, sex, bideltoid breadth, hand breadth, hand length, body weight, stature, body mass index (BMI), chest circumference, chest breadth, and chest depth.

The GS was measured using a Stoelting Smedley Spring Grip Strength hand dynamometer. Participants sat upright in a chair and held the dynamometer in their dominant hand at a 90° shoulder flexion (forward) with a 0° elbow flexion and the forearm in a neutral position. They were instructed to maintain a neutral wrist position as much as possible and were allowed to adjust their wrist position for comfort if necessary. Participants then squeezed the dynamometer with their maximum force for 3 s and then relaxed. This grip test was repeated three times, with a rest period of 15 s between trials. The highest force achieved among the three trials was recorded as the GS.

The posture and arm position during grip measurements can significantly impact the results obtained. Research has shown that standing typically yields higher grip strengths compared to sitting (Balogun et al., 1991; Amosun et al., 1995). In this study, a seated posture was utilized for grip measurements, consistent with the National Institute of Health (NIH) Toolbox grip strength measurement protocol (Bohannon et al., 2019), ensuring comparability with data from other studies. GS measurements taken with the arm at 180° shoulder flexion (arm up) generally produce higher values than those taken at 0° flexion (arm down) (Su et al., 1994). This study adopted a 90° shoulder flexion position, reflecting or mimicking the typical hand posture during duty activities and firearm handling.

Regarding the effect of elbow angle on GS measurement, conflicting findings exist, with some studies suggesting greater strength in full extension compared to 90° flexion (Kuzala and Vargo, 1992), others reporting the opposite (Mathiowetz et al., 1985), and some finding no difference (Ferraz et al., 1992). This study opted for full elbow extension (0° elbow angle) alongside 90° shoulder flexion, aligning with typical hand posture during duty activities and firearm handling.

Forearm supination has been associated with greater grip strength than the neutral position, and the neutral position has been found to be stronger than pronation (Richards et al., 1996). Similarly, wrist flexion tends to weaken grip strength compared to the neutral and extended positions (Hazelton et al., 1975). The current study employed a neutral forearm and wrist position, consistent with common GS measurement practices, facilitating reliable comparisons with normative data.

Various protocols exist regarding the number of trials and determination of maximum GS data, ranging from one trial to the best of two or three trials, or the mean of two or three trials (Trossman et al., 1990; Härkönen et al., 1993; Crosby et al., 1994; Hamilton et al., 1994). However, literature suggests no significant differences among these approaches (Trossman et al., 1990; MacDermid et al., 1994). This study conducted three trials and recorded the maximum GS achieved, minimizing the need for practice trials.

The nine body dimensions relevant to GS: bideltoid breadth, hand breadth, hand length, body weight, stature, BMI, chest circumference,

Table 1
Participants by racial/ethnic group, sex, and age (Hsiao et al., 2021).

Race/ethnicity	White n = 685						Black n = 124		Hispanic/Other n = 165		Total
Sex	Males			Females			Males	Females	Males	Females	
Age (years)	18–34	35–44	45–54	18–34	35–44	45–54	24–57	24–63	23–57	23–56	
Stratified Samples	188	183	172	52	62	28	93	31	120	45	974
Proposed Samples	172	165	163	72	71	71	82	35	118	51	1000

chest breadth, and chest depth, are described in detail in Appendix A.

3. Data analysis

3.1. LEO grip strength by sex and age brackets

A one-tailed *t*-test procedure with pooled variance at $\alpha = .05$ was employed to evaluate the difference in GS between sex groups. Additionally, Cohen's d was calculated to assess the effect size of the difference in means. For comparisons of GS among age groups, an ANOVA was performed for each sex grouping. Following this, Tukey's Studentized Range honestly significant difference (HSD) test was used to determine significance for all pairs of age groups at $\alpha = .05$. Cohen's d was also calculated for the pairs identified by Tukey's HSD as significantly different.

3.2. Difference in mean of hand grip strength between LEOs and general population

Five pairs of t-tests were conducted to compare the mean GS between LEOs and the general population for each sex group, using a significance level of 0.05. For males, the adjusted p-value for five paired comparisons (i.e., five age groups) was 0.01 (0.05/5), while for females, it was 0.0125 (0.05/4) for four paired comparisons (i.e., four age groups). Cohen's d was also computed to determine the effect size of the difference in means for each pair compared.

3.3. Correlation between grip strength and body dimensions

The Pearson correlation procedure was used to assess the linear relationship (r) between GS and nine anthropometric measurements: bideltoid breadth, hand breadth, hand length, body weight, stature, BMI, chest circumference, chest breadth, and chest depth. Analyses were conducted separately for each sex group and for combined sex groups. In this research context, the correlation is classified as follows: weak for $0 < r < 0.3$ or $-0.3 < r < 0$, moderate for $0.3 \leq r < 0.5$ or $-0.5 \leq r < -0.3$, strong for $0.5 \leq r < 0.7$ or $-0.7 \leq r < -0.5$, and very strong for $0.7 \leq r \leq 1$ or $-0.7 \leq r \leq -1$.

3.4. Projected health risk and firearm trigger implication based on grip strength

The distribution of GS data as percentages within each sex group was calculated across five score categories (Excellent, Very Good, Good, Fair, and Poor) according to the ACSM guidelines for exercise testing and prescription (ACSM, 2017; Shaw, 2024). The ACSM scoring system combines strength data from both the right and left hands. In this study, the ACSM scores were divided by two to evaluate the health risk levels within our LEO population.

Additionally, the distribution of GS, categorized as percentages for values less than 36.36 kg, was computed separately for each sex group. This threshold is associated with scoring approximately 85% on standard police pistol qualification (PPQ) tests when using a heavy trigger weight (Brown et al., 2021).

4. Results

4.1. LEO grip strength by sex and age brackets

Table 2 summarizes the GS of LEOs by sex and age brackets. Male LEOs exhibited significantly higher ($t_{972} = 24.39$; $p < .001$, $d = 1.88$) GS (49.53 ± 9.94 kg) compared to female officers (32.14 ± 6.43 kg) (Fig. 1). Among male officers, GS varied significantly across different age groups ($F_{4,\ 755} = 5.18$, $p < .001$). Specifically, the age group of 30–39 demonstrated significantly stronger GS (50.98 ± 10.31 kg) compared to the age groups of 50–59 (46.71 ± 8.56 kg) ($p = .044$, $d = 0.43$) and 60–69 (43.23 ± 7.9 kg) ($p = .001$, $d = 0.76$) (Fig. 2). Conversely, no statistically significant differences were observed among the four age groups for female officers ($F_{3,\ 215} = 2.14$, $p = .096$): age 18–29 years (30.93 ± 6.48 kg), age 30–39 years (33.38 ± 6.72 kg), age 40–49 years (31.92 ± 8.16 kg), and age 50–59 years (30.53 ± 3.72 kg) (Fig. 3). However, there appears to be a trend indicating that GS peaks in the 30–39 age group and gradually declines with age for both male and female officers (Table 2).

4.2. Difference in mean of hand grip strength between LEOs and general population

For males, significant differences were found between the LEO and general populations for all age groups: 18–29 year ($p < .001$, $d = 0.3$), 30–39 years ($p < .001$, $d = 0.7$), 40–49 years ($p < .001$, $d = 0.7$), 50–59 years ($p < .001$, $d = 0.4$), the age 60–69 group ($p = .01$, $d = 0.7$) (Table 3). For females, significant differences were also observed between LEO and general population data for all four age groups: 18–29 year ($p = .002$, $d = 0.3$), 30–39 years ($p < .001$, $d = 07$), 40–49 years ($p < .001$, $d = 0.4$), and 50–59 years ($p < .001$, $d = 0.6$) (Table 3).

4.3. Correlation between grip strength and body dimensions

LEO GS was found to correlate with Bideltoid Breadth, BMI, Chest Breadth, Chest Circumference, Chest Depth, Hand Breadth, Hand Length, Stature, and Weight for male and female officers combined ($p < .001$) (Table 4). Of the dimensions, Bideltoid Breadth, Hand Breadth,

Table 2
Grip strength of LEOs by sex and age brackets.

Sex	Age Group	n	Mean (kg)	Std Dev (kg)	Std Error (kg)
Male	18–29	123	49.02	10.27	0.93
	30–39	286	50.98	10.31	0.61
	40–49	227	49.67	9.63	0.64
	50–59	107	46.71	8.56	0.83
	60–69	13	43.23	7.9	2.19
	Total	756	49.53	9.94	0.36
Female	18–29	41	30.93	6.48	1.01
	30–39	95	33.38	6.72	0.69
	40–49	61	31.92	6.16	0.79
	50–59	19	30.53	3.72	0.85
	60–69	1	20[a]		
	70–79	1	21[a]		
	Total	218	32.14	6.43	0.44

[a] Statistical comparisons could not be conducted across these groups where n = 1.

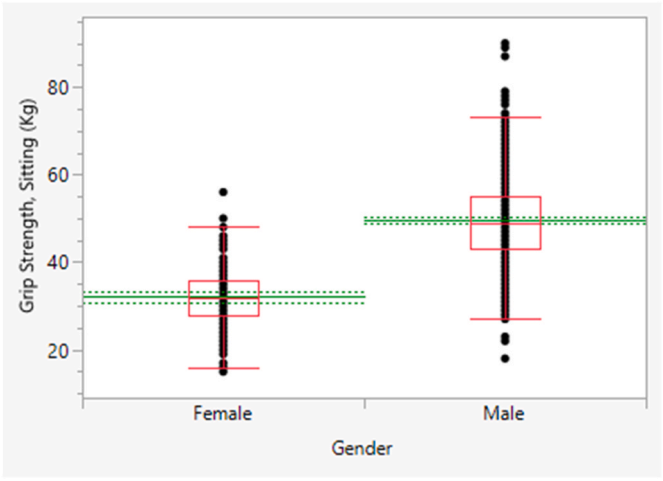


Fig. 1. Female officers exhibited lower hand grip strength (32.14 ± 6.43 kg) compared to male officers (49.53 ± 9.94 kg). The Cohen's d for effect size is 1.88, indicating a large difference.

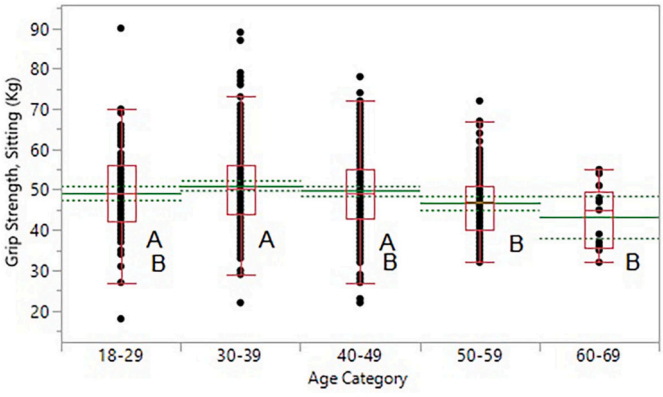


Fig. 2. Hand grip strengths in different age brackets among male LEOs. Means marked with different letters (e.g., A or B) are significantly different. The Cohen's d for effect size is 0.43 between the age groups 30–39 and 50–59, indicating a medium difference, and 0.76 between the age groups 30–39 and 60–69, indicating a large difference.

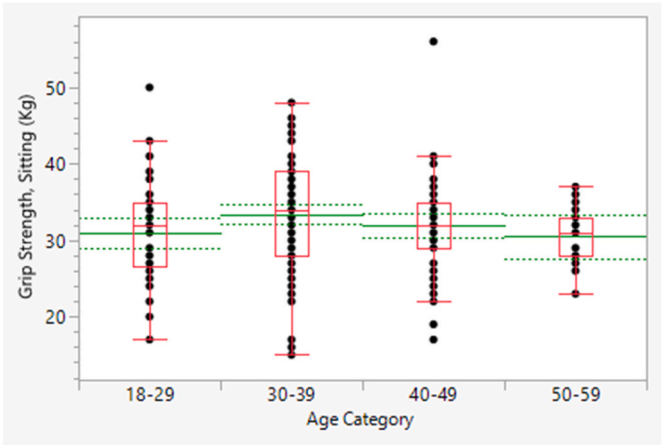


Fig. 3. Hand grip strengths in different age brackets among female LEOs, excluding one age 60+ and one 70+ for small numbers in the age brackets. Significant difference was not found in mean grip strength among the four age groups.

Hand Length, and Stature showed positive strong relationship with GS (r ranged 0.5–0.7), while Chest Breadth, Chest Circumference, and Weight show positive moderate relationship with GS (r ranged 0.3–0.5). While a significant correlation was reported for BMI and Chest Depth with GS ($p < .001$), the correlation was weak (r ranged 0.176–0.183) (Table 4 and Fig. 4a – i).

When correlation analyses were performed by sex, Bideltoid Breadth, Chest Breadth, Chest Circumference, Hand Breadth, Hand Length, Stature, and Weight were found significantly interrelated to GS ($p < .001$), while BMI and Chest Depth were not. However, only Hand Breadth, Hand Length, and Stature demonstrate a positive weak to moderate correlation with GS (r ranged 0.273–0.408) for both sex groups.

4.4. Projected physical/health risk and firearm trigger implication based on grip strength

While LEOs on average are stronger in GS than the general population (Table 2), a sizable portion of LEOs are still considered at a risk level in health, fit, or occupational operation based on their measured GS which are categorized as Fair or Poor. For male LEOs, 45.5% of age 18–29 years group, 44.2% of age 30–39 ages group, 26.4% of age 40–49 years group, 29.9% of age 50–59 years group, and 46.2% of age 60–69 years group have a grip strength that is in the category of Fair or Poor. For female LEOs, 39.1% of age 18–29 years group, 26.3% of age 30–39 years group, 19.6% of age 40–49 years group, and 5.3% of age 50–59 years group possess a GS that falls in the category of Fair or Poor (Table 5).

Additionally, the GS data from the current national study indicate that 7.8% male officers and 78.9% of female officers have a GS of less than 36.36 kg (Table 6). The 36.36 kg threshold grip strength corresponds to projected score of 85 % of the police pistol qualification score when using a heavy trigger weight (3.64–5.45 kg).

5. Discussion

5.1. LEO grip strength by sex and age

Sex and age are two significant factors influencing GS (Li et al., 2010; Bardo et al., 2022; Nicolay and Walker, 2005; Werle et al., 2009). This trend extends to the law enforcement occupational group. In the present study, female LEOs exhibited a notably lower average GS (32.14 ± 6.43 kg) compared to male officers (49.53 ± 9.94 kg). A separate local investigation involving Colorado State troopers revealed similar findings, with female officers displaying a mean grip strength of 37.88 ± 5.34 kg (n = 32) and male officers significantly surpassing them with a mean grip strength of 55.04 ± 7.77 kg (n = 589) (Dawes et al., 2017). This consistent sex-based disparity in GS, approximately 17 kg in both studies, underscores its significance in law enforcement contexts. Notably, the Colorado State troopers' study omitted details regarding GS testing posture (standing or seated), shoulder pose, and elbow angle, leaving unanswered questions regarding the factors contributing to the observed 5 kg discrepancy between their results and those of the current national study.

Interestingly, while there is a trend indicating that GS peaks between the ages of 30 and 39, gradually declining with age for both male and female officers, no statistically significant differences were observed among the age groups for female officers in either the current study or the Colorado State troopers' study. This suggests that while gender disparities in GS exist, the effects of aging may be mitigated by other factors, particularly for female officers. These factors could include the physical demands inherent in police work and the necessity for regular training, which may contribute to maintaining a requisite level of physical fitness.

Table 3
Difference in mean of hand grip strength between LEOs and the general population.

Sex	Law Enforcement Officers					General Civilian Population[a]				Comparison				
	Age Group (years)	n	Mean (kg)	Std Dev (kg)	Std Error (kg)	n	Mean (kg)	Std Dev (kg)	Std Error (kg)	S pooled	t value	DOF	p-value[b]	Cohen's d
Male	18–29	123	49.02	10.27	0.93	68	46.3	8.2	0.93	9.50	3.57	189	**<.001**	0.3
	30–39	286	50.98	10.31	0.61	56	43.6	10.7	0.61	10.23	5.67	340	**<.001**	0.7
	40–49	227	49.67	9.63	0.64	75	43.2	9.3	0.64	9.57	6.25	300	**<.001**	0.7
	50–59	107	46.71	8.56	0.83	77	42.7	10.2	0.83	9.37	4.08	182	**<.001**	0.4
	60–69	13	43.23	7.9	2.19	57	37.3	9.9	2.19	8.90	2.57	68	**.01**	0.7
Female	18–29	41	30.93	6.48	1.01	166	29.0	7.3	1.01	6.74	3.09	205	**.002**	0.3
	30–39	95	33.38	6.72	0.69	204	29.1	6.1	0.69	6.24	6.94	297	**<.001**	0.7
	40–49	61	31.92	6.16	0.79	143	29.4	6.5	0.79	6.54	3.62	202	**<.001**	0.4
	50–59	19	30.53	3.72	0.85	98	27.1	6.4	0.85	6.15	3.26	115	**<.001**	0.6

[a] National Institute of Health (NIH) Toolbox values per Bohannon et al. (2019).
[b] Bolded p-values indicate a significance in means of hand grip strength between LEOs and the general populations.

Table 4
Correlation between grip strength and body dimensions (Bideltoid Breadth, Body Mass Index, Chest Breadth, Chest Circumference, Chest Depth, Hand Breadth, Hand Length, Stature.

Sex	Body Dimension	N	Correlation (r)[a]	Significant Prob (p)
Combined	Bideltoid Breadth	973	**.532**	<0.001
	BMI	973	0.176	<0.001
	Chest Breadth	973	**.419**	<0.001
	Chest Circumference	973	**.364**	<0.001
	Chest Depth	973	0.183	<0.001
	Hand Breadth	973	**.654**	<0.001
	Hand Length	973	**.570**	<0.001
	Stature	973	**.616**	<0.001
	Weight	973	**.428**	<0.001
Male	Bideltoid Breadth	756	0.239	<0.001
	Body Mass Index	756	0.034	0.348
	Chest Breadth	756	0.133	<0.001
	Chest Circumference	756	0.124	<0.001
	Chest Depth	756	0.088	0.0156
	Hand Breadth	756	**.408**	<0.001
	Hand Length	756	**.351**	<0.001
	Stature	756	**.390**	<0.001
	Weight	756	0.205	<0.001
Female	Bideltoid Breadth	217	0.209	0.002
	Body Mass Index	217	0.036	0.601
	Chest Breadth	217	0.149	0.028
	Chest Circumference	217	0.115	0.009
	Chest Depth	217	0.058	0.398
	Hand Breadth	217	**.418**	<0.001
	Hand Length	217	**.273**	<0.001
	Stature	217	**.384**	<0.001
	Weight	217	0.181	0.007

[a] Bolded r indicates moderate or strong correlation between the body dimension and grip strength.

5.2. Difference in hand grip strength between LEOs and general population

Significant disparities in GS were evident between LEOs and the general population across all age groups and both sexes. The demanding nature of law enforcement duties, coupled with the physical rigor inherent to the profession, likely contribute to these observed differences. Specifically, LEOs undergo routine physical training and conditioning as part of their job requirements, which likely enhances GS compared to the general populace (Dodds et al., 2014). Additionally, individuals opting for a career in law enforcement may possess inherently higher levels of physical fitness, including GS, than the average person (Gill, 2024). Furthermore, LEOs are frequently mandated to maintain specific standards of physical fitness, often including targeted strength training exercises aimed at improving GS. Conversely, the general population may not engage in regular exercise programs or may not prioritize GS in their workouts (Dodds et al., 2014).

5.3. Correlation between grip strength and body dimensions

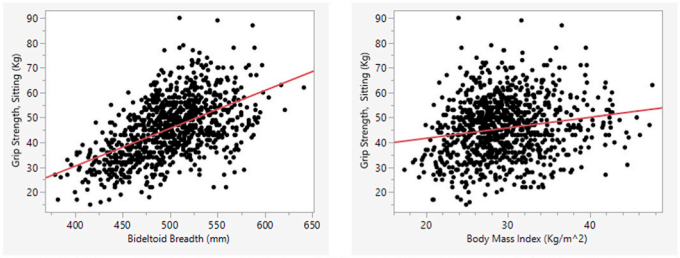
Law Enforcement Officer (LEO) GS was found to correlate with Bideltoid Breadth, BMI, Chest Breadth, Chest Circumference, Chest Depth, Hand Breadth, Hand Length, Stature, and Weight. This correlation between GS and body dimensions likely arises from a combination of biomechanical, physiological, and lifestyle factors influencing muscle development and physical performance.

Firstly, larger body dimensions typically signify greater muscle mass, contributing to stronger GS (Nayak et al., 2023). Secondly, specific body dimensions like hand length and breadth offer mechanical advantages that enhance GS. For instance, a longer hand can generate more torque, facilitating better grip and object retention (Nayak et al., 2023). Thirdly, indicators of overall physical fitness such as stature and weight, often associated with increased physical activity levels, are linked to better GS (Ahmad et al., 2021). Fourthly, body proportions, including the ratio of limb length to torso size, can influence physical capabilities, with a wider bideltoid breadth (shoulder width) potentially enhancing GS (Nayak et al., 2023). Fifthly, BMI can reflect both higher body fat and greater muscle mass in physically active individuals, correlating with stronger GS (Krakauer and Krakauer, 2020). Finally, the mentioned body dimensions are often associated with the functional use of muscles in daily activities; individuals with larger hands may engage more frequently in activities demanding GS, thereby enhancing it (Nayak et al., 2023).

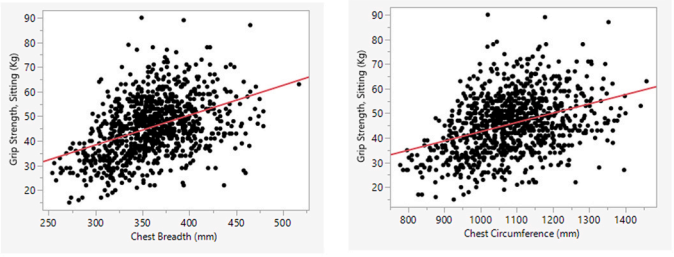
5.4. Projected health risk and firearm trigger implication based on grip strength

The GS data from the current national study reveal that 7.8% of male officers and 78.9% of female officers exhibit a GS of 36.36 kg or less. This 36.36-kg threshold aligns with a projected grip strength value for officers to achieve approximately 85% or better of the standard PPQ score when a heavy trigger weight is used (Brown et al., 2021). The GS data highlight the potential benefits of enhancing GS training for officers, particularly female officers.

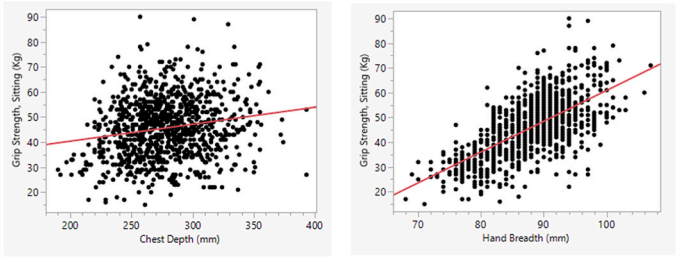
In a study assessing the impact of GS on shooting performance (n = 118) when a heavy trigger weight (i.e., 8lbs–12lbs) is used, female officers (n = 32) exhibited an average grip strength of 35.2 kg (Brown et al., 2021), placing them at a disadvantage and resulting in a significantly higher failure rate in meeting mandated PPQ standards compared to male officers (21.9% vs. 8.1%). The study suggests considering a lighter trigger pull weight, such as the standard 2.73 kg used in 9 mm duty pistols, as an alternative to the 3.64–5.45 kg weights found in double-action pistols, which involve both cock and hammer releases in



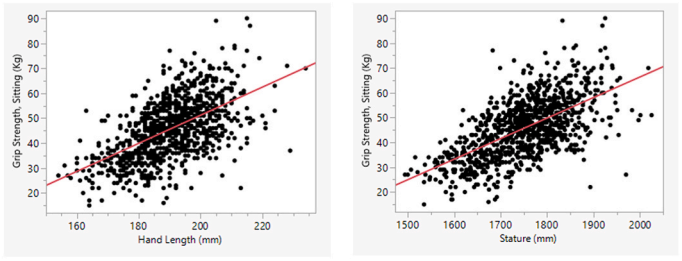
(a) Bideltoid Breadth: Grip Strength (kg) = -30.30641 + 0.1518941*Bideltoid Breadth (mm).
(b) Body Mass Index: Grip Strength (kg) = 33.246972 + 0.4205489*Body Mass Index.



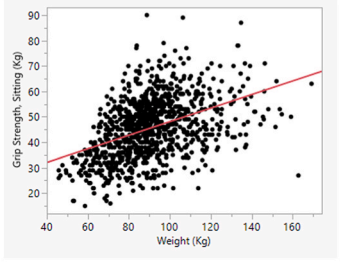
(c) Chest Breadth: Grip Strength (kg) = 2.0401304 + 0.1210522*Chest Breadth (mm).
(d) Chest Circumference: Grip Strength (kg) = 4.9069573 + 0.0376222*Chest Circumference (mm).



(e) Chest Depth: Grip Strength (kg) = 26.894124 + 0.0675788*Chest Depth (mm).
(f) Hand Breadth: Grip Strength (kg) = -63.48724 + 1.2440645*Hand Breadth (mm).



(g) Hand Length: Grip Strength (kg) = -61.39506 + 0.5630163*Hand Length (mm).
(h) Stature: Grip Strength (kg) = -99.26858 + 0.0828272*Stature (mm).



(i) Weight: Grip Strength (kg) = 21.42989 + 0.2668236*Weight (kg).

Fig. 4. Correlation between grip strength and body dimensions (males and females combined).

triggering a gunshot.

6. Study limitations

6.1. LEO grip strength by sex and age brackets

The current study employed a stratified sample that mirrored the age and ethnicity distribution of national law enforcement officers (LEOs). This approach provides valuable insights into the status of GS among LEOs nationwide. However, when the data were segmented by age group, some categories (such as males aged 60–69 years and females aged 50–59 and 60–69 years) had smaller sample sizes. Therefore, caution should be exercised when interpreting data from these smaller samples.

6.2. Difference in mean of hand grip strength between LEOs and general population

The NIH Toolbox data were collected with participants squeezing a dynamometer while seated, with their arms at their sides, elbows flexed at 90°, and forearms in a neutral position. In this study, participants assumed a similar seated posture, but with their dominant arm extended 90° forward, elbows flexed at 0°, and forearms in a neutral position. Research has shown that full elbow extension (0° elbow angle) combined with 90° shoulder flexion typically yields higher GS measurements compared to having the arms at the sides with elbows flexed at 90° (Su et al., 1994). This variation in posture represents a limitation of this study component. Nonetheless, detailed comparisons of GS between these two postures show a 0.23 kg difference in mean GS among males (33.31 ± 5.18 kg vs. 33.08 ± 5.10 kg) and a 0.50 kg difference in mean GS among females (18.50 ± 3.50 kg vs. 18.00 ± 4.09 kg) (Parvatikar and Mukkannavar, 2009). Given the observed differences of 2.72 kg–7.38 kg across age groups between LEOs and the general population (Table 3), the impact of the elbow posture factor is minimal in concluding that a difference in mean GS exists between LEOs and the general population.

6.3. Correlation between grip strength and body dimensions

This study examined the correlation between GS and various body dimensions, including BMI. Absolute GS adjusted for BMI has been used to identify age-related health conditions (Abdalla et al., 2022). This study did not perform such an adjustment, which represents a minor limitation. Despite this, the study was not designed to investigate age-related conditions in older adults with extreme body sizes, so normalizing grip strength by BMI would not have been particularly beneficial or practical for the study's objectives, especially for LEO equipment design and work simulation applications.

6.4. Projected health risk and firearm trigger implication based on grip strength

The differences in GS between the dominant and non-dominant hands range from 5.0% to 5.6% (Wang et al., 2019), or 1.0–2.4 kg for

Table 5
Grip strength normative data in five categories (adopted and modified for signal hand from ACSM guidelines) and percentages of LEOs in the categories within each age bracket.

Sex	Age	18–29	30–39	*40–49*	*50–59*	*60–69*
Male	**Excellent**	≥ 58 kg	≥ 58 kg	≥ 54 kg	≥ 51 kg	≥ 50 kg
	N/	21	64	73	31	3
	Percentage	(17.1%)	(22.4%)	(32.2%)	(29.0%)	(23.1%)
	Very Good	52–57	52–57	49–53	46–50	46–49
	N/	kg	kg	kg	kg	kg
	Percentage	26	62	47	28	3
		(21.1%)	(21.7%)	(20.7%)	(26.2%)	(23.1%)
	Good	48–51	48–51	44–48	42–45	42–45
	N/	kg	kg	kg	kg	kg
	Percentage	20	45	47	16	1
		(16.3%)	(15.7%)	(20.7%)	(15.0%)	(7.7%)
	Fair	42–47	42–47	40–43	38–41	37–41
	N/	kg	kg	kg	kg	kg
	Percentage	29	71	33	14	2
		(23.6%)	(24.8%)	(14.5%)	(13.1%)	(15.4%)
	Poor	42 < kg	42 < kg	40 < kg	38 < kg	<37 kg
	N/	27	44	27	18	4
	Percentage	(21.9%)	(15.4%)	(11.9%)	(16.8%)	(30.8%)
	Total	123	286	227	107	13
Female	**Excellent**	≥ 35 kg	≥ 36 kg	≥ 35 kg	≥ 31 kg	
	N/	11	39	20	10	
	Percentage	(26.8%)	(41.1%)	(32.8%)	(52.6%)	
	Very Good	32–34	32–35	31–34	27–30	
	N/	kg	kg	kg	kg	
	Percentage	10	22	18	7	
		(24.4%)	(23.2%)	(29.5%)	(36.8%)	
	Good	29–31	29–31	27–30	25–26	
	N/	kg	kg	kg	kg	
	Percentage	4	9	11	1	
		(9.8%)	(9.5%)	(18.0%)	(5.3%)	
	Fair	26–28	26–28	25–26	23–24	
	N/	kg	kg	kg	kg	
	Percentage	9	15	6	1	
		(22.0%)	(15.8%)	(9.8%)	(5.3%)	
	Poor	<26 kg	<26 kg	<25 kg	<23 kg	
	N/	7	10	6	0 (0%)	
	Percentage	(17.1%)	(10.5%)	(9.8%)		
	Total	41	95	61	19	

N/Percentage: count and percentage of distribution of grip strength in the five scoring categories within each age bracket.

Table 6
Percentage of LEO grip strength greater than 36.36 kg for each age bracket by sex.

Sex	Age Group (years)	Grip Strength >36.36 kg		Grip Strength ≤ 36.36 kg		Total N
		N	Percentage	N	Percentage	
Male	18–29	113	91.9%	10	8.1%	123
	30–39	272	95.1%	14	4.9%	286
	40–49	210	92.5%	17	7.5%	227
	50–59	93	86.9%	14	13.1%	107
	60–69	9	69.2%	4	30.8%	13
	Total	697	**92.2%**	59	**7.8%**	756
Female	18–29	5	12.2%	36	87.8%	41
	30–39	29	30.5%	66	69.5%	95
	40–49	11	18.0%	50	82.0%	61
	50–59	1	5.3%	18	94.7%	19
	60–69	0	0%	1	100%	1
	70–79	0	0%	1	100%	1
	Total	46	**21.1%**	172	**78.9%**	218

males and 0.8–1.7 kg for females based on NIH Toolbox data (Bohannon et al., 2019). Dividing the ACSM scoring system by two provides a conservative estimate (i.e., an underestimation of 1.7 kg for males and 1.3 kg for females) of the proportion of LEOs falling into health risk categories without altering the ACSM categorizations. This is a limitation of this study component.

7. Conclusion

On average, male LEOs exhibit stronger GS (49.53 ± 9.94 kg) compared to female officers (32.14 ± 6.43 kg). Significant disparities between LEOs and the general population were noted across all age groups. Furthermore, GS was found to correlate with, hand breadth, hand length, stature, and bideltoid breadth.

A notable percentage of LEOs (ranging from 26% to 46% for males and 5%–39% for females across different age groups) were identified as being at a risk level for health or occupational activities, based on their measured GS. Furthermore, 7.8% of male officers and 78.9% of female officers demonstrated GS of 36.36 kg or less, a value associated with achieving projected approximately 85% on standard police pistol qualification (PPQ) tests when a heavy trigger weight (i.e., 3.64–5.45 kg) is used. This study provides essential baseline data for advancing LEO equipment design and ensuring officer protection. It also serves as a valuable reference for individuals in the general population preparing to enter the law enforcement profession. The findings highlight the potential benefits of enhancing grip strength training, especially for female officers, or considering lighter equipment. For example, agencies might consider avoiding pistols with heavy trigger weights, as these can disproportionately affect shooting accuracy among female officers.

Disclaimer

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CRediT authorship contribution statement

Hongwei Hsiao: Writing – review & editing, Writing – original draft, Resources, Project administration, Formal analysis, Conceptualization.

Declaration of competing interest

The author declares no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

LEO grip strength measurement and nine body dimensions relevant to grip strength (adapted from Hsiao et al., 2021; Hotzman et al., 2011)

Item	Variable	Description	
1	Bideltoid Breadth		The maximum horizontal distance between the lateral margins of the upper arms on the deltoid muscles is measured with a beam caliper. The participant sits erect, looking straight ahead. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The measurement is taken at the maximum point of quiet respiration.
2	Body Mass Index (BMI)		BMI = Weight/Stature^2
3	Chest Breadth		The maximum horizontal breadth of the chest at the level of the chest point anterior landmark.
4	Chest Circumference (Chest/ Bust Girth)		The maximum circumference of the chest at the fullest part of the breast.
5	Chest Depth		The horizontal distance between the right chest point anterior landmark and the back at the same level.
6	Hand Breadth		The breadth of the right hand between the landmarks at metacarpale II and metacarpale V is measured with a sliding caliper. The participant places the palm on a table with the fingers together and the thumb abducted. The middle finger is parallel to the long axis of the forearm. The two distal phalanges of the fingers lie on a flat surface 8 mm higher than the table.
7	Hand Length		The length of the right hand between the stylion landmark on the wrist and the tip of the middle finger is measured with a sliding caliper. The participant places the palm on a table with the fingers together and the thumb abducted. The middle finger is parallel to the long axis of the forearm. The two distal phalanges of the fingers lie on a flat surface 8 mm higher than the table.
8	Stature		The vertical distance from a standing surface to the top of the head.

(*continued on next page*)

(*continued*)

Item	Variable	Description	
9	Weight (kg)		Participant stands on the platform of the scale with weight distributed evenly on both legs. Stand in front of the participant and take the weight of the participant to the nearest tenth of a kilogram.

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