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Research Article

A Comparison of Hand Grip Strength Among Healthy Young Adult Malaysian and Thai Women

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ABSTRACT

Hand grip strength (HGS) is a well-known parameter of physical capability, clinical health status, and functional work performance. However, the scarcity of standardized, region-specific HGS data for Southeast Asian populations restricts the accuracy of health screening practices and the development of ergonomics and occupational safety guidelines. The aim of this study was to measure the dominant-hand HGS for healthy young adult women of Malaysia and Thailand, to compare the HGS of these two groups of women, and to investigate the relationship between age and anthropometric variables and the HGS. Researchers conducted a cross-sectional study involving 166 healthy women aged 20 to 39 years. This study recruited 92 participants from Malaysia and 74 from Thailand, primarily from university students and staff populations. Dominant-hand HGS was measured using a Jamar dynamometer (Sammons Preston, USA) while participants adopted a standardized standing position with the forearm in a neutral posture. Thai women demonstrated significantly greater mean HGS than Malaysian women (27.31 ± 6.96 kg vs. 23.64 ± 4.67 kg; $p < 0.001$), corresponding to an approximately 16% difference and a medium-to-large effect size (Cohen's d = 0.63). Among Thai participants, HGS was significantly associated with palm circumference (r = 0.544), height, weight, and age. These variables collectively explained 44.8% of the variation in HGS. In contrast, only height showed a modest association with HGS among Malaysian participants. Meanwhile, the corresponding regression model demonstrated limited explanatory capability. These findings reveal population-specific differences in both HGS and its anthropometric correlates when assessed under standardized testing conditions. The study provides protocol-specific, preliminary reference data for healthy young adult Malaysian and Thai women, which may inform future development of validated, population-specific reference standards. By generating population-specific reference data, this study contributes to improving the accuracy and equity of health monitoring practices, in line with the objectives of United Nations SDG 3 (Good Health and Well-being).

Keywords: Hand grip strength, young adult women, anthropometric variables, cross-sectional study, Malaysia, Thailand

INTRODUCTION

A Hand grip strength (HGS) is a well-established predictor of important health outcomes, including mobility limitations [1], disease progression [2], cognitive impairment [3], functional disability [4], cardiovascular events [5], and even mortality [6]. Although hand HGS is widely recognized as a critical indicator of functional performance and overall health, the absence of robust comparative data between Malaysia and Thailand limits the development of regionally relevant reference values and evidence-based clinical or public-health guidelines. Despite the countries' geographical proximity and cultural similarities, systematic comparisons of HGS in these populations remain limited, creating a significant gap in understanding population-specific muscular performance in Southeast Asia. The HGS refers to the maximal force generated by the muscles of the hand and forearm during gripping, and is increasingly recognized as a reliable, non-invasive indicator of overall muscular strength and functional capacity. HGS is an important component of physical performance. It plays a crucial role in many occupational activities. Based on literature, lower HGS has been associated with reduced work performance, a greater chance of injury, and an increased likelihood of developing work-related musculoskeletal disorders (WMSDs) [7]. The WMSDs remain one of the most prevalent occupational health problems worldwide. Healthcare workers (particularly nurses) are among the occupational groups most affected by the WMSDs. A recent systematic review reported that more than 80% of nurses across Asia experienced WMSDs in at least one body region, with an overall prevalence of 84.3% [8]. The WMSDs not only compromize workers' health and well-being but also contribute to absenteeism, reduced productivity, and increase healthcare and compensation costs. Consequently, study on HGS become necessity for supporting occupational health and injury prevention initiatives.

Recent international research has also highlighted the need for population-specific reference values for HGS with significant differences in HGS between different countries, even in similar age groups. For example, the mean HGS in young adult women in Germany varied from 30.5 kg to 32.3 kg [9], which is significantly higher than the values reported for China (24.4 kg to 25.6 kg) [10], [11] or for Colombia (24.8 kg to 25.3 kg) [12]. This is a 1.25 to 1.30 times higher value in the German group. Similarly, in Nepal, the values for women were extremely high at age 20 - 29 years (33.1 kg), but decreased to age 35 – 39 years (27.6 kg) [13]. In comparison, values of intermediate (28.1 kg to 31.4 kg) were consistently reported from studies conducted in the United States [14] and Great Britain [15] corresponding to 1.15 to 1.20 times higher than the values typically observed in East Asian groups. Another observation, women populations in China tend to exhibit lower mean HGS compared with their European and American counterparts. This suggests that there may be regional differences and context-specific benchmarks should be established in Southeast Asian women populations.

In addition to inter-country differences, the differences in methodological approaches to the testing procedures also play a significant role in the differences in test results. There is a consistent body of evidence that the capability of the HGS is greater in the 0° elbow flexion compared to the flexed position. For instance, Rajendran et al. [16] reported the reductions of almost 6.0 kg at 90° flexion versus full extension in young Indian women. In the same way, Aziz et al. [17] have reported the same for Malaysian participants and the same trend was reported by Mullerpatan et al. [18] and De and Sengupta [19]. In these studies, HGS reductions ranged from about 2 kg to 6 kg depending on the population and the degree of elbow flexion. Combined, these studies suggest that non-standardized testing conditions, such as seated positions or flexed elbow angles, systematically decrease grip strength in measures; sometimes by several kg by position. Therefore, making international comparisons is complicated if the protocols vary, as the differences in posture can lead to differences in weight of 2 kg to 6 kg which are not due to anthropometric or cultural differences.

Numerous studies have concentrated on older adults [20] and [21] or athletes [22] or even on regional subgroups [23] limiting the generalizability to healthy young adults, as tabulated in Table 1. Furthermore, the methods used to assess the HGS were not uniform as some studies used seated positions with elbow flexed at 90° or unclear descriptions of positions [24], [25]. Few studies used young adults [26], [27] and those that did used non-standard postures (shoulder adduction or forearm pronation) rather than the neutral forearm position recommended for hand functional assessment. HGS data from Thailand is even more scarce. There is only one study [28] that has focused on

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Table 1. Past Studies related to HGS in Malaysia and Thailand - Testing Protocols and Research Limitations

Studies	**Participants**	**Age range**	**Body position**	**Hand posture**	**Limitations**
Jaafar et. al [20]	Malaysian	35 to 70 years old	Not reported	Elbow flexed to 90°.	Did not include young adults or Thai population; body position not reported, making comparisons difficult.
Nor et. al [24]	Malaysian	23 to 28 years old	Sitting	45°, 90° and 135° flexions	Lacks standardized standing neutral posture data; no cross-population comparison.
Zahudi et. al [22]	Malaysian tenpin bowlers.	mean ± SD age of 33.81 ± 7.82 years	Standing	Shoulder adduction with elbow extension at 90°	Not general population; posture involved shoulder adduction with elbow extension, which differs from standardized clinical testing positions.
Hossain et. al [23]	Sabahans (Malaysian)	18 to 25 years old	Standing	Elbows were flexed at 90°, forearms in neutral	Findings are not generalizable across populations or to Thai young adults.
Salim et. al [29]	Malaysian	18 to 69 years old	Standing	Arm in a neutral position	Not focused on young adults; hand posture not clearly standardized; no comparative data with other populations.
Kang et. al [30]	Malaysian	30 to 60 years old	Not reported	Not reported	Body position and hand posture not specified, limiting methodological clarity; no young adult or cross-national focus.
Daruis et. al [26]	Malaysian	19 to 24 years old	Sitting	Neutral, supination, and pronation	Not representative of standard neutral standing HGS.
Saifuzzaman et. al [27]	Malaysian	18 to 30 years old	Standing	Shoulder in adduction position	Only standing with shoulder adduction reported, lacked standard neutral forearm posture and no cross-country comparison.
Moy et. al [21]	Malaysian	30.0 to 96.9 years old	Not reported	Not reported	Participants were senior citizens.
Hossain et. al [25]	Malaysian	18 to 65 years old	Sitting	Shoulders adducted and elbow flexed at 90°. Wrist in neutral position.	HGS in standing posture. No comparison between Malaysia and Thai participants.
Charoensri et. al [28]	Thailand	Aged over 20 years	Sitting	Shoulder adduction 90° and neutral rotation, elbow flexion 90° and neutral rotation and ulnar deviation 30°.	The equation predicted an overestimated HGS.

HGS in Thai adults, but it has measured HGS only at specific joint angles (shoulder adduction 90° with neutral rotation, elbow flexion 90° with neutral rotation and ulnar deviation 30°). The predictive equation from the study slightly overestimated actual HGS [28] that could lead to inaccurate assessment of hand capability.

Based on the literatures, this study revealed two important research gaps. Firstly, while population-specific HGS reference values have been reported in several studies [20], [23] there is a lack of data obtained with standardized testing protocols, especially measurements obtained in the standing position with a neutral forearm that reflect functional activities more closely. Previous studies have shown that posture has a significant effect on HGS data [16], [18], [19] but there is still a lack of standardization in the measurement protocols which makes it difficult to compare data from different populations. Secondly, a comparison between Malaysia and Thailand is not available, despite the geographical proximity and the likely similarity in anthropometric parameters. These restrictions highlight the need for comparative and standardized investigations to enhance the validity and applicability of HGS assessment. Therefore, the objective of the present study was to apply a standardized protocol for measuring dominant-hand HGS in healthy Malaysian and Thai women aged 20-39 years in a standing position with neutral forearm posture. The study aimed to establish age-specific reference values for these populations and facilitate direct comparisons between the two groups. The study aimed to establish age-specific reference values for these populations and facilitate direct comparisons between the two groups.

By establishing population-specific reference values of HGS for the Malaysian and Thai women, this study supports the objective of United Nations Sustainable Development Goal (SDG) 3: Good Health and Well-being. Furthermore, the findings provide a practical foundation for more accurate and equitable evaluations of HGS within local populations. Standardized reference data are fraught with importance in ergonomics, clinical evaluation and occupational health. In the field of ergonomics, they can be used to shape the design of hand tools that can better accommodate a user's grip. In the clinical setting, they aid in the more precise diagnosis of weakness of the hand muscles and functional impairments. The data can be used in occupational health for risk assessment, and for developing intervention strategies aimed at preventing WMSDs. Contributions of this study emphasize the need for contextually appropriate benchmarks in the promotion of culturally relevant human performance and workplace safety.

METHODS

Study design and HGS testing protocols

A cross-sectional design was used for this study to measure dominant-hand HGS in healthy young women of Malaysian and Thai. The participant was divided into four age groups (20-24, 25-29, 30-34, and 35-39 years). These age groups were chosen because they are the largest working population in Malaysia [31] and Thailand [32]. The dominant-hand HGS was measured using the Jamar hand-held dynamometer (Sammons Preston, USA) referring to testing protocols recently reviewed [33]. The units used for measurement were in kilogram-force. Prior to each HGS measurement session, the dynamometer was verified for proper functioning and accuracy. The dynamometer was calibrated daily with three calibration weights of 5 g, 10 g, and 15 g, corresponding to low, medium and high force ranges. The applied reference loads were compared with the dynamometer reading and the agreement was determined by an allowable tolerance of ± 3% of the applied load, following the recommended procedures for calibration of handgrip dynamometers [34]. If the values obtained on the dynamometer were within a tolerance range, it was acceptable for data collection. If readings are above this limit, recalibration or servicing was done before more readings are taken. In addition, a check was made with the needle indicator before each participant was tested to ensure that the needle was pointing at the "zero" mark, so that the dynamometer was reset for each test.

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Figure 1. HGS measurement using a hand dynamometer (left) of Malaysian (center) and Thai (right)

HGS was measured in a standing position with the wrist and forearm in a neutral posture using a Jamar hand-held dynamometer (Figure 1), thus creating consistency and reducing biomechanical variability. Participants stood upright in the anatomical position with feet slightly spaced facing forwards. The arm that was not dominant was hanging at the side of the body. Unintended shoulder abduction during HGS measurement was minimized with an easy tactile cue positioned gently under the participant's axilla to ensure a neutral and adducted shoulder position, if necessary. In order to ensure adherence to standardized HGS testing protocols, which suggests keeping the upper limb close to the trunk with the shoulder in adduction during HGS measurement [35], this approach was used. The cue was not to limit motion, but to help the participants to stay in the same position during the HGS measurement. The thumb was on one side, and the four fingers on the other side of the dynamometer. The dynamometer's handle was individually adjusted for each participant based on hand size to afford a comfortable and secure handle grip and to facilitate a maximum approximation of right-angle flexion at the proximal interphalangeal joints during maximum contraction. The handle settings chosen were recorded for every participant and were fixed from trial to trial. The researcher provided a light support under the dynamometer (not under the participant's hand) to remove the gravitational load on the dynamometer without having any effect on the participant's grip force (see Figure 1). The researcher placed one hand under the base of the dynamometer to balance the weight of the dynamometer, so that no lifting force or stabilizing force was applied to the hand of the participant. This allowed only the mass of the device to be supported and no effort was made by the researcher at any time to exert a grip force. Participants were asked to squeeze as hard as they can for 3 seconds. All participants ran two trials with a minimum of 2 minutes rest between trials to reduce fatigue effects. The maximum value of the two trials was used as a measure of the maximum voluntary HGS and to minimize the effects of submaximal effort or initial familiarization. Hands and device handles were protected from water, oil and sweat to maximize effort.

Prior to the data collection, the researchers presented the HGS measurement procedures and gave the participant the opportunity to become familiar with the dynamometer and testing protocols. Five minutes of rest was provided prior to testing. The study objectives, possible risks, benefits, voluntary participation, confidentiality and the testing protocols were thoroughly explained to the participants. Prior to participating, participants gave their informed consent in writing. After the HGS measurements were taken, participants were thanked for their cooperation.

All HGS measurements were performed between 8:00 AM and 5:00 PM to have all the same conditions. Primary data collection was conducted at the Ergonomics Laboratory, Faculty of Industrial and Manufacturing Technology and Engineering (FTKIP), Universiti Teknikal Malaysia Melaka (UTeM), Malaysia, and at the Biomedical Laboratory, Faculty of Engineering, Prince of Songkla University (PSU), Thailand.

If these participants could not get to the laboratory, HGS measurements were taken at another site, such as their home or workplace. To replicate a controlled laboratory environment several specific measures were implemented: testing was conducted in a quiet area away from any distractions, with adequate light and ventilation; the temperature in the testing room was monitored and maintained within a comfortable and consistent range of approximately 23 to 25 °C, which minimizes the influence of a variation in thermal conditions on the performance of the hand muscles; floor surfaces were standardized for proper posture and stability; the dynamometer was calibrated on-site before testing to ensure measurement accuracy; and participants were given clear instructions and supervised to ensure that the positioning of the arm and hand remains consistent throughout the measurements, thus mimicking the controlled environment of the laboratory as much as possible. Safety and comfort were maintained and all the procedures adopted were the same as those carried out in the laboratory to provide a uniform set of data and make it easy to compare the results. Testing sessions were set up based on the availability of participants. Researchers in Malaysia and Thailand adopted the same procedures for measuring to ensure consistency and validity of data collected.

Participants' recruitment

The study was performed among women participants with majority being students in undergraduate and post-graduate programs as well as university staff. An attempt was made to have non-academic participants to increase the representation of the working population. Recruitment from a university may provide a controlled setting for testing, but would also be subject to limitation in generalizability to manual workers or other occupations. Standardized testing protocols were used for all participants to ensure consistency within the data.

This study recruited participants from multiple states and regions across Malaysia and Thailand for better representation of the demographic and anthropometric parameters. Recruitment in Malaysia involved representation of the major ethnicities: Malay, Chinese and Indian. They came from different states like Melaka, Johor, Perak, Negeri Sembilan, Pahang, Selangor, Kuala Lumpur, and Kedah. Thailand participants were mainly from the Songkhla and surrounding provinces in the southern part of Thailand including Nakhon Si Thammarat, Narathiwat, Pattani, Phatthalung, Satun, Surat Thani, Trang and Yala, representing regional variation in Thailand population. The inclusion of participants from these multiple states and regions was planned to provide greater representativeness and generalizability of the results for Malaysian and Thai young adult women.

The researchers conducted a screening process to determine the eligibility of the participants. It was based on pre-defined inclusion and exclusion criteria. Inclusion criteria were healthy young adults aged 20 to 39 years with a body mass index (BMI) of 18.5 to 24.9 kg/m^2. All participants had to be Malaysian citizens and able to communicate in either the native Malaysian language (Bahasa Melayu) or English. Thai participants should be able to communicate in Thai. While this is a physical measure, the basic language skills were essential to allow the participants to fully understand the procedures of the testing protocols, ask questions if clarification was needed, and be able to give informed consent. Appropriate communication was also necessary for providing uniform instructions in the process of the HGS measurements and for completing the demographic form.

Exclusion criteria included non-Malaysian and non-Thai individuals, permanent residents, and immigrants. Pregnant women, individuals younger than 20 or older than 40 years, and those with a BMI outside the 18.5 to 24.9 kg/m^2 range were also excluded. Additional exclusion factors were a history of diabetes, physical disabilities, upper-limb fractures, musculoskeletal disorders (e.g., carpal tunnel syndrome), or recent injuries affecting HGS. Furthermore, participants were excluded if they had engaged within the past two weeks in high-intensity forearm activities such as rock climbing, competitive weightlifting, or repeated maximal grip exercises (defined as more than 70% maximal effort) or sessions exceeding 15 minutes, to prevent acute fatigue from affecting HGS measurements.

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The required sample size for comparing two independent groups was estimated using the following formula [30]:

$$n = 2\left(SD^2/\Delta^2\right) \times \left(Z_{1-\alpha/2} + Z_{1-\beta}\right)^2 \quad (1)$$

where

n = Sample size

SD = Standard deviation

$Z_{1-\alpha/2}$ = 1.96, Type I error (alpha) at 5% (2-sided)

$Z_{1-\beta}$ = 0.84, Type II error at 20% (power= 80%)

Δ = detectable difference

Therefore,

$$n = [2\,(5.542)/52] \times [1.96 + 0.84]^2$$
$$n = 19$$

The standard deviation (SD = 5.54 kg) used in the sample size calculation was derived from a recent study [20], who reported normative handgrip strength values for healthy Malay adults. The difference of detection (Δ = 5 kg) was adapted from Kang et al., 2021 [30] in their study of HGS in Malaysian middle aged adults. The number of participants per group was obtained by calculation to be (n = 19). However, a much larger number of participants (n = 166) was recruited including young adults from Malaysia (n = 92) and Thailand (n = 74) who were able to complete the HGS measurements successfully. This larger sample was sufficient to increase the strength and validity of the results.

Ethical approval

The HGS measurement protocols were reviewed and approved by the Research Ethics Committee of Universiti Teknikal Malaysia Melaka (Reference number: UTeM.11.02/500-25/1/4 Jilid 3(4)), and the PSU Human Research Ethic Committee of Prince of Songkla University (Reference number: PSU-HREC 2024-066-1-3).

Statistical analysis

Data were analysed statistically using the software JASP version 0.95.1. The data for the HGS were tabulated using descriptive statistics and included minimum, maximum, mean and standard deviation (SD). Data were subjected to test of normality before inferential analysis. Independent samples t-tests were used for variables that were normally distributed while Mann–Whitney U tests were used for variables with non-normal distribution to assess differences between the Malaysian and the Thai participants. Pearson correlation was used to assess the associations between the HGS and anthropometric variables and multiple linear regression was used to identify the anthropometric variables associated with HGS. The p value of < 0.05 was considered to be statistically significant.

RESULTS AND DISCUSSION

Descriptive statistics

Descriptive statistics of demographic and anthropometric parameters of women adults of Malaysia (n = 92) and Thailand (n = 74) in standing position were shown in Table 2. The Thai participants had an older mean age (27.36 years) compared to the Malaysian group (24.54 years) and a larger age range and SD. The average height of Thai participants was also higher compared to the Malaysian participants (1.642 m versus 1.590 m) and the average weight was higher (57.36 kg versus 54.74 kg). The mean BMI values of both groups were similar (Malaysia: 21.49 kg/m^2; Thailand: 21.27 kg/m^2) and ranges were overlapping, suggesting that both participants in both groups were in a

Table 2. Demographic and Anthropometric Statistics of Malaysian and Thai Adult Women (Standing Position)

Demography/ Anthropometry	**Malaysia (n = 92)**				**Thailand (n = 74)**			
	Min	**Mean**	**Max**	**SD**	**Min**	**Mean**	**Max**	**SD**
Age (year)	20.20	24.54	39.00	3.47	20.10	27.36	39.00	5.33
Height (m)	1.46	1.590	1.80	0.07	1.47	1.642	1.82	0.08
Weight (kg)	40.00	54.74	68.00	6.52	45.30	57.36	76.55	7.32
BMI (kg/m^2)	18.67	21.49	24.61	1.62	18.51	21.27	24.86	1.94
Forearm circumference (cm)	19.00	23.12	29.00	1.79	15.00	17.22	20.00	1.43
Palm circumference (cm)	16.00	18.47	26.00	1.47	15.00	20.07	24.00	1.63
HGS (kg)	13.00	23.64	37.00	4.67	12.00	27.31	43.00	6.96

healthy BMI category. Thai women had a higher mean HGS (27.31 kg) than Malaysian women (23.64 kg), and a wider range and higher SD (6.96 vs. 4.67 kg) of HGS.

Limb measurements were also significantly different. The mean forearm circumference of the Malaysian participants was found to be significantly higher than that of the Thai participants (23.12 cm vs. 17.22 cm), while that of the Thai participants was significantly higher than that of the Malaysian participants for palm circumference (20.07 cm vs. 18.47 cm). Several possible explanations should be considered since the HGS was lower in the Malaysian group although they had larger forearm circumference. Part of the disparity could be due to physiological differences. Forearm circumference is an indicator of both muscle and fat and simply a larger circumference does not necessarily mean a larger functional muscle mass. Circumference may have been larger in the Malaysian but a higher proportion of subcutaneous fat in this region may have resulted in this rather than increased HGS. Second, there may be anthropometric differences between populations, as well. Factors that affect lifestyle including participation in sports, physical activity, and nutrition may act differently on the intrinsic muscle development as compared to the extrinsic muscles between groups.

This study observed that the differences between the groups in the measurements taken on the limbs, the Malaysian participants had a greater forearm circumference, but were found to have a lower HGS, indicating that the measurement of circumference is not necessarily a good indicator of functional capacity of muscle in these samples.

Table 3 compares the mean HGS (kg) of the dominant hand among women participants aged 20 to 40 years in previous studies across different countries and continents, compared with values from the present study. The percentage difference was calculated as: [(present study – past study)/ past study] x 100. The ratio was calculated as: (present study ÷ past study). Positive values indicate higher HGS in the present study compared to past studies, while negative values indicate lower HGS.

In the present study, the mean HGS of Malaysian women participants (23.64 kg) was slightly higher than the value of 22.38 kg reported by Jaafar et. al [20], with a percentage difference of 5.6% and a ratio of 1.06. This result implies that there was a relative consistency of the two studies because both selected Malaysian adults of a similar age range but the difference can be due to the sampling procedure, the physical activity of participants or the testing protocols. In the present study, the mean HGS was 34.3% higher than that of Hossain et. al [25] who reported a mean HGS of 17.60 kg among Malaysian women, with ratio of 1.34. This is a large difference that may be partly due to the differences in the temporal and demographic characteristics of the two studies, or to the use of instruments and procedures which vary from current standardized practices. These comparisons suggest that the HGS values noted for Malaysian women in this study are generally congruent with more recent local studies [20] and higher than previous studies [25]. It is important to note that these differences are not necessarily indicative of temporal variation in strength of the population due to differences in measurement protocol, participant characteristics or study design.

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Table 3. Mean Dominant HGS (kg) in Women: Cross-Country Studies vs Malaysia and Thailand

		Present study (Malaysian), mean HGS = 23.64 kg		**Present study (Thai), mean HGS = 27.31 kg**	
Previous study/ Country	**HGS (kg)**	**% difference**	**Ratio**	**% difference**	**Ratio**
Jaafar et. al [20]/ Malaysia	22.38	5.63%	1.05	22.02%	1.22
Hossain et. al [25]/ Malaysia	17.60	34.32%	1.34	55.17%	1.55
Charoensri et. al [28]/ Thailand	15.00	57.60%	1.58	82.07%	1.82
Charoensri et. al [28]/ Thailand	25.00	-5.44%	0.95	9.24%	1.09
Nawangsasi et. al [36]/ Indonesia	21.49	10.00%	1.10	27.08%	1.27
Mullerpatan et. al [18]/ India	19.51	21.19%	1.21	39.97%	1.40
Bimali et. al [13]/ Nepal	27.56	-14.25%	0.86	-0.91%	0.99
Bimali et. al [13]/ Nepal	33.11	-28.58%	0.71	-17.48%	0.83
Lee et. al [37]/ Korea	25.30	-6.57%	0.94	7.95%	1.08
Lee et. al [37]/ Korea	27.20	-13.12%	0.87	0.40%	1.00
He et. al [10]/ China	24.44	-3.28%	0.97	11.74%	1.12
He et. al [10]/ China	25.55	-7.50%	0.93	6.90%	1.07
Yu et. al [38]/ China	21.80	8.44%	1.08	25.28%	1.25
Yu et. al [38]/ China	22.00	7.45%	1.07	24.14%	1.24
Ekşioğlu et. al [39]/ Turkey	25.80	-8.37%	0.92	5.85%	1.06
Ekşioğlu et. al [39]/ Turkey	30.50	-22.56%	0.78	-10.44%	0.90
Massy-Westropp et. al [40]/ Australia	29.00	-18.48%	0.82	-5.83%	0.94
Massy-Westropp et. al [40]/ Australia	31.00	-23.74%	0.76	-11.90%	0.88
Huemer et. al [9]/ Germany	30.50	-22.56%	0.78	-10.44%	0.90
Huemer et. al [9]/ Germany	32.30	-26.84%	0.73	-15.45%	0.85
Ramirez-Velez et. al [12]/ Columbia	24.80	-4.68%	0.95	10.12%	1.10
Ramirez-Velez et. al [12]/ Columbia	25.30	-6.57%	0.94	7.95%	1.08
Wang et. al [14]/ USA	28.10	-15.89%	0.84	-2.72%	0.97
Wang et. al [14]/ USA	29.60	-20.16%	0.80	-7.74%	0.92
Dodds et. al [15]/ Great Britain	28.40	-16.74%	0.83	-3.84%	0.96
Dodds et. al [15]/ Great Britain	31.40	-24.69%	0.75	-13.00%	0.87

Regarding the Thai women participants, this study found that they had a mean HGS of 27.31 kg, higher than the upper limit of Charoensri et al. [28] report of 15.00 to 25.00 kg. Specifically, the current Thai sample revealed a significantly higher mean than the lower bound of the range reported by Charoensri et al. [28] (15.00 kg) which equates to an 82.07% increase (ratio = 1.82), and slightly higher than the upper bound (25.00 kg) with 9.24% increase (ratio = 1.09). Differences in participant characteristics (body size, nutrition status, physical activity) could account for some of this difference, but the level of difference (82%) is a strong indication that methodological factors were influential. The Charoensri et al. [28] used a seated posture particularly. The standing posture in the present study was fully standardized and the forearm was maintained in a neutral position which will promote optimum biomechanical alignment, reduce joint restriction, and better activate the flexors of the forearm for maximum grip strength. The standardized posture may explain the significantly higher HGS in the current cohort of Thai participants. The results again highlight the importance of standardized protocols and methods of producing population reference values, remembering that different methods may significantly overestimate or underestimate the strength and make cross-study comparisons difficult.

The HGS values of the current Malaysian and Thai participants were higher than the values from other neighboring and regional countries. For instance, the Indian women (19.51 kg) [18] and Indonesian women (21.49 kg) [36] with percentage increase ranging from 10% to 40%. This implies that Malaysian women may have relatively stronger muscle strength, which might be due to differences in anthropometric variations, level of activities among women of different ethnic origin, or socioeconomic status between the two groups. On the other hand, the mean HGS of the current study was 14 to 29% lower than that of the Nepalese women with HGS of 24.56 – 35.11 kg [13] whereas the mean HGS of Thai women was closer to the lower limit of the Nepali range. Likewise, thresholds from Korea (25.30 to 27.20 kg) [37] and from China (24.44 to 25.55 kg) [10] [38] were quite similar, with Thais having a slightly higher range of means and Malaysian having similar and/or moderately lower. Values were lower than those prevailing in the West, both for the Malaysian and the Thai. For example, the average HGS of the Australian (29.00 to 31.00 kg) [40] women, German (30.50 to 32.30 kg) [9] women, British (28.40 to 31.40 kg) [15] and American (28.10 - 29.60 kg) [14] women were significantly higher than those of Malaysian women, whereas the average HGS of Thai women was within the lower or upper boundaries of the above ranges. Such differences could be attributed to genetic, nutritional and lifestyle factors, as well as differences in body size and recreational or occupational physical activity patterns that are seen in Asian and Western populations.

The present results show significant inter-regional differences in women HGS, with Malaysia and Thailand in the higher end of the range compared to some populations from South and Southeast Asian countries, and close to the values from the East Asian populations, but generally lower than the HGS observed in the Western populations. This highlights the need for population-specific HGS data to enable accurate assessment and clinical decision making both within the health and rehabilitation contexts.

Normality test

Table 4 tabulates the results of the normality test for HGS data among women Malaysian and Thai adults in a standing position, indicate that the data are approximately normally distributed for both groups. The skewness values (Malaysia: 0.152; Thailand: 0.158) are close to zero, suggesting minimal asymmetry in the data distribution. Similarly, the kurtosis values (Malaysia: 0.196; Thailand: -0.524) are within an acceptable range, indicating no significant deviation from the normal peak or flatness. The Shapiro-Wilk test, a formal test for normality, yielded values of 0.985 for Malaysians and 0.982 for Thais, with corresponding p-values of 0.352 and 0.357, respectively. Since both p-values are greater than the standard significance level of 0.05, we fail to reject the null hypothesis of normality. Therefore, it can be concluded that the HGS data for both Malaysian and Thai women adults are normally distributed.

Independent samples t-test

The results of the independent samples t-test (Table 5) indicate a statistically significant difference in HGS between Malaysian and Thai women adults. The t-test yielded $t = -4.358$ ($df = 164$, $p < 0.001$), and this finding was corroborated by the Mann–Whitney U test ($U = 2259.000$, $p < 0.001$), demonstrating that the difference remains robust even without assuming normality. Descriptive statistics show that Thai participants exhibited higher mean HGS (M = 27.31 kg, SD = 6.962) compared with Malaysian participants (M = 23.64 kg, SD = 4.673). The coefficient

Table 4. Normality Test of HGS Data of Women Malaysian and Thailand

	HGS data - Malaysia	**HGS data - Thailand**
Skewness	0.152	0.158
Kurtosis	0.196	-0.524
Shapiro-Wilk	0.985	0.982
P-value of Shapiro-Wilk	0.352	0.357

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Table 5. Results of Independent Samples t-Test

	Test	Statistic	df	p-value
HGS (kg)	Student	-4.358	164	< 0.001
	Mann-Whitney	2259.000		< 0.001
Age (year)	Student	-4.115	164	< 0.001
	Mann-Whitney	2671.500		0.17
Height (m)	Student	-4.187	164	< 0.001
	Mann-Whitney	2162.500		< 0.001
Weight (kg)	Student	-2.438	164	0.016
	Mann-Whitney	2774.000		0.041

	Group	n	Mean	SD	SE	Coeff. of variation	Mean rank	Sum rank
HGS (kg)	Malaysian	92	23.64	4.673	0.473	0.194	71.05	6537
	Thai	74	27.31	6.962	0.809	0.255	98.97	7324
Age (year)	Malaysian	92	24.540	3.471	0.362	0.141	75.54	6950
	Thai	74	27.365	5.329	0.619	0.195	93.40	6912
Height (m)	Malaysian	92	1.594	0.068	0.007	0.043	70.01	6441
	Thai	74	1.642	0.080	0.009	0.049	100.28	7421
Weight (kg)	Malaysian	92	54.739	6.528	0.681	0.119	76.65	7052
	Thai	74	57.363	7.316	0.850	0.128	92.01	6809

of variation was also higher among Thai participants (0.255 vs. 0.194), suggesting greater relative variability within the Thai sample. Importantly, several baseline characteristics differed significantly between the groups. Thai participants were significantly older ($t = -4.115$, $p < 0.001$), taller ($t = -4.187$, $p < 0.001$), and heavier ($t = -2.438$, $p = 0.016$) than Malaysian participants.

Mann–Whitney results for height ($U = 2162.500$, $p < 0.001$) and weight ($U = 2774.000$, $p = 0.041$) similarly indicated significant group differences. However, for age, the Mann–Whitney test showed no significant difference ($U = 2671.500$, $p = 0.170$), in contrast to the significant t-test result. This discrepancy may be attributed to differences in the underlying assumptions and sensitivity of the two tests; while the t-test detects differences in group means, the Mann–Whitney test evaluates differences in rank distributions and may be less sensitive when there is substantial overlap between groups or non-normality in the data. Therefore, although the t-test suggests a difference in mean age, the non-significant Mann–Whitney result indicates that the overall age distributions between groups may not differ markedly. Given that height and weight showed consistent significant differences across both tests, these variables represent more robust baseline inequalities and may act as confounding factors in the observed HGS differences. In contrast, the role of age as a confounder should be interpreted more cautiously due to the inconsistency between statistical tests.

Furthermore, the Mann–Whitney mean ranks align with the t-test findings: Thai participants consistently showed higher rankings for HGS (98.97 vs. 71.05), height (100.28 vs. 70.01), and weight (92.01 vs. 76.65). In summary, these results demonstrate that Thai women in this sample had significantly stronger HGS than Malaysian women.

The descriptive and bar plots in Figure 2 visually reinforce the outcomes of the Independent Samples T-Test. The error bars represent 95% confidence intervals (CI) for the mean HGS. The Malaysian group demonstrated a mean HGS of 23.64 kg with a 95% CI of approximately 22.69 to 24.59 kg, whereas the Thai group showed a higher mean of

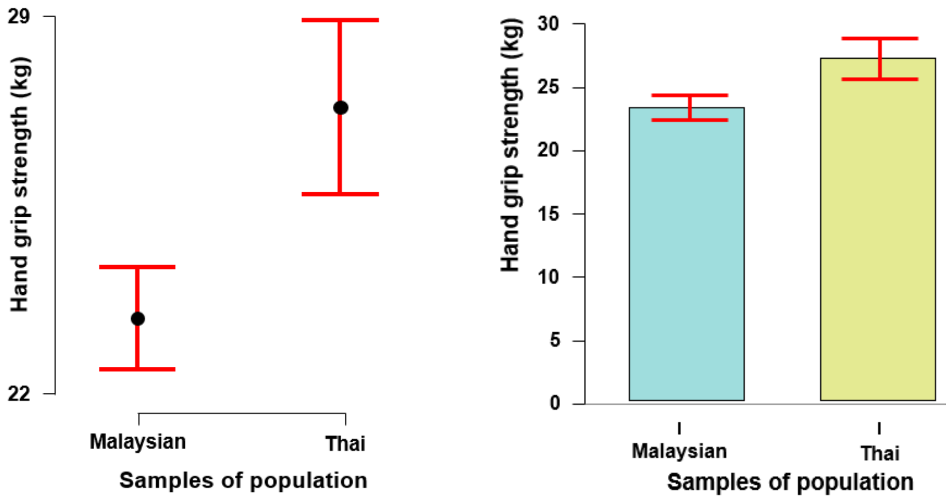

Figure 2. Descriptive and bar plots

27.31 kg with a 95% CI of approximately 25.72 to 28.90 kg. The minimal overlap between these intervals visually supports the statistical findings, indicating a clear and meaningful difference in HGS between the two groups. These graphical representations align with the Independent Samples T-Test results, confirming that Thai participants exhibited significantly stronger HGS than their Malaysian counterparts.

Correlation between HGS, age, and anthropometry of Malaysian participants

The correlation analysis of Malaysian subjects showed some interesting results between HGS and anthropometric parameters. The Pearson's Correlation (Table 6) revealed a weak but statistically significant positive correlation between HGS and height (r = 0.228, p = 0.029), indicating that taller participants tended to have a higher HGS. Slightly weak positive correlation was found between palm circumference and HGS (r = 0.205, p = 0.050) in the present study. This implies that the palm size is somewhat connected with HGS, but the small size of the correlation coefficient and the fact that the correlation was only marginally statistically significant. Thus, caution needs to be taken with these findings and more detailed work with larger samples or more accurate measurements should be carried out to determine the importance of palm morphology in HGS. In contrast, correlations with age (r = 0.089, p = 0.399), weight (r = 0.196, p = 0.061), and BMI (r = 0.066, p = 0.531) were not statistically significant, although weight showed a trend toward significance. Interestingly forearm circumference did not have any meaningful relationship with HGS (r = -0.020, p = 0.852). In general, the study results showed that with regard to Malaysian participants, there were moderate relationships between HGS and height and palm size, while other variables like age, BMI and forearm circumference had less relationship with HGS.

Table 6. Results of Pearson's Correlation Analysis among Malaysian Participants

			Pearson's *r*	**p-value**
HGS (kg)	-	Age	0.089	0.399
HGS (kg)	-	Height	0.228	0.029
HGS (kg)	-	Weight	0.196	0.061
HGS (kg)	-	BMI	0.066	0.531
HGS (kg)	-	Forearm circumference	-0.020	0.852
HGS (kg)	-	Palm circumference	0.205	0.050

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Table 7. Results of Pearson's Correlation Analysis among Thai Participants

			Pearson's *r*	p-value
HGS (kg)	-	Age	0.365	0.001
HGS (kg)	-	Height	0.534	< 0.001
HGS (kg)	-	Weight	0.493	< 0.001
HGS (kg)	-	BMI	0.125	0.289
HGS (kg)	-	Forearm circumference	0.006	0.959
HGS (kg)	-	Palm circumference	0.544	< 0.001

Correlation between HGS, age, and anthropometry of Thai participants

Table 7 shows the results of Pearson's correlation analysis among Thai participants. The correlation analysis demonstrated several significant relationships between HGS and anthropometric variables. Notably, HGS showed a moderate positive correlation with palm circumference ($r = 0.544$, $p < 0.001$) and height ($r = 0.534$, $p < 0.001$), suggesting that individuals with greater stature and larger palms tend to have stronger HGS. Weight was also significantly correlated with HGS ($r = 0.493$, $p < 0.001$), indicating that heavier individuals generally exhibited stronger hand grip. A moderate, statistically significant correlation was found between HGS and age ($r = 0.365$, $p = 0.001$), which may reflect developmental or occupational influences on muscle strength in this population. In contrast, BMI ($r = 0.125$, $p = 0.289$) and forearm circumference ($r = 0.006$, $p = 0.959$) were not significantly associated with HGS, suggesting these factors may have less relevance in predicting hand grip performance among Thai participants.

Discussion of HGS, age, and anthropometry correlations

In comparing the determinants of HGS among Malaysian and Thai participants, there was a clear difference in the factors that affect grip strength between the two populations. It means that the underlying factors affecting grip strength may differ between these populations. One distinction is in the strength and consistency of associations found within the Thai sample compared to the Malaysian sample. HGS was also positively correlated with some anthropometric parameters among Thai participants. This indicates that body size parameters have impact on the output of HGS. The strongest correlation was with palm circumference, and this was closely followed by height and weight. The results suggest that for larger body size and larger palm size, HGS is higher. These findings are consistent with the results from previous studies, which found that hand size, stature and body weight are important factors that influence HGS [41, 42]. A moderate positive correlation was also found between age and HGS which might be related to physical development as a young adult, or to occupational activities [15] and similar to that found with other research [43] which reported an increase in HGS but a gradual decrease after reaching peak adulthood. BMI and forearm circumference, however, were not significantly correlated with HGS, which is consistent with previous studies where BMI demonstrated less relationships than were observed with other measures of hand or palm size [44]-[45]. The overall results indicated that stature and palm size are more important than BMI or forearm circumference in accounting for variability in HGS among Thai participants, which further confirms and builds upon the evidence of anthropometric determinants of HGS.

The correlation of anthropometric parameters was calculated with HGS. Different patterns were observed between the populations. For Malaysian participants, height was the only anthropometric parameter that was significantly correlated. Meanwhile, palm circumference and weight were weak correlation. This finding is in line with previous studies showing that taller people have larger grip force because of their greater muscle mass and skeletal leverage

[41], [42]. However, the correlation and consistency were more pronounced and significant with respect to HGS for Thai participants. Palm circumference, height, and weight were also reported in previous studies [44] and [45] that showed body size as well as hand size to be significant in predicting HGS. Within the Thai participants, the age had an important influence for HGS, but not in Malaysia, which may be due to the fact that HGS increases up to adulthood and then decreases with age as reported [15] [43]. One likely explanation for this discrepancy is that the two groups of participants are of different age groups. There were statistically adequate age differences within the Thai group such that age related trends in HGS could be observed. The Malaysian group were also younger and more age homogenous, which might reduce the amount of age effects that could be detected in HGS. The significant correlation found for the Thai group may represent real age-related physiological differences, while that of the more restricted age range of the Malaysian sample may have prevented the detection of similar age effects.

In addition to anthropometric parameters, other factors including the level of physical activity, occupational exposure and lifestyle factors could also contribute to the stronger anthropometric correlations that were found in the Thai participants. These factors may affect muscle growth and functional strength not just reflected by body size. The Thai participants had a greater representation of palm circumference, which may indicate that hand morphology has a larger role in HGS with standardized testing procedures. In the Malaysian group, the lower correlation indicates that there may be other factors not measured that are contributing more to HGS, for examples, neuromuscular efficiency or daily activities.

As a whole, the results emphasis the need to take into account specific characteristics of the population when understanding the results of the HGS as well as the determinants of the HGS. The findings indicate significant differences between the Malaysian and Thai participants and confirm the importance of having specific reference values for each population and the possible variability of the relative influence of anthropometric parameters on HGS.

Linear Regression for Malaysian

The multiple linear regression analysis for Malaysian participants aimed to examine whether a combination of anthropometric variables could significantly predict HGS. In Model 1 (M_1), which included age, height, weight, BMI, forearm circumference, and palm circumference as predictors, the model accounted for approximately 10.9% of the variance in HGS ($R^2 = 0.109$), with a lower adjusted R^2 of 0.046, indicating limited explanatory power.

The objective of the multiple linear regression analysis for Malaysian participants was to test whether a combination of anthropometric parameters could significantly predict HGS. Model 1 (M_1) accounted for only about 10.9% of the variance in HGS ($R^2 = 0.109$), and the adjusted R^2 was 0.046. This indicating that the model had a low level of explanatory power. However, it should be noted that height, weight, and BMI are mathematically related variables, and their simultaneous inclusion may introduce multicollinearity. This can lead to instability in coefficient estimates and may partially explain the non-significant predictors and counterintuitive coefficient patterns observed. Therefore, the individual regression coefficients should be interpreted with caution, and the overall model fit is more informative than the contribution of specific predictors in this context.

The model did not reach statistical significance ($F(6, 85) = 1.725$, $p = 0.125$), indicating that the combination of these variables does not significantly predict HGS in this sample. Referring to Table 8, the linear regression coefficients indicate that none of the individual predictors reached statistical significance ($p > 0.05$), although palm circumference ($\beta = 0.178$, $p = 0.151$) and forearm circumference ($\beta = -0.209$, $p = 0.112$) showed trends toward an association. Height and BMI also had relatively higher standardized coefficients but did not achieve significance.

In summary, the regression model indicates that, for the Malaysian cohort, these commonly measured anthropometric parameters do not provide a strong or statistically significant prediction of HGS. This suggests that,

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Table 8. Coefficients of Linear Regression for Malaysian

Model	Unstandardized	Std. Error	Standardized	t	p-value
M_0 (Intercept)	23.641	0.487		48.525	< .001
M_1 (Intercept)	-153.324	151.834		-1.010	0.315
Age	0.025	0.154	0.019	0.165	0.870
Height	108.301	95.835	1.579	1.130	0.262
Weight	-1.388	1.409	-1.938	-0.985	0.327
BMI	3.807	3.560	1.320	1.069	0.288
Forearm circumference	-0.543	0.339	-0.209	-1.605	0.112
Palm circumference	0.564	0.389	0.178	1.449	0.151

Table 9. Coefficients of Linear Regression for Thai

Model	Unstandardized	Std. Error	Standardized	t	p-value
M_0 (Intercept)	27.311	0.809		33.748	< .001
M_1 (Intercept)	-267.578	155.281		-1.723	0.089
Age	0.212	0.131	0.162	1.615	0.111
Height	156.874	94.447	1.801	1.661	0.101
Weight	-1.785	1.337	-1.875	-1.334	0.187
BMI	5.211	3.553	1.455	1.467	0.147
Forearm circumference	-0.385	0.681	-0.079	-0.565	0.574
Palm circumference	1.477	0.494	0.346	2.989	0.004

HGS may be influenced more by unmeasured factors such as muscle quality, regular physical activity, or genetic variability than by simple body dimensions alone. The absence of a strong predictor model highlights the multifactorial nature of HGS and implies that relying solely on external anthropometric parameters may be insufficient for accurately estimating muscular strength in this group. Future studies may therefore benefit from incorporating physiological or lifestyle-related variables to better explain individual differences in HGS. Based on Table 8, the mathematical equation for predicting HGS (kg) can be written using the unstandardized coefficients as follows:

$$HGS = -153.324 + 0.025\,(Age) + 108.301\,(Height) - 1.388\,(Weight) + 3.807\,(BMI) - 0.543\,(Forearm\ Circumference) + 0.564\,(Palm\ Circumference) \quad (2)$$

Linear Regression for Thai

The multiple linear regression analysis for Thai participants revealed that a combination of anthropometric and demographic variables significantly predicted HGS. Model 1 (M_1), which included age, height, weight, BMI, forearm circumference, and palm circumference, accounted for approximately 44.8% of the variance in HGS ($R^2 = 0.448$, Adjusted $R^2 = 0.399$), indicating a moderate to strong model fit. The model was statistically significant overall ($F(6, 67) = 9.068$, $p < 0.001$), demonstrating that, collectively, these predictors provide meaningful explanatory power. As shown in Table 9, among the individual predictors, palm circumference was the only statistically significant contributor to HGS ($\beta = 0.346$, $p = 0.004$), suggesting that individuals with larger palms tend to have stronger HGS. Other variables such as age, height, weight, and BMI showed positive trends but did not reach statistical significance ($p > 0.05$). Notably, forearm circumference had a negligible and non-significant relationship with HGS ($p = 0.574$).

These findings highlight palm size as a key predictor of HGS in the Thai population, while other factors may contribute to variance but not independently predict HGS within this model. Using the unstandardized coefficients, the regression equation for predicting HGS (kg) in Thai participants is:

$$HGS = -267.578 + 0.212\,(Age) + 156.874\,(Height) - 1.785\,(weight) + 5.211\,(BMI) - 0.385\,(Forearm\ Circumference) + 1.477\,(Palm\ Circumference) \quad (3)$$

CONCLUSION

This study presented the mean HGS values for comparison and preliminary reference data for healthy young adult Malaysian and Thai women measured following a standardized standing protocol in a neutral forearm posture. In line with the statistical results, Thai participants could perform the HGS with greater strength than Malaysian participants, and distinct predictive patterns between the two groups were identified by regression analyses. The combined anthropometric and demographic model did not significantly predict HGS among the Malaysian participants, while the model's predictive capacity was higher for the Thai group and the variables explained a meaningful proportion of the variance in HGS. In this model, palm circumference proved to be the sole individual predictor that was statistically significant, indicating that hand anthropometry can contribute meaningfully to HGS in standardized testing protocols. Such divergent patterns could be due to differences in habitual physical activity, lifestyle-related muscle conditioning, or genetic factors; however, these factors were not directly measured. Accordingly, the observed differences suggest that HGS may be more closely associated with measured anthropometric variables in the Thai group, whereas the weaker model in the Malaysian cohort may indicate the influence of additional unmeasured factors. Bridging these findings to practical application, the protocol-specific reference data support population- and context-specific assessments of HGS and provide benchmark data that may inform the development of reference standards for clinical, community, and occupational health settings, and establishing such standardized reference values is critical for strengthening equitable and contextually relevant health and ergonomics practices. Future research should address the limitation of the current sampling by incorporating participants from diverse occupational backgrounds, and should assess older and middle-aged people to provide a more representative measure of age-related decline. To maintain methodological consistency and improve regional comparability, gender comparisons should be carried out using the same standardized posture, and longitudinal research would help elucidate the interplay between anthropometry, lifestyle, and occupational exposures in determining HGS trajectories.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to the publication of this article.

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DATA AVAILABILITY STATEMENT

Due to privacy and ethical restrictions, the data are not publicly available. However, de-identified data may be obtained from the corresponding author upon reasonable request.

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