ORIGINAL ARTICLE

Hand Strength Differences Across Cardiometabolic Conditions: A Cross-Sectional Comparative Study

A.Wahab AA[a], Danik NH[a], Jamaludin AF[a], Mohd Nayan NA[a], Sankar G[b], Che Daud AZ[ac]

[a]Centre for Occupational Therapy Studies, Faculty of Health Sciences, Universiti Teknologi MARA, Malaysia
[b]SRM College of Occupational Therapy, Medicine & Health Sciences, Kattankulathur, Chennai, India
[c]Special Population Research, Innovation and Knowledge, Faculty of Health Sciences, Universiti Teknologi MARA, Malaysia

ABSTRACT

INTRODUCTION: Handgrip and pinch strength are critical indicators of upper limb function and health, and may be affected by cardiometabolic conditions such as type 2 diabetes mellitus (T2DM), hypertension (HPT), and hyperlipidemia (HPL). This study aimed to compare handgrip and pinch strength among healthy adults, individuals with T2DM+HPT, and those with T2DM+HPT+HPL in a Malaysian population. **MATERIALS AND METHODS**: A cross-sectional study was conducted with 204 adults (n=68 per group), matched by age, gender, and health condition. Handgrip and pinch strength were assessed using the Jamar Hydraulic Dynamometer and Pinch Gauge following the American Society of Hand Therapists (ASHT) protocol. Statistical analyses included One-way ANOVA and Pearson correlation. **RESULTS**: Hand strength differed significantly across groups ($p<0.001$). Healthy adults demonstrated higher grip and pinch strength than participants with T2DM+HPT and T2DM+HPT+HPL. Strength measures showed strong bilateral correlations (0.85-0.92, $p<0.001$). Weak positive associations were observed between random blood sugar and grip/pinch strength ($r=0.239$-0.271), while diastolic blood pressure showed weak associations with grip strength only ($r=0.239$-0.265). HbA1c was not significantly associated with hand strength. **CONCLUSION**: Cardiometabolic conditions are associated with reduced hand strength, particularly when T2DM coexists with HPT and HPL. Grip and pinch strength may serve as accessible functional markers for clinical assessment and early intervention in at-risk populations.

Keywords
Hand Strength, Type 2 Diabetes Mellitus, Hypertension, Hyperlipidemia, Functional Assessment

Corresponding Author
Assoc. Prof. Dr. Ahmad Zamir Che Daud
Centre for Occupational Therapy Studies, Faculty of Health Sciences, Universiti Teknologi MARA, Selangor, Malaysia
E-mail: zamir5853@uitm.edu.my

Received: 8th July 2025; Accepted: 9th June 2026

Doi: https://doi.org/10.31436/imjm.v25i03/3025

INTRODUCTION

Hand function plays a critical role in daily living, enabling both fine and gross motor activities. In particular, handgrip and pinch strength are essential for prehensile and precision tasks.[1,2] Beyond their mechanical role, handgrip strength also serves as a biomarker that reflects the integrity of various physiological systems and is associated with chronic disease risk and premature mortality.[3] Biomarkers, as defined by the World Health Organization, are objective indicators of medical status based on body function, structure, or participation.[4]

Adults aged 18-65, whether healthy or living with conditions such as Type 2 Diabetes Mellitus (T2DM), hypertension (HPT), or hyperlipidemia (HPL), may exhibit varying levels of handgrip and pinch strength. These measures are predictive of future morbidity, functional disability, and mortality.[5] Individuals with T2DM often experience muscle weakness, particularly in handgrip and pinch strength, due to impaired glucose regulation and insulin resistance.[6] Similarly, hypertension has been associated with reduced muscle strength, likely due to the effects of elevated blood pressure on vascular and muscular function.[7] In contrast, individuals without T2DM or HPT tend to have stronger hand strength, which may reflect better overall muscle function.[8]

Previous studies have primarily compared handgrip strength between healthy and diabetic individuals or between healthy and hypertensive individuals, with limited research examining the combined effects of T2DM, HPT, and HPL, particularly within the Malaysian population.[7,9] Therefore, this study aimed to compare handgrip and pinch strength across cardiometabolic groups, and examine correlations with biomarkers including random blood sugar, HbA1c, and blood pressure.

MATERIALS AND METHODS

A total of 204 participants were recruited using purposive sampling and divided equally into three groups: healthy controls (n=68), adults with Type 2 Diabetes Mellitus and hypertension (T2DM+HPT, n=68), and adults with T2DM, HPT, and hyperlipidemia (T2DM+HPT+HPL, n=68). Participants with cardiometabolic conditions were recruited from Sungai Buloh Health Clinic while healthy controls were recruited in Kuantan area. Participants were matched based on age group, gender, and health condition to minimize potential confounding factors.

Exclusion criteria included individuals with current or previous hand injuries, Type 1 Diabetes Mellitus (T1DM), upper limb pain, cardiovascular disease, or other comorbidities beyond the specified group classifications. Demographic data, body weight, and height were recorded prior to strength testing. Additionally, relevant clinical parameters such as random blood sugar (RBS), fasting blood sugar (FBS), HbA1c, and blood pressure readings were obtained from medical records or measured at the clinic to profile the cardiometabolic status of participants.

Handgrip and pinch strength were assessed using a Jamar Hydraulic Hand Dynamometer and a Jamar Hydraulic Pinch Gauge. All measurements adhered to the American Society of Hand Therapists (ASHT) protocol, with participants seated upright, shoulders adducted and neutrally rotated, elbows flexed at 90°, forearms in a neutral position, and wrists positioned between 0° and 30° extension. Three trials were performed for each hand, with a 30-second rest between trials, in accordance with standardized testing protocols. The mean of the three trials was used for analysis. [10]

Data were analyzed using IBM SPSS Statistics version 28.0. Descriptive statistics were calculated, followed by One-Way Analysis of Variance (ANOVA) to compare group differences, and Pearson correlation tests to examine relationships between strength measures and physiological markers.

RESULTS

Out of 204 participants who met the inclusion criteria, three equal groups were formed: healthy controls (n=68), individuals with Type 2 Diabetes Mellitus and hypertension (T2DM+HPT, n=68), and individuals with T2DM, hypertension, and hyperlipidemia (T2DM+HPT+HPL, n=68). Table I summarizes the demographic and clinical characteristics of each group. Participants were matched by age and gender. Clinical variables such as body mass index (BMI), blood pressure, random blood sugar (RBS), fasting blood sugar (FBS), and HbA1c were collected to describe the cardiometabolic profile of each group.

Table I: Demographic and Clinical Characteristics of Participants by Group (N=204)

Characteristics	Healthy Controls (n=68)	T2DM + HPT (n=68)	T2DM + HPT + HPL (n=68)
Age (years)	44.75 ± 12.70	51.09 ± 10.72	51.65 ± 9.96
Gender - Female	24 (35.3%)	24 (35.3%)	24 (35.3%)
Gender - Male	44 (64.7%)	44 (64.7%)	44 (64.7%)
Dominant Hand - Right	61 (89.7%)	59 (86.8%)	53 (77.9%)
Dominant Hand - Left	7 (10.3%)	9 (13.2%)	15 (22.1%)
BMI - Underweight	4 (5.9%)	0 (0.0%)	0 (0.0%)
BMI - Normal	25 (36.8%)	23 (33.8%)	26 (38.2%)
BMI - Overweight	32 (47.1%)	26 (38.2%)	24 (35.3%)
BMI - Obese	7 (10.3%)	19 (28.0%)	18 (26.5%)
RBS (mmol/L)	-	7.83 ± 3.84	8.31 ± 3.94
FBS (mmol/L)	-	7.02 ± 3.43	6.92 ± 2.83
HbA1c (%)	-	6.84 ± 1.82	6.95 ± 1.54

Descriptive Measurements of Grip and Pinch Strength

Table II shows handgrip and pinch strength by age group in the healthy control group. Among young adults (18-39 years), the mean right-handgrip strength was 33.58 kgf (SD=12.76), while the left-handgrip strength was 30.86 kgf (SD=10.86). Right and left pinch strengths were 5.83 kgf (SD=1.65) and 5.02 kgf (SD=1.57), respectively.

Middle-aged adults (40-59 years) showed slightly lower grip strength values, with 32.85 kgf (SD=11.58) on the right and 30.25 kgf (SD=11.95) on the left. However, their pinch strength was slightly higher than that of the younger group. Older adults (60-65 years) demonstrated the lowest grip and pinch strength across all measures.

Table II: Handgrip and pinch strength by age group in healthy controls

Age Group	Strength Measure	Female (n, %)	Male (n, %)	Mean ± SD
Young (18-39)	Grip Right	7 (43.75%)	9 (56.25%)	33.58 ± 12.76
	Grip Left	7 (43.75%)	9 (56.25%)	30.86 ± 10.86
	Pinch Right (Lateral)	7 (43.75%)	9 (56.25%)	5.83 ± 1.65
	Pinch Left (Lateral)	7 (43.75%)	9 (56.25%)	5.02 ± 1.57
Middle-aged (40-59)	Grip Right	14 (31.82%)	30 (68.18%)	32.85 ± 11.58
	Grip Left	14 (31.82%)	30 (68.18%)	30.25 ± 11.95
	Pinch Right (Lateral)	14 (31.82%)	30 (68.18%)	6.62 ± 1.89
	Pinch Left (Lateral)	14 (31.82%)	30 (68.18%)	6.16 ± 1.89
Older (60-65)	Grip Right	3 (37.50%)	5 (62.50%)	26.88 ± 5.88
	Grip Left	3 (37.50%)	5 (62.50%)	25.67 ± 8.56
	Pinch Right (Lateral)	3 (37.50%)	5 (62.50%)	4.85 ± 2.07
	Pinch Left (Lateral)	3 (37.50%)	5 (62.50%)	5.02 ± 2.52

Table III shows the hand strength levels in the T2DM+HPT group. Young adults showed lower strength than their healthy counterparts, with right-handgrip strength averaging 26.67 kgf (SD=10.41) and left-handgrip 24.62 kgf (SD=10.94). Pinch strength was also reduced. Middle-aged participants demonstrated further declines, with slightly reduced grip and pinch strength on both sides. Among older adults (60-65 years), hand strength remained relatively low and showed limited variation.

Table III: Handgrip and pinch strength by age group in adults with T2DM and hypertension (T2DM+HPT)

Age Group	Strength Measure	Female (n, %)	Male (n, %)	Mean ± SD
Young (18-39)	Grip Right	7 (43.75%)	9 (56.25%)	26.67 ± 10.41
	Grip Left	7 (43.75%)	9 (56.25%)	24.62 ± 10.94
	Pinch Right (Lateral)	7 (43.75%)	9 (56.25%)	4.01 ± 1.36
	Pinch Left (Lateral)	7 (43.75%)	9 (56.25%)	3.54 ± 1.11
Middle-aged (40-59)	Grip Right	14 (31.82%)	30 (68.18%)	21.10 ± 8.54
	Grip Left	14 (31.82%)	30 (68.18%)	21.71 ± 8.54
	Pinch Right (Lateral)	14 (31.82%)	30 (68.18%)	3.41 ± 1.17
	Pinch Left (Lateral)	14 (31.82%)	30 (68.18%)	3.57 ± 1.21
Older (60-65)	Grip Right	3 (37.50%)	5 (62.50%)	22.75 ± 5.72
	Grip Left	3 (37.50%)	5 (62.50%)	20.25 ± 8.06
	Pinch Right (Lateral)	3 (37.50%)	5 (62.50%)	3.63 ± 0.83
	Pinch Left (Lateral)	3 (37.50%)	5 (62.50%)	3.27 ± 1.05

Table IV shows hand strength values for the T2DM+HPT+HPL group. Young adults in this group showed slightly higher grip strength than those in the T2DM+HPT group, but still below healthy controls. Middle-aged participants displayed a decline in both grip and pinch strength. Interestingly, older adults showed slightly better strength than middle-aged participants in some measures, though the differences were small and within the margin of variation.

Table IV: Handgrip and pinch strength by age group in adults with T2DM, hypertension, and hyperlipidemia (T2DM+HPT+HPL)

Age Group	Strength Measure	Female (n, %)	Male (n, %)	Mean ± SD
Young (18-39)	Grip Right	7 (43.75%)	9 (56.25%)	27.17 ± 10.85
	Grip Left	7 (43.75%)	9 (56.25%)	26.71 ± 10.52
	Pinch Right (Lateral)	7 (43.75%)	9 (56.25%)	3.64 ± 1.65
	Pinch Left (Lateral)	7 (43.75%)	9 (56.25%)	3.41 ± 1.30
Middle-aged (40-59)	Grip Right	14 (31.82%)	30 (68.18%)	22.10 ± 8.20
	Grip Left	14 (31.82%)	30 (68.18%)	21.87 ± 8.47
	Pinch Right (Lateral)	14 (31.82%)	30 (68.18%)	3.57 ± 1.34
	Pinch Left (Lateral)	14 (31.82%)	30 (68.18%)	3.40 ± 1.34
Older (60-65)	Grip Right	3 (37.50%)	5 (62.50%)	25.17 ± 5.14
	Grip Left	3 (37.50%)	5 (62.50%)	21.08 ± 4.77
	Pinch Right (Lateral)	3 (37.50%)	5 (62.50%)	4.19 ± 1.23
	Pinch Left (Lateral)	3 (37.50%)	5 (62.50%)	3.96 ± 0.62

Differences in Hand and Pinch Strength Between Groups

One-way ANOVA revealed statistically significant differences in hand strength across the three groups. For right-handgrip strength, the F-statistic was 20.224 with a p-value of less than 0.001. Left-handgrip strength also showed a significant difference with an F-value of 12.365 ($p<0.001$). Differences in pinch strength were even more obvious, with the right lateral pinch showing an F-value of 64.931 and the left lateral pinch an F-value of 51.232, both statistically significant at $p<0.001$.

Post hoc Tukey tests indicated that healthy individuals had significantly greater handgrip and pinch strength than participants with T2DM and hypertension (T2DM+HPT), who in turn had higher strength levels than those with additional hyperlipidemia (T2DM+HPT+HPL). These findings confirm a clear, graded decline in hand strength corresponding with increasing cardiometabolic burden. Figure 1 displays boxplots of handgrip and pinch strength (right/left) across groups, illustrating the group differences.

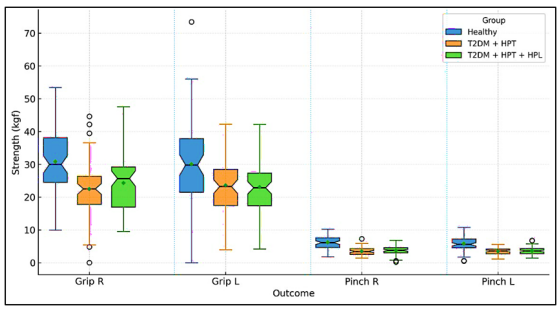

Figure 1: Boxplots of handgrip and pinch strength (right/left) across groups ($p<0.001$).

Correlation with Clinical Biomarkers

HbA1c showed no significant correlations with right-handgrip strength ($r=0.129$, $p=0.297$), left-handgrip strength ($r=0.157$, $p=0.205$), left pinch strength ($r=0.073$, $p=0.559$), or right pinch strength ($r=0.094$, $p=0.451$).

RBS demonstrated weak but statistically significant positive correlations with right-handgrip strength ($r=0.251$, $p=0.039$), left-handgrip strength ($r=0.239$, $p=0.049$), left pinch strength ($r=0.260$, $p=0.032$), and right pinch strength ($r=0.271$, $p=0.025$). SBP was not significantly correlated with any grip or pinch strength measure. Correlations were weak and non-significant for right grip strength ($r=0.006$, $p=0.962$), left grip strength ($r=-0.052$, $p=0.673$), right pinch strength ($r=0.029$, $p=0.815$), and left pinch strength ($r=-0.113$, $p=0.359$). In contrast, diastolic blood pressure (DBP) demonstrated weak but statistically significant positive correlations with right-handgrip strength ($r=0.265$, $p=0.029$) and left-handgrip strength ($r=0.239$, $p=0.049$). No significant associations were observed between DBP and left pinch strength ($r=0.130$, $p=0.290$) or right pinch strength ($r=0.206$, $p=0.093$). Figure 2 provides a visual summary of these correlations.

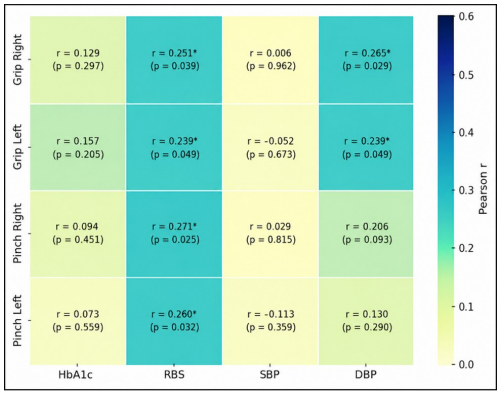

Figure 2: Pearson's correlations (r) between hand strength measures and cardiometabolic biomarkers (n=68) (**p < 0.01).

DISCUSSION

This study aimed to compare handgrip and pinch strength across different cardiometabolic conditions, assess age-related differences, and examine correlations with clinical biomarkers, including random blood sugar (RBS), HbA1c, and blood pressure (BP). The findings demonstrate that cardiometabolic disease status significantly affects hand strength, with greater functional decline observed in individuals with combined T2DM, hypertension, and hyperlipidemia. Descriptive patterns also suggested age-related differences in strength, consistent with prior literature.[11,12] Additionally, random blood sugar demonstrated weak positive associations with both grip and pinch strength, while diastolic blood pressure showed weak associations with grip strength only.

Age-related reductions in hand strength were most evident among healthy controls, whereas patterns were less consistent in participants with cardiometabolic conditions. While age-related decline in strength has been well documented in previous literature, our study observed a similar trend across age strata.[11,12] This trend may be more evident in individuals with chronic conditions such as Type 2 Diabetes Mellitus (T2DM) and hypertension (HPT), where aging is compounded by metabolic and vascular impairments.[13]

In addition to age, disease status significantly influenced hand strength. Participants with both T2DM and HPT demonstrated lower grip and pinch strength compared to healthy controls, while those with additional hyperlipidemia (T2DM+HPT+HPL) exhibited the most pronounced deficits. These findings suggest a cumulative negative effect of comorbid cardiometabolic conditions on muscle function. Specifically, hyperlipidemia may exacerbate insulin resistance, impairing glucose uptake in skeletal muscle and reducing cellular energy availability, thereby weakening contractile ability.[14] Furthermore, elevated lipid levels can accelerate atherosclerotic processes, restricting blood flow and oxygen delivery to muscle tissues. This ischemia may result in muscle fatigue and reduced function, contributing to the strength impairments observed in this group.[14]

These findings are consistent with previous studies reporting lower grip strength in individuals with T2DM and HPT compared to healthy counterparts. For example, significantly reduced hand strength has been observed in diabetic adults, as well as in individuals with hypertension.[9,15,16] Muscle strength reduction in T2DM has been attributed to both metabolic dysfunction and neuromuscular impairment, further supporting this study's results.[17,18] Moreover, the underutilization of hand function assessments in diabetes care has been highlighted in recent literature, highlighting the importance of incorporating grip and pinch evaluations into routine practice to detect functional decline early.[19] This aligns with emerging research emphasizing that diabetic peripheral neuropathy can significantly compromise hand function and daily activity performance.[20] Therefore, integrating simple hand strength measures may complement existing clinical tools to assess disability risk and functional impairment in people with DM and related comorbidities.

Beyond group comparisons, this study also examined correlations between hand strength and physiological markers. Strong bilateral correlations were observed between right and left hand strength measures, indicating substantial symmetry in upper limb strength performance. Notably, random blood sugar (RBS) demonstrated weak positive correlations with both grip and pinch strength, whereas diastolic blood pressure (DBP) showed weak positive correlations with grip strength only. In contrast, HbA1c, which reflects long-term glycemic control, showed no significant association with grip or pinch strength. This aligns with findings that HbA1c may not be a reliable indicator of muscle performance in diabetic populations.[8] These results suggest that acute metabolic and vascular factors, rather than chronic glycemic levels, may have a more modest influence on hand strength. The positive correlations between RBS and strength were weak and should be interpreted cautiously, as they do not imply a beneficial effect of hyperglycaemia on muscle function. Residual confounding, treatment effects, or variability in acute glucose measurements may explain these associations.

Clinically, these findings highlight the importance of evaluating hand strength in individuals with T2DM, HPT, and HPL. Reduced grip and pinch strength not only reflect musculoskeletal decline but may also indicate broader metabolic and cardiovascular dysfunction. Early detection of hand strength deficits can support timely rehabilitation planning, guide functional goal setting, and potentially improve long-term outcomes. Routine hand strength assessment may offer a practical, non-invasive method for identifying individuals at elevated risk of disability, enabling targeted intervention to preserve independence and enhance quality of life.

CONCLUSION

This study demonstrated that healthy adults exhibited significantly greater handgrip and pinch strength compared to individuals with T2DM+HPT and those with T2DM+HPT+HPL. RBS was weakly and positively correlated with both grip and pinch strength, whereas diastolic blood pressure showed weak positive correlations with grip strength only. HbA1c was not significantly associated with hand strength measures. These findings highlight the impact of cardiometabolic conditions on upper limb strength and support the utility of grip and pinch strength as functional indicators in clinical assessments. Although limited by the small number of young adults with comorbidities, the study provides important reference data for clinicians in evaluating and managing patients with diabetes and hypertension. Future research should adopt longitudinal designs and recruit more diverse populations to validate hand strength as a biomarker for chronic disease burden and functional decline.

ACKNOWLEDGEMENTS

The authors would like to thank Faculty of Health Sciences, Universiti Teknologi MARA for support and encouragement. We also sincerely acknowledge all participants and staff at Sungai Buloh Health Clinic for their valuable assistance and cooperation throughout the study.

FUNDINGS

This study was supported by the Dana Universiti

Teknologi MARA Cawangan Selangor (DUCS-F), reference number: 600-UiTMSEL (PI. 5/4) (158/2022).

CONFLICT OF INTEREST

None declared.

ETHICS APPROVAL

This study was approved by the Human Research Ethics Committee of Universiti Teknologi MARA (Ref No: FERC/FSK/MR/2023/00288) and Medical Ethics and Research Committee of Ministry of Health Malaysia (Ref No: NMRR-ID-24-00274-N8M-(IIR))

REFERENCES

1. Alahmari KA, Kakaraparthi VN, Reddy RS, et al. Percentage difference of hand dimensions and their correlation with hand grip and pinch strength among schoolchildren in Saudi Arabia. Niger J Clin Pract. 2019 Oct 1;22(10):1356–64.
2. Alahmari KA, Silvian SP, Reddy RS, et al. Hand grip strength determination for healthy males in Saudi Arabia: A study of the relationship with age, body mass index, hand length and forearm circumference using a hand-held dynamometer. Journal of International Medical Research. 2017 Apr 1;45(2):540-8.
3. Cheung CL, Nguyen USDT, Au E, Tan KCB, Kung AWC. Association of handgrip strength with chronic diseases and multimorbidity: A cross-sectional study. Age (Omaha). 2013 Jun;35(3):929–41.
4. World Health Organization. International Programme on Chemical Safety. Biomarkers in risk assessment: validity and validation. Geneva; 2001.
5. Leong DP, Teo KK, Rangarajan S, et al. Prognostic value of grip strength: Findings from the Prospective Urban Rural Epidemiology (PURE) study. The Lancet. 2015 Jul 18;386(9990):266-73.
6. Lee MR, Jung SM, Bang H, Kim HS, Kim YB. Association between muscle strength and type 2 diabetes mellitus in adults in Korea: Data from the Korea national health and nutrition examination survey (KNHANES) VI. Medicine (United States). 2018 Jun 1;97(23).
7. Dong B, Wang Z, Arnold L, et al. The association between blood pressure and grip strength in adolescents: Does body mass index matter. Hypertension Research. 2016 Dec 1;39(12):919–25.
8. Mainous AG, Tanner RJ, Anton SD, Jo A. Grip Strength as a Marker of Hypertension and Diabetes in Healthy Weight Adults. Am J Prev Med. 2015 Dec 1;49(6):850–8.
9. Neha M. Comparison of Hand Grip Strength in Diabetics and Non-Diabetics-An Observational Study. Medical Journal of Clinical Trials & Case Studies. 2019;3(3).
10. Fess FE. Grip strength. Casanova JS clinical assessment recommendations. 1992;41–5.
11. Kamarul T, Ahmad TS, Loh W. Hand grip strength in the adult Malaysian population. Journal of Orthopaedic Surgery. 2006;14(2):172–7.
12. Tanimoto Y, Watanabe M, Kono R, et al. Aging changes in muscle mass of Japanese. Nihon Ronen Igakkai zasshi. Japanese Journal of Geriatrics. 2010;47 (1):52–7.
13. Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: Revised European consensus on definition and diagnosis. Vol. 48, Age and Ageing. Oxford University Press; 2019. p. 16–31.
14. Grundy SM, Brewer HB, Cleeman JI, Smith SC, Lenfant C. Definition of Metabolic Syndrome: Report of the National Heart, Lung, and Blood Institute/American Heart Association Conference on Scientific Issues Related to Definition. In: Circulation. 2004. p. 433–8.
15. Kaur Sandhu Gill P, Sandhu R, Kaur Arora A. Hand Grip Strength in Type 2 Diabetics and Non-Diabetics. Pak J Physiol [Internet]. 2015;11(3):32–6. Available from: http://www.pps.org.pk/PJP/11-3/Parminder.pdf32
16. Zhang X, Huang L, Peng X, et al. Association of handgrip strength with hypertension among middle-aged and elderly people in Southern China: A cross-sectional study. Clin Exp Hypertens. 2020 Feb 17;42 (2):190–6.
17. Leenders M. Exercise and nutrition to support healthy aging [Internet]. maastricht university; 2016. Available from: https://cris.maastrichtuniversity.nl/en/publications/2e1677c8-177d-4ea1-b6e4-75b7cdd70144

18. Sénéchal M, McGavock JM, Church TS, et al. Cut points of muscle strength associated with metabolic syndrome in men. Med Sci Sports Exerc. 2014;46 (8):1475–81.
19. Mohd Nayan NA, Che Daud AZ, Chien C wen, Ahmad Roslan NF. The road less taken : A scoping review of the utilisation of hand assessments in individuals with diabetes mellitus. Medical Journal Malaysia. 2024;79(September 2023):176–86.
20. Mohd Nayan NA, Chien CW, Lokman N, et al. Translation and validation of the Malay version of the Duruöz hand index in individuals with diabetic peripheral neuropathy. Hand Ther. 2025;1–11.