ISSN- O: 2458 - 868X, ISSN–P: 2458 – 8687
National Library of Medicine - ID: 101731606

International Journal of Medical Science and Innovative Research (IJMSIR)
IJMSIR : A Medical Publication Hub
Available Online at: www.ijmsir.com
Volume – 11, Issue – 4, August – 2026, Page No. : 17 – 26

Handgrip Strength as a Surrogate Marker of Sarcopenia in Postmenopausal Women - A Cross - Sectional Comparative Study

[1]Dr. Palak Mittal, MD, General Medicine, Resident, Department of General Medicine, GSVM Medical College, Kanpur, Uttar Pradesh, India.

[2]Dr. Richa Giri, MD, General Medicine, Professor, Department of Medicine, GSVM Medical College, Kanpur, Uttar Pradesh, India.

[3]Dr. Mahendra Pal Singh, MD, General Medicine, Associate Professor, Department of General Medicine, GSVM Medical College, Kanpur, Uttar Pradesh, India.

Corresponding Author: Dr. Palak Mittal, MD, General Medicine, Resident, Department of General Medicine, GSVM Medical College, Kanpur, Uttar Pradesh, India.

Citation this Article: Dr. Palak Mittal, Dr. Richa Giri, Dr. Mahendra Pal Singh, " Handgrip Strength as a Surrogate Marker of Sarcopenia in Postmenopausal Women - A Cross - Sectional Comparative Study", IJMSIR – August – 2026, Vol – 11, Issue – 4, P. No. 17 – 26.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Postmenopausal oestrogen deficiency accelerates skeletal muscle catabolism, predisposing women to Sarcopenia. Handgrip strength is a validated neuromuscular surrogate for Sarcopenia endorsed by international consensus groups, but integrated data from Indian postmenopausal women remain scarce.

This cross-sectional study, conducted at GSVM Medical College, Kanpur, between August 2024 and January 2026, evaluated bilateral handgrip strength in 150 postmenopausal women (age 45 years or more; amenorrhoea for more than five years) compared with 50 premenopausal controls, using a calibrated Jamar hand dynamometer and the Southampton protocol. Sarcopenia was classified using two internationally recognised diagnostic thresholds.

Fasting lipids, glycated haemoglobin, vitamin D, thyroid-stimulating hormone, haemoglobin, calcium and electrolytes were measured, and ten-year fracture risk was estimated using a validated fracture-risk assessment algorithm. Postmenopausal women showed significantly lower right-hand (17.48±4.24 versus 22.82±2.15 kg) and left-hand (16.90±4.21 versus 22.18±2.12 kg) grip strength than controls (both $p<0.0001$), representing a 23–24% reduction.

Sarcopenia prevalence was 18.0% by the earlier, more liberal threshold and 4.1% by the revised, stricter threshold. Mean fracture-risk score was higher in postmenopausal women (15.35±5.71 versus 7.71±1.49; $p<0.0001$), with 44% classified as high risk. Triglycerides, glycated haemoglobin and blood pressure were significantly higher, while vitamin D, haemoglobin and serum calcium were significantly lower in postmenopausal women (all $p\leq0.01$); total cholesterol and thyroid-stimulating hormone did not differ between groups. Grip strength is a reliable, reproducible and cost-

effective surrogate for early Sarcopenia screening in postmenopausal women, and the accompanying metabolic derangements amplify musculoskeletal vulnerability beyond oestrogen deficiency alone.

Routine grip - strength measurement combined with metabolic profiling and fracture-risk assessment should be integrated into postmenopausal healthcare.

Keywords: Handgrip strength, Menopause, Osteoporosis, Postmenopausal women, Sarcopenia, Vitamin D deficiency, Fracture risk

Introduction

Menopause is defined as the permanent cessation of menstruation resulting from irreversible loss of ovarian follicular activity, confirmed after 12 consecutive months of amenorrhoea.

It is characterised by a profound decline in endogenous 17-β oestradiol (E2) and a compensatory rise in follicle-stimulating hormone (FSH), influencing multiple organ systems and producing vasomotor instability, genitourinary atrophy, neuro psychological disturbances, and progressive musculoskeletal deterioration.[1,2]

Among the musculoskeletal consequences of oestrogen deficiency, Sarcopenia - defined by EWGSOP2 as the presence of low muscle strength as the primary criterion, with reduced muscle mass confirming the diagnosis and poor physical performance indicating severity - has emerged as a major public health concern.[3]

Postmenopausal women face a nearly threefold greater risk of Sarcopenia compared to premenopausal women. Globally, Sarcopenia affects approximately 10% of individuals above 60 years, with prevalence of 14–33% in institutionalised populations.[4]

An equally important phenomenon is Dynapenia - the age-related decline in muscle strength independent of muscle mass — which frequently precedes measurable mass loss in postmenopausal women. Oestrogen maintains skeletal muscle integrity through satellite cell stimulation, up regulation of insulin-like growth factor-1 (IGF-1), and attenuation of pro-inflammatory cytokines including interleukin-6 (IL-6) and tumour necrosis factor-alpha (TNF-α).[5,6] Withdrawal of oestrogen at menopause compromises these pathways simultaneously, producing accelerated muscle catabolism.

Handgrip strength (HGS), measured with a portable calibrated dynamometer, has been extensively validated as a non-invasive surrogate of overall neuromuscular integrity. It is a primary diagnostic criterion in both EWGSOP2 and AWGS 2019, correlating strongly with lower limb strength, physical performance, and all-cause mortality.[3,7]

In resource-limited settings, its portability and low cost make it a practical first-line screening tool.

Despite growing recognition of Sarcopenia, systematic studies simultaneously evaluating HGS with metabolic, hematological, and skeletal parameters in Indian postmenopausal women remain limited. This study was undertaken to assess bilateral HGS in postmenopausal women, compare it with premenopausal controls using both EWGSOP1 and EWGSOP2 criteria, and characterize the metabolic derangements that amplify musculoskeletal vulnerability.

Materials and Methods

Study design and setting

A cross-sectional observational study was conducted at the KPS Post Graduate Institute of Medicine, Lala Lajpat Rai Hospital, GSVM Medical College, Kanpur, Uttar Pradesh, India, from August 2024 to January 2026.

The study was approved by the Institutional Ethics Committee (IEC), GSVM Medical College, Kanpur. All participants provided written informed consent in accordance with the Declaration of Helsinki.

Participants

A total of 200 women were enrolled: 150 post menopausal and 50 premenopausal. Postmenopausal women were defined as those with natural amenorrhoea for ≥ 12 consecutive months, confirmed for >5 years at enrolment, aged > 45 years.

Premenopausal women aged ≥ 45 years with regular menstrual cycles served as controls. Women with surgical or iatrogenic menopause, current/prior hormone replacement therapy, known diabetes mellitus, serious acute illness (stroke, acute coronary syndrome), or menopausal duration <5 years were excluded.

Handgrip strength measurement and Sarcopenia classification

Bilateral HGS was measured using a calibrated Jamar hydraulic hand dynamometer (Sammons Preston, USA) following the Southampton protocol[8]: standardised standing position, arms relaxed alongside torso, elbows at 90°, forearms in neutral rotation.

Two successive measurements per hand were recorded; the higher value was used. Sarcopenia was classified using EWGSOP1 criteria (HGS <20 kg for women)[9] and EWGSOP2 criteria (HGS <16 kg for women).[3]

Metabolic, hematological and skeletal assessment

Fasting venous blood samples were analysed for: serum total cholesterol and triglycerides by enzymatic colorimetric method; HbA1c by HPLC; 25- Hydroxyl vitamin D [25(OH) D] by chemilumine scence immunoassay; TSH by electro chemilumine scence immunoassay; haemoglobin by automated haematology analyser; serum calcium, sodium, and potassium by standard laboratory methods. Fracture risk was estimated using the FRAX® algorithm for the Indian population (www. shef.ac.uk/FRAX), computing the 10-year probability of major osteoporotic fracture. Osteoporosis risk was stratified as low (A1), moderate (A2), or high (A3). Blood pressure was recorded in the seated position after five minutes of rest. BMI (weight [kg]/height [m]²) and waist–hip ratio (WHR) were measured using standard anthropometric methods.

Statistical analysis

Data were analysed using SPSS version 20.0 (IBM Corp., USA). Continuous variables are expressed as mean ± standard deviation (SD). Between-group comparisons were made using the independent samples t-test. Categorical variables were compared using Pearson's chi-square test. A p-value <0.05 was considered statistically significant.

Results and Discussion

Demographic and anthropometric profile

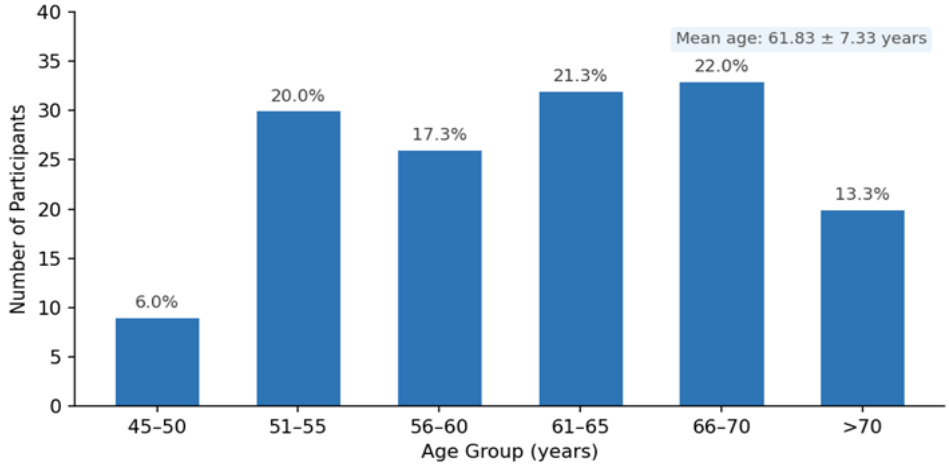
The 150 postmenopausal participants had a mean age of 61.83±7.33 years. The largest proportions were in the 65–70 year (22.0%) and 61–65 year (21.33%) age groups (Table 1). Mean BMI was 26.52±4.84 kg/m² in post menopausal versus 28.69±3.53 kg/m² in premenopausal women (p=0.003). Mean WHR was 17.76±3.79 versus 23.89±2.31 (p<0.0001), reflecting significant differences in body fat distribution between groups.

Table 1: Age distribution of postmenopausal women (n=150)

Age group (years)	n	Percentage (%)
45–50	9	6.00
51–55	30	20.00
56–60	26	17.33
61–65	32	21.33
66–70	33	22.00

Age group (years)	n	Percentage (%)
>70	20	13.33
Total	150	100.00
Mean ± SD (years)	61.83 ± 7.33	

Figure 1: Age distribution of postmenopausal women (n=150)



Handgrip strength: postmenopausal versus premenopausal women

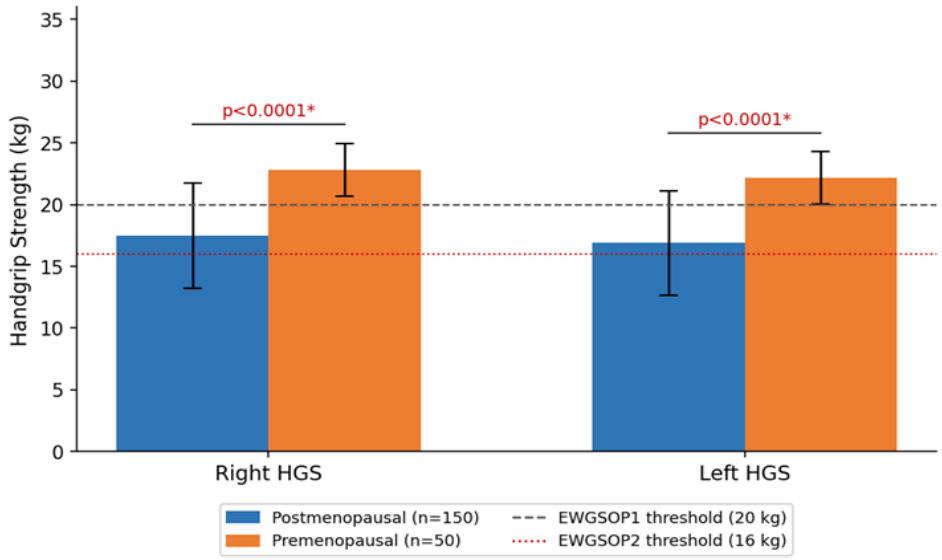
Postmenopausal women demonstrated significantly lower bilateral HGS compared to premenopausal controls (Table 2). Mean right HGS was 17.48±4.24 kg versus 22.82±2.15 kg (p<0.0001) and mean left HGS 16.90±4.21 kg versus 22.18±2.12 kg (p<0.0001), representing a 23–24% reduction.

Table 2: Comparison of handgrip strength between postmenopausal and premenopausal women.

Parameter	Postmenopausal (n=150) Mean ± SD	Premenopausal (n=50) Mean ± SD	p-value
Right HGS (kg)	17.48 ± 4.24	22.82 ± 2.15	<0.0001*
Left HGS (kg)	16.90 ± 4.21	22.18 ± 2.12	<0.0001*

*Statistically significant (p<0.05). HGS = Handgrip Strength; SD = Standard Deviation

Figure 2: Comparison of bilateral handgrip strength between postmenopausal and premenopausal women



This magnitude of decline is consistent with data from the SWAN cohort (Kurina et al.), where the transition to post menopause was independently associated with a 1.04 kg decline in grip strength beyond the effect of ageing alone,[10] and with Phillips et al., who first demonstrated a rapid decline in specific muscle force in women at menopause, effectively prevented by hormone replacement therapy.[11]

The hormonal basis of this decline is multi factorial: oestrogen deficiency impairs my osatellite cell proliferation, attenuates IGF – 1 - mediated anabolic signaling via the PI3K/ Akt/ mTOR pathway, and amplifies the NF-κB-driven inflammatory cascade characterised by elevated IL-6 and TNF-α, collectively producing a catabolic myocellular environment.[5,6] Willoughby et al.

confirmed that even early – to – inter mediate postmenopausal women exhibit significantly elevated biomarkers of neuromuscular junction degeneration (c-terminal fragment of agrin), inflammation (TNF-α), and muscle proteolysis (urinary titin), alongside reduced motor unit activation.[14]

Sarcopenia prevalence

Applying EWGSOP1 criteria (HGS <20 kg), Sarcopenia was identified in 27 of 150 postmenopausal women (18.0%). Under the more stringent EWGSOP2 threshold (HGS <16 kg), prevalence was 4.1% (n=6).

This divergence is consistent with findings by Warzecha et al., who reported identical prevalence rates (18% vs. 4.1%) using the same two criteria in postmenopausal women aged >60 years,[12] and with Buckinx& Aubertin - Leheudre, who highlighted that updated EWGSOP2 thresholds may underestimate prevalence in women who develop weakness at relatively younger ages.[13]

The clinically meaningful intermediate HGS deficit range (16–20 kg), not captured by EWGSOP2, carries appreciable fall and fracture risk in Indian post menopausal women, whose mean age at natural menopause (~46–47 years) is substantially earlier than in Western populations, supporting retention of the EWGSOP1 threshold for early detection in this population.[15]

FRAX® score, osteoporosis risk and comparative data

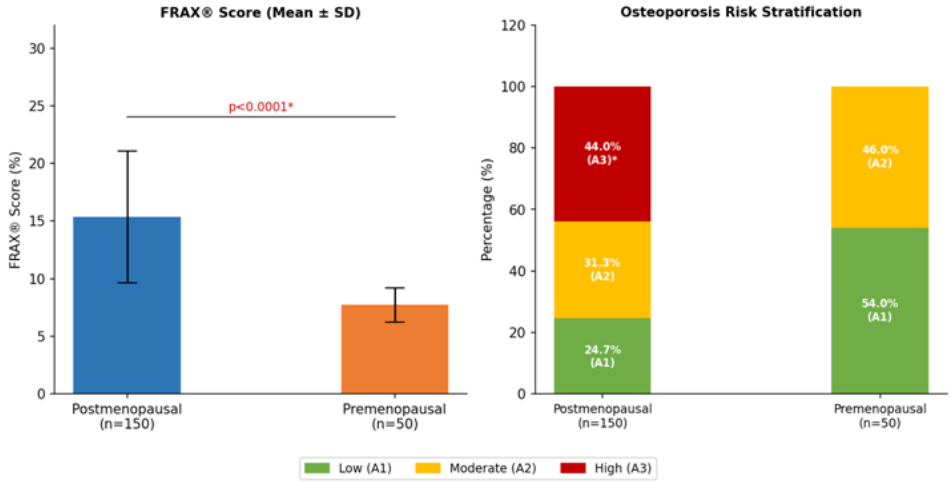
Mean FRAX score was significantly higher in postmenopausal women (15.35±5.71 vs. 7.71±1.49; p<0.0001) (Table 3). On osteoporosis risk stratification, 44.0% of postmenopausal women were in the high-risk category (A3) versus none of the premenopausal women (p<0.0001). The moderate-risk (A2) category also differed significantly (31.33% vs. 46.0%; p=0.004).

Table 3: Comparison of FRAX® score and osteoporosis risk stratification between groups.

Parameter	Postmenopausal (n=150)	Premenopausal (n=50)	p-value
FRAX® score (Mean ± SD)	15.35 ± 5.71	7.71 ± 1.49	<0.0001*
Low risk A1, n (%)	37 (24.67%)	27 (54.0%)	0.21
Moderate risk A2, n (%)	47 (31.33%)	23 (46.0%)	0.004*
High risk A3, n (%)	66 (44.00%)	0 (0.0%)	<0.0001*

*Statistically significant (p<0.05). FRAX® = Fracture Risk Assessment Tool

Figure 3: Comparison of FRAX® score and osteoporosis risk stratification between groups.



The significantly elevated FRAX scores and the finding that 44% of postmenopausal women were in the high osteoporosis risk (A3) category — compared to none in the premenopausal group — reflect the bone–muscle unit paradigm: loss of mechanical loading through sarcopenic muscle synergises with the direct skeletal effects of oestrogen deficiency to accelerate bone loss.[16] Long et al., in a meta-analysis of 10 studies encompassing 1,287,021 postmenopausal women, confirmed that advancing age, BMI, diabetes mellitus, prior fractures, and early menopause are the strongest predictors of osteoporotic fracture.[17]

Metabolic, haematological and blood pressure parameters

Full comparative data between groups are presented in Table 4. Triglycerides (142.58±32.01 vs. 130.64±26.27 mg/dL; p=0.01) and HbA1c (6.10±0.88 vs. 5.51±0.48%; p<0.0001) were significantly higher in postmenopausal women. Total cholesterol (203.52±31.30 vs. 202.44±24.28 mg/dL; p=0.82) and TSH (3.48±1.46 vs. 3.46±1.29 µIU/mL; p=0.93) did not differ significantly. Vitamin D was significantly lower in postmenopausal women (21.27±5.04 vs. 27.12±4.11 ng/mL; p<0.0001), indicating deficiency across the cohort (sufficiency threshold ≥30 ng/mL). Haemoglobin was markedly lower (8.63±1.05 vs. 10.58±0.69 g/dL; p<0.0001), reflecting high anaemia prevalence. Serum calcium was significantly lower (3.92±0.66 vs. 4.14±0.08 mg/dL; p=0.01). Serum sodium was significantly higher (142.40±4.17 vs. 139.3±1.56 mEq/L; p<0.0001); potassium did not differ (4.41±1.05 vs. 4.34±0.47 mEq/L; p=0.64). Both systolic (140.60±10.09 vs. 126.62±4.84 mmHg; p<0.0001) and diastolic blood pressure (84.10±8.07 vs. 81.54±4.12 mmHg; p=0.03) were significantly elevated in postmenopausal women.

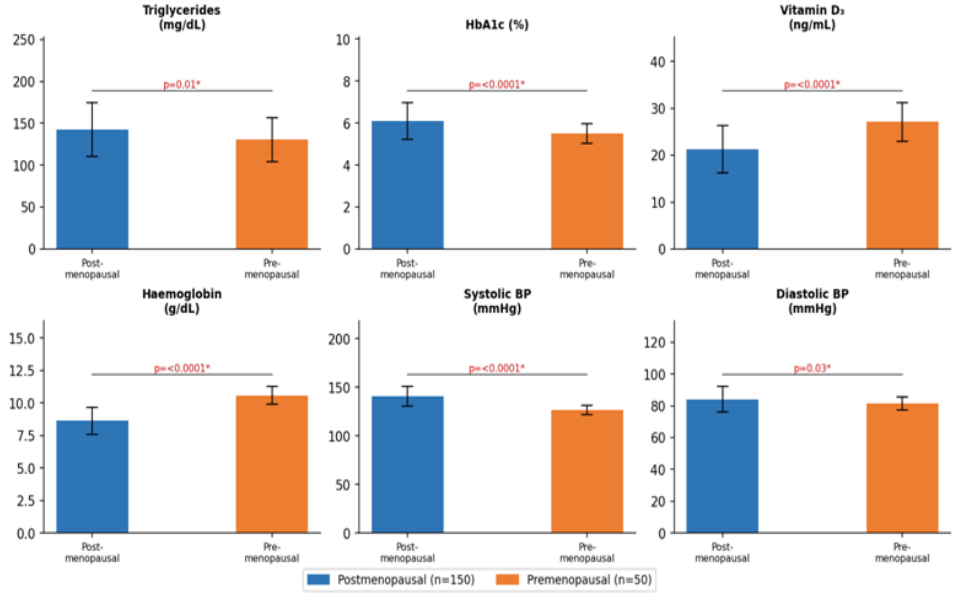
Table 4: Comparison of metabolic, hematological and blood pressure parameters between groups.

Parameter	Postmenopausal (n=150) Mean ± SD	Premenopausal (n=50) Mean ± SD	p-value
Total cholesterol (mg/dL)	203.52 ± 31.30	202.44 ± 24.28	0.82
Triglycerides (mg/dL)	142.58 ± 32.01	130.64 ± 26.27	0.01*
TSH (µIU/mL)	3.48 ± 1.46	3.46 ± 1.29	0.93

HbA1c (%)	6.10 ± 0.88	5.51 ± 0.48	<0.0001*
Vitamin D_3 [25(OH)D] (ng/mL)	21.27 ± 5.04	27.12 ± 4.11	<0.0001*
Haemoglobin (g/dL)	8.63 ± 1.05	10.58 ± 0.69	<0.0001*
Serum calcium (mg/dL)	3.92 ± 0.66	4.14 ± 0.08	0.01*
Serum sodium (mEq/L)	142.40 ± 4.17	139.3 ± 1.56	<0.0001*
Serum potassium (mEq/L)	4.41 ± 1.05	4.34 ± 0.47	0.64
Systolic BP (mmHg)	140.60 ± 10.09	126.62 ± 4.84	<0.0001*
Diastolic BP (mmHg)	84.10 ± 8.07	81.54 ± 4.12	0.03*
BMI (kg/m²)	26.52 ± 4.84	28.69 ± 3.53	0.003*
WHR	17.76 ± 3.79	23.89 ± 2.31	<0.0001*

*Statistically significant (p<0.05). BP = Blood pressure; WHR = Waist–hip ratio; SD = Standard Deviation

Figure 4: Comparison of metabolic, haematological and blood pressure parameters between groups.



Each of these metabolic derangements exerts an independent adverse effect on skeletal muscle. Vitamin D deficiency (mean 25[OH]D 21.27 ng/mL) impairs type II muscle fibre integrity and calcium–calmodulin-mediated myosin–actin cross-bridge cycling, contributing to neuromuscular weakness independent of oestrogen status.[18] Anaemia (mean Hb 8.63 g/dL) reduces skeletal muscle oxygen delivery, accelerating aerobic fatigue and functional weakness. The significantly higher triglycerides and HbA1c in postmenopausal women represent cardio metabolic risk that further compromises functional capacity through endothelial dysfunction and advanced glycation end-product accumulation in myofibrillar proteins.[19] Notably, total cholesterol and TSH did not differ significantly between groups, consistent with Fouad Kadhuim, who similarly found no significant difference in total cholesterol between pre- and postmenopausal women despite significant elevations in triglycerides, LDL-C, and VLDL-C.[20] This reinforces that total cholesterol alone is an insufficient marker of cardiovascular risk in postmenopausal women; composite atherogenic indices incorporating triglycerides

and HDL-C provide better risk stratification. The significantly elevated blood pressure (systolic 140.60 mmHg; diastolic 84.10 mmHg) is consistent with published data on postmenopausal hypertension driven by oestrogen-mediated vasodilatory loss and rennin – angiotensin – aldosterone system activation.[21] The lower BMI in postmenopausal compared to premenopausal women (26.52 vs. 28.69 kg/m²; p=0.003) in this cohort may reflect the specific demographic profile of this tertiary care population and the exclusion of women with known diabetes mellitus, who tend to have higher adiposity.

Comparison with other studies

Compared to prior Indian studies, these findings are consistent with Mahishale & Kulkarni, who reported mean HGS of 15.39±5.47 kg (right) and 15.10 ±5.35 kg (left) in postmenopausal women in a cross - sectional design,[22] and with Khadilkar, who highlighted that musculoskeletal deterioration during menopause significantly contributes to loco motor disability and reduced quality of life in Indian women.[15]

The meta-analysis by Zhao et al. further corroborates the observation that multiple interacting factors - weight, physical inactivity, prior fractures, and co morbidities - collectively determine fall risk, reinforcing the value of composite rather than isolated assessment.[23]

Strengths and limitations

Strengths of this study include the simultaneous evaluation of musculoskeletal, metabolic, cardiovascular, hematological, and skeletal parameters in a single cohort with a premenopausal comparison group, and the application of both EWGSOP1 and EWGSOP2 criteria.

Limitations include the cross-sectional design (precluding causal inference), single-centre recruitment, unequal group sizes, and the absence of DEXA-based body composition, hormonal profiling (oestradiol, FSH), physical activity quantification, and dietary assessment. Future longitudinal, multicentre studies incorporating these parameters are warranted.

Conclusion

Handgrip strength is a valid, reproducible, and cost-effective surrogate marker for early Sarcopenia screening in postmenopausal women. Postmenopausal women exhibit a 23–24% bilateral HGS reduction, Sarcopenia prevalence of 18.0% (EWGSOP1) and 4.1% (EWGSOP2), significantly elevated FRAX scores with 44% in the high osteoporosis risk category, higher triglycerides, HbA1c, and blood pressure, and lower vitamin D, haemoglobin, and serum calcium compared to premenopausal women. These findings underscore the multisystem vulnerability of this population. Routine HGS measurement, FRAX risk assessment, and integrated metabolic profiling should be incorporated into postmenopausal health surveillance to facilitate early preventive interventions - including structured resistance training, vitamin D and calcium supple mentation, glycaemic optimisation, and cardiovascular risk reduction strategies.

References

1. World Health Organization. Research on the Menopause in the 1990s. WHO Technical Report Series 866. Geneva: WHO; 1996.

2. Ji MX, Yu Q. Primary osteoporosis in post menopausal women. Chronic Dis Trans l Med 2015; 1: 9 –13.

3. Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 2019; 48: 16–31.

4. Shafiee G, Keshtkar A, Soltani A, et al. Prevalence of Sarcopenia in the world: a systematic review and meta-analysis of general population studies. J Diabetes Meta b Disord 2017; 16: 21.

5. Geraci A, Calvani R, Ferri E, Marzetti E, Arosio B, Cesari M. Sarcopenia and menopause: the role of estradiol. Front Endocrinol (Lausanne) 2021; 12: 682012.

6. Sipílá S, Törmäkangas T, Sillanpää E, et al. Muscle and bone mass in middle-aged women: role of menopausal status and physical activity. J Cachexia Sarcopenia Muscle 2020; 11: 698–709.

7. Chen LK, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc 2020; 21: 300–307.e2.

8. Roberts HC, Denison HJ, Martin HJ, et al. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. Age Ageing 2011; 40: 423–429.

9. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. Sarcopenia: European consensus on definition and diagnosis. Age Ageing 2010; 39: 412–423.

10. Kurina LM, Gulati M, Everson-Rose SA, et al. The effect of menopause on grip and pinch strength: results from the Study of Women's Health Across the Nation. Am J Epidemiol 2004; 160: 484–491.

11. Phillips SK, Rook KM, Siddle NC, Bruce SA, Woledge RC. Muscle weakness in women occurs at an earlier age than in men, but strength is preserved by hormone replacement therapy. Clin Sci (Lond) 1993; 84: 95–98.

12. Warzecha M, Amarowicz J, Berwecka M, Czerwiński E, Kumorek A. Relation between risk of falls, sarcopenia and parameters assessing quality of skeletal muscles in postmenopausal women. Prz Meno pauzalny 2020; 19: 123–129.

13. Buckinx F, Aubertin - Leheudre M. Sarcopenia in menopausal women: current perspectives. Int J Women's Health 2022; 14: 805–819.

14. Willoughby DS, Florez C, Davis J, et al. Decreased neuromuscular function and muscle quality in early to intermediate post-menopausal women. Nutrients 2024; 16: 197.

15. Khadilkar SS. Musculoskeletal disorders and menopause. J Obstet Gynaecol India 2019; 69: 99–103.

16. Maurel DB, Jahn K, Lara-Castillo N. Muscle bone crosstalk: emerging opportunities for novel therapeutic approaches to treat musculoskeletal pathologies. Biomedicines 2017; 5: 62.

17. Long G, Liu C, Liang T, et al. Predictors of osteoporotic fracture in postmenopausal women: a meta-analysis. J OrthopSurg Res 2023; 18: 574.

18. Bischoff-Ferrari HA, Borchers M, Gudat F, et al. Vitamin D receptor expression in human muscle tissue decreases with age. J Bone Miner Res 2004; 19: 265–269.

19. Rahman A, Jabeen A, Ravirala T. A cross-sectional study to assess lipid profile and atherogenic index of plasma in premenopausal and postmenopausal women in rural Telangana. Int J Clin Biochem Res 2021; 8: 29–32.

20. Fouad Kadhuim A. Estimation of serum lipid profile among pre- and post-menopausal women in Baghdad City. Medico-Legal Update 2020; 20: 452–457.

21. Jain A, Kumar S, Acharya S, Kabra R, Sawant R. Assessment of blood pressure variability in postmenopausal women. Cureus 2022; 14: e29471.

22. Mahishale AV, Kulkarni MP. Evaluation of muscle strength and endurance in postmenopausal women: a cross-sectional study. J South Asian Feder Obst Gynae 2021; 13: 163–166.

23. Zhao J, Liang G, Huang H, et al. Identification of risk factors for falls in postmenopausal women: a systematic review and meta-analysis. Osteoporos Int 2020; 31: 1895–1904.

24. Greeves JP, Cable NT, Reilly T, Kingsland C. Changes in muscle strength in women following the menopause: a longitudinal assessment. Clin Sci (Lond) 1999; 97: 79–84.

25. Rolland YM, Perry HM, Patrick PP, Banks WA, Morley JE. Loss of appendicular muscle mass and loss of muscle strength in young postmenopausal women. J Gerontol ABiol Sci Med Sci 2007; 62: 330–335.

26. Saha KR, Rahman MM, Paul AR, et al. Changes in lipid profile of postmenopausal women. Mymensingh Med J 2013; 22: 706–711.

27. Balogun S, Winzenberg T, Wills K, et al. Prospective associations of low muscle mass and function with 10-year falls risk, incident fracture and mortality in community-dwelling older adults. J Nutr Health Aging 2017; 21: 843–848.

28. Trémollières F, Cochet T, Cohade C, Pouillès JM, Ribot C. Fracture risk in early postmenopausal women assessed using FRAX®. Joint Bone Spine 2010; 77: 345–348.

29. Iolascon G, de Sire A, Calafiore D, et al. Multi factorial assessment of risk of falling in 753 post-menopausal women: a multicenter cross-sectional study. Clin Interv Aging 2020; 15: 1077–1084.

30. Dodds RM, Syddall HE, Cooper R, et al. Grip strength across the life course: normative data from twelve British studies. PLoS One 2014; 9: e113637.