SPORT TK-EuroAmerican Journal of Sport Sciences

https://revistas.um.es/sportk Online ISSN: 2340-8812

Received: **04/10/2024.** Accepted: **03/02/2025.** Published: **16/05/2025**

Relative hand grip strength and functional fitness among older adults with type II diabetes in Egypt: A cross-sectional study

Mohammed Youssef Elhamrawy[1]*, Ali Mohammed Hassan[2,3], Jobby George[4], Sami Ahmed Zaher Basha[5,6], Mohammed Ali Mohammed Sarhan[7], Zeinab M Abdelrehim[8], Mohamed T. Said[9,8], Saher Lotfy Elgayar[1]

[1] Department of Physical Therapy, Faculty of Allied Medical Sciences, Middle East University, Amman, Jordan.

[2] Department of Physical Therapy, Faculty of Allied Medical Science, Zarqa University, Zarqa, Jordan.

[3] Faculty of Physical Therapy, South Valley University, Qena, Egypt.

[4] College of Health Sciences, University of Fujairah, Fujairah, UAE.

[5] Faculty of Physical Therapy, Pharos University, Alexandria, Egypt.

[6] Faculty of Allied Medical Sciences, Zarqa University, Zarqa, Jordan.

[7] Faculty of Physical Therapy, Suez Canal University, Egypt.

[8] Department of Physical Therapy, Faculty of Allied Medical Sciences, Aqaba University of Technology, Jordan.

[9] Department of Physical Therapy for Elderly, National Institute of Longevity Elderly Sciences (NILES), Beni-Suef University, Beni-Suef, Egypt.

* Correspondence: Mohammed Youssef Elhamrawy; dr_melhamrawy@yahoo.com

ABSTRACT

Population aging, diabetes, and insufficient physical activity have become pressing public health issues in Egypt. Addressing these challenges can enhance the quality of life for the aging population and reduce the overall public health burden. This study recruited 200 participants, divided into two groups: individuals with type 2 diabetes mellitus (T2DM) and healthy non-diabetic controls. Participants were assessed for relative handgrip strength (rHGS) using a hand dynamometer, and for functional fitness using the Timed Up and Go test (TUG), the 30-second chair stand, and the 2-minute walk test (2-MWT), all during the same visit. The mean relative hand grip strength (rHGS) and the functional assessment (TUG, 30-second chair stands and 2-MWT) were significantly lower in the diabetic group compared to the group with no diabetes ($p<0.05$). Both rHGS and functional level are significantly lower in elderly diabetics as compared with healthy elderly subjects in Egypt ($p<0.05$). Also, among the Egyptians, rHGS and functional level in elderly participants with type 2 diabetes are strongly correlated with their glycemic control ($p<0.05$). The study highlights the importance of monitoring physical function as part of diabetes management in older adults.

KEYWORDS

Relative Hand Grip Strength; Functional Fitness; Elderly; Diabetes

1. INTRODUCTION

The global aging population, rising from 9.2% in 1990 to 21.1% by 2050 (United Nations, 2022), is influenced by morphological, physiological, and pathological changes, impairing physical and cognitive abilities, balance, and motor functions (Naushin et al., 2015; Shao et al., 2023).

Over the past decade, the ageing population has seen a rise in type 2 diabetes, suspecting them to multiple comorbidities, hypoglycemia susceptibility, care dependence, and frailty (Bellaryet al., 2012). Assessing muscle strength may be beneficial in the clinical examination of the oldest patients to identify those at heightened risk of imminent deterioration (Bilajac et al., 2019). Either aging or diabetes mellitus (DM) have an impact on muscular function, functional capacity, balance, and other health issues such diabetic neuropathy development, hypoglycemia, hypotension, and cognitive decline (Abdelbasset et al., 2021).

Combined aging and diabetes could result in more progressive deteriorations. Older adults with diabetes have diverse medical, functional, and cognitive statuses, necessitating personalized treatment regimens (Munshi et al., 2020; Elgayar et al., 2019). Both directly, via decreasing β-cell activity that highlights the absence of insulin release, and indirectly, through increased insulin resistance due to obesity and other risk factors, aging plays a role in the pathophysiology of T2DM (Lee et al., 2017; Chia et al., 2018). Older individuals with T2DM experience increased chronic complications and severe functional impairments, with a 4% prevalence of severe impairment compared to 1% in controls (Sinclair et al., 2008).

Despite HGS and functional fitness were examined in T2DM in previous studies (Kaur et al., 2021), Egypt faces a rising prevalence of diabetes, a global epidemic. Risk factors such as obesity, sedentary lifestyles, hepatitis C infections, smoking, and pesticides, highlight the need for urgent attention (Abouzid et al., 2022).

Clinical rehabilitation and public health research use handgrip strength (HGS) as a biomarker to measure musculoskeletal functioning and frailty or impairment in older individuals (Wiśniowska-Szurlej et al., 2021; Pettersson-Pablo et al., 2024).

Functional fitness significantly enhances the autonomy and independence of the elderly, promoting emotional and social well-being and effective aging through physical attributes like strength, flexibility, balance, and aerobic capacity (Vagetti et al., 2021).

The study compares hand grip strength and functional fitness in elderly type 2 diabetics compared to those without diabetes and investigates correlations between glycemic control and these variables.

2. METHODS

2.1. Participants

This study was done between November 2023 and October 2024. The required data was collected from elderly participants, over 60 years old participants, from endocrine out clinics in Egypt, the study was registered on the clinicaltrials.gov website with identification number: NCT06645418. The study received approval from the Faculty of Physical Therapy Ethics Committee, Cairo university, Egypt (Approval No: P.T.REC/012/004983). All research participants were made aware of its goals and methodology. Also, via signing informed consents by all participants, the agreements to participate in the study were confirmed.

Into two equal groups, this study recruited 200 participants including: Group 1 with T2DM (50 males, 50 females), and Group 2 healthy non-diabetic (50 males, 50 females). Inclusion criteria included the capability of independent walking, the cognitive and mental capacity recognizing and doing the tests, and no musculoskeletal, neurological, rheumatological problems, or hand deformities that could hinder grasping (Dupuytren's contracture and carpal tunnel syndrome). In order to rule out any mental or physical health issues, we employed the Arabic version of the 12-item health survey (SF-12) (Haddad et al., 2021). The flow chart for the study participants is presented in Figure 1.

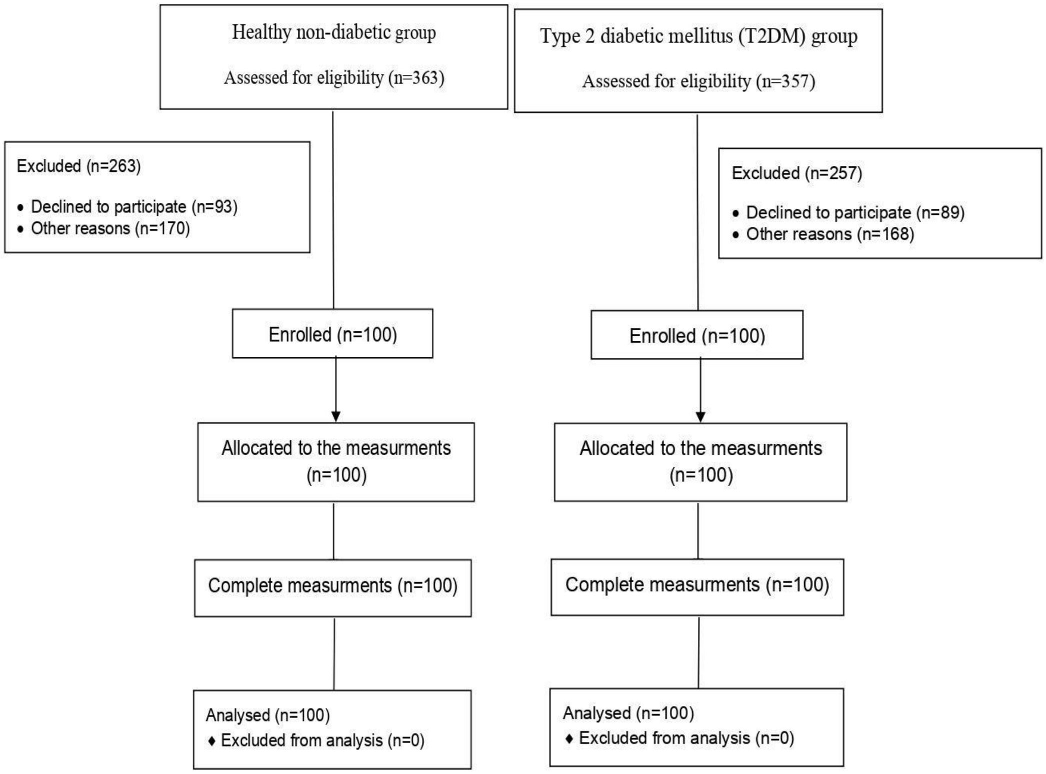

Figure 1. Flow chart for study participants

2.2. Instruments and procedures

The relative handgrip strength (rHGS) index was measured, followed by a functional fitness assessment including timed up and 30-second chair stands and 2-minute walk test.

2.2.1. Assessment of relative hand grip strength (rHGS)

rHGS is a non-invasive and easy-to-use tool, used mainly in clinical settings on elderly populations, and is considered a better prognostic tool than handgrip strength. The rHGSi is calculated through adding the handgrip strength (HGS) of both hands dividing them by body mass index (BMI) (İmre et al., 2022). To assess the, the calibrated digital hand dynamometer (The CAMRY EH101) was employed, which is a reliable, affordable, and practical tool for assessing grip strength among elderly due to its excellent reliability and validity (Huang et al., 2022).

Following a practice trial, each participant did three sets of maximum contractions for each hand while sitting with their elbows bent at a 90-degree angle. They rested for about 30 seconds in between sets. The statistical analyses were based on the highest test result, which was represented in kilos. The body mass index (BMI) was computed through obtaining measures of weight and height through a standardized weight and height scale.

2.2.2. Assessment of the Functional fitness

A) Timed up and go test (TUG)

The TUG, commonly used in geriatric and rehabilitative care, is a suitable clinical evaluation instrument to assess balance, due to its connection to executive function, regular distribution, and lack of ceiling effect restrictions (Herman et al., 2011). The TUG test required participants to get out of an armrest-less chair, ambulate three meters, spin around, return to the chair, and take a seat. After 3 repetitions of the test, the three times were averaged (Valenzuela et al., 2023).

B) 30-second chair stands to assess lower extremity function

For usually active, community-dwelling older persons, 30-second chair standing tests provide a rather accurate and valid measure of lower extremities strength. Participants were instructed to take a seat kept the back straight, the feet flat on the ground, the arms against the chest, and the hands on the other shoulder, after selecting "Go," get up completely and then take a seat again. Do this again for 30 seconds (Langhammer et al., 2015).

C) 2-minute walk test (2-MWT)

Validation of the 2-MWT for fragile older adults has been previously confirmed (Gil-Calvo et al., 2024). For two minutes, the participants were motivated to walk the maximum distance possible without stopping, and the distance they covered was then calculated in meters.

2.3. Sample size calculation

The optimal number of participants for the two groups was determined by establishing the sample size using the G Power 3.1 software. This calculation was informed by the research conducted by Kaur et al., which employed hand grasp strength as a metric for calculation. The calculations were conducted using a two-tailed t-test with a 95% power, a 0.67 effect size, and an α error probability of 5%. As a result, the sample size per group was determined to be 58 subjects. Nevertheless, we considered a sample of 100 individuals per group for greater reliability of the results.

2.4. Statistical analysis

For all statistical tests, SPSS version 15.0 for Windows (SPSS, Inc., Chicago, IL) was employed. Mean (SD) for continuous-level characteristics and frequencies with percentages of distributions for categorical measures defined the criteria of the research population. Independent-samples t-test helped one to find statistically significant variations in certain criteria between the two groups. Chi square test let one find the variations in categorical variables. Every outcome metric was subjected to Pearson's correlation. P below 0.05 indicated statistical significance.

3. RESULTS

A total of 200 participants were analyzed, with 100 of them having type 2 diabetes and 100 being non-affected. The clinical characteristics of participants with and without diabetes for each sex are compared in Table 1. Age, height, weight, BMI, educational status, and physical activity level, and the associated medical problems did not show any significant disparities across the two groups. Means of HbA1c was significantly higher among diabetics either in males (p=0.001) or females (p=0.001) relative to the non-diabetics.

Table 1. Participants' criteria

Variable		Males			Females		
		Diabetics (n = 50)	Non- Diabetics (n = 50)	p-value	Diabetics (n = 50)	Non- Diabetics (n = 50)	p-value
Age (years)		67.96± 4.36	68.24± 4.93	0.83	66.76± 4.21	67.04± 4.01	0.81
Weight (kg)		71.76± 8.22	75.96± 9.31	0.1	75.96± 7.88	78.42± 7.36	0.38
Height (cm)		163± 6.38	164.32± 7.88	0.53	161.04± 6.03	162.32± 6.81	0.49
BMI (kg/m^2)		27.09± 1.26	27.32± 1.57	0.56	28.29± 1.46	28.52± 1.39	0.94
Diabetes duration (years)		8.44± 4.25	NA	NA	6.44± 5.08	NA	NA
Highest educational level	Primary school	27(54%)	19(38%)	0.28	27(54%)	19(38%)	0.28
	Secondary school	13(26%)	17(34%)	0.46	13(26%)	17(34%)	0.46
	High education	10(20%)	14(28%)	0.33	10(20%)	14(28%)	0.33
Diabetes treatments	Oral	34(68%)	NA	NA	40(80%)	NA	0.92
	Insulin	16(32%)			10(20%)		
Dominant hand	Right	37(74%)	39(78%)	0.82	33(74%)	35(70%)	0.8
	Left	13(26%)	11(22%)		17(34%)	15(30%)	
Associated medical problems	Hypertension	41(82%)	36(72%)	0.47	37(74%)	31(72%)	0.36
	Hyperlipidemia	31(62%)	28(56%)	0.36	42(84%)	32(64%)	0.12
	Knee osteoarthritis	41(82%)	42(84%)	0.88	45(90%)	41(82%)	0.54
	Back pain	38(76%)	32(64%)	0.6	36(72%)	31(62%)	0.5
HbA1C (%)		8.22± 0.88	6.43± 0.48	0.001*	8.06± 0.81	6.36± 0.56	0.001*
6-point physical activity scale		1.44± 0.5	1.48± 0.51	0.78	1.32± 0.47	1.6± 0.5	0.07

*Note. Data is expressed using mean values and standard deviations in addition to percentages of distribution. Compared continuous variables across groups using the un-paired t test. Chi-square contrasted group categories. *P-value < 0.05 indicates significance. BMI was used as abbreviation for body mass index and HbA1C for glycated Hemoglobin.*

Men with diabetes had a much lower mean rHGS than men without diabetes (p= 0.006), as seen in Table 2. In the same way, women with diabetes had significantly lower relative hand grip strengths than women without diabetes (p= 0.001), as seen in Table 2. The mean repetitions from 30-second chair-stand test was significantly greater in diabetic men than in non-diabetic men (p= 0.03) (Table 2). Similarly, mean repetitions from 30-second chair-stand test was significantly greater than women with diabetes compared with women without diabetes (p= 0.009) (Table 2). The mean distance from 2-minute walk test was significantly greater in diabetic men than in non-diabetic men (p= 0.005) (Table 2). Similarly, the mean distance from 2- minute walk test was significantly greater than women with diabetes compared with women without diabetes (p= 0.002). As compared with the men with no diabetes, the mean duration resulted from timed up and go test was significantly lower in men with diabetes (p= 0.001). Similarly, the mean duration resulted from timed up and go test (TUG) was significantly less in diabetic women than in non-diabetic women (p= 0.001) (Table 2).

Table 2. Comparisons between groups

Outcome	**Males**			**Females**		
	Diabetics (n = 50)	**Non- Diabetics (n = 50)**	**p-value**	**Diabetics (n = 50)**	**Non- Diabetics (n = 50)**	**p-value**
Relative hand grip strength (kg/BMI)	1.11± 0.27	1.33± 0.26	0.006*	0.82± 0.28	1.13± 0.29	0.001*
Timed up and go test (second)	10.6± 1.97	7.4± 3	0.001*	12.6± 1.43	9.08± 1.03	0.001*
30-second chair-stand test (repetition)	12.4± 4.15	15.16± 4.8	0.03*	10.4± 4	13.16± 3.96	0.009*
2- minute walk test (m)	124.8 ± 27.56	147.4± 27.02	0.005*	115.16± 24.42	140.4± 25.07	0.002*

*Note. Data is expressed using mean values and standard deviations. Compared continuous variables across groups using un-paired t test. *P-value < 0.05 indicates significance.*

Additionally, in diabetics, a strong positive linear correlation was found between the HbA1c and duration resulted from timed up and go test in men (r= 0.86, p=0.001) and women (r= 0.82, p=0.001). Also, in diabetics, a moderate negative linear correlation was found between the HbA1c and the relative hand grip strength in men (r= -0.48, p=0.02) and women (r= -0.5, p=0.01), as shown in Table 3. Additionally, in diabetics, a strong negative linear correlation was found between the HbA1c and distance from 2- minute walk test in men (r= -0.88, p=0.001) and women (r= -0.81, p=0.001), as shown in Table 3.

Table 3. Correlations between glycemic control and outcome measures

Correlation	Males			Females		
	N	Pearson Correlation Coefficient (r)	p-value	N	Pearson Correlation Coefficient (r)	p-value
Relative hand grip strength X **HbA1c**	50	-0.48	0.02*	50	-0.5	0.01*
Timed up and go test X **HbA1c**	50	0.86	0.001*	50	0.81	0.001*
30-second chair-stand test X HbA1c	50	-0.91	0.001*	50	-0.9	0.001*
2- minute walk test X **HbA1c**	50	-0.88	0.001*	50	-0.81	0.001*

*Note. Data is expressed using mean values and standard deviations. Pearson Correlation analyzed correlations between variables. *P-value < 0.05 indicates significance.*

4. DISCUSSION

In our study, significantly lower hand grip strength (rHGS) and low physical fitness were found in men and women with T2DM as compared with healthy participants without diabetes. The lower rHGS among diabetics as compared with the non-diabetics either in men (1.11 kg/BMI vs. 1.33 kg/BMI, p=0.006) or women (0.82 kg/BMI vs. 1.13 kg/BMI, p=0.001) could be related to the general muscle weakness and the progressive reduction in muscle mass as a consequence of poor glycemic control, complications of neuropathy or vasculopathy (Lien et al., 2018), in addition to due to lack of physical activity (Nomura et al., 2018). In specific, low rHGS among diabetics might be attributed to the specific intrinsic muscular atrophy and weakening, specifically affecting the first dorsal interosseous and abductor pollicis brevis muscles, also diminished sensory feedback, which is crucial for motor adjustments during hand function (Li et al., 2018). In line with a recent meta-analysis, older patients with diabetes have lower muscle mass index and strength, lower handgrip strength, and greater loss in thigh muscle compared to non-diabetes individuals. Also, the meta-analysis found higher functional decline and disability among older adults with diabetes (Wen et al., 2022).

Another important notice in the present study was that older adults with T2DM exhibited significantly lower balance and mobility compared to those without diabetes as assessed using TUG test in either men (10.6 vs. 7.4, p=0.001) or women (12.6 vs. 9.08, p=0.001). This suggests that diabetes negatively impacts balance in older individuals. In agreement, as previously confirmed, older adults diagnosed with T2DM have a 63% greater falling risk compared to non-diabetic individuals (Freire et al., 2024). This is due T2DM can lead to complications like reduced sensory and motor abilities, cognitive decline, and falls. Poor nutrition, particularly protein, can also impact muscle health, affecting balance and muscle mass, especially in diabetic patients (Nugraha et al., 2024; Elhamrawy et al., 2021). Furthermore, two previous studies revealed a high prevalence of reduced mobility and balance in elderly participants, particularly in ankle and subtalar joints, and significant reductions in range of motion, especially in diabetics (Bursać et al., 2018).

The 30-second chair-stand test revealed lower extremity function in diabetic men and women compared to healthy individuals, possibly due to metabolic changes linked to diabetes, such as increased visceral fat and reduced muscle mass, and insulin resistance, which leads to decreased muscle protein synthesis and degradation (Kovalchuk, et al., 2022). Furthermore, the presence of diabetes accelerates age-related muscle loss and muscle weakness, which are early indicators of frailty (Jang, 2019).

As exercise capacity is a strong predictor of long-term mortality in elderly diabetic patients (Nylen et al., 2010), in our study the T2DM participants group show reduced exercise capacity as assessed by distance walked 2MWT. A low exercise capacity in diabetics is primarily related to the decline of cardiopulmonary functions as a result of hyperglycemia in addition to the reduced muscle aerobic power (Nesti et al., 2020). Poor nutrition, especially protein, can lead to reduced muscle mass and strength, affecting hip girdle strength, impaired mobility, gait impairment, and falls, especially in diabetic individuals (Almurdhi et al., 2017; IJzerman et al., 2011). Additionally, the muscle impairments associated with diabetes are important contributors of slower walking speed among older adults. This highlights the role of muscle quality and strength in maintaining mobility (Volpato et al., 2012).

5. CONCLUSIONS

Both rHGS and functional level are significantly lower in elderly diabetics as compared with healthy elderly subjects in Egypt. Also, among the Egyptians, rHGS and functional level in elderly participants with type 2 diabetes are strongly correlated with their glycemic control. The study highlights the importance of monitoring physical function as part of diabetes management in older adults.

6. REFERENCES

1. Abdelbasset, W. (2021). Physical Exercise and Falling among Older Patients with Diabetes: A Narrative Review. *International Journal of Biomedicine, 11*(4), 473–479. https://doi.org/10.21103/article11(4)_ra3
2. Abouzid, M. R., Ali, K., Elkhawas, I., & Elshafei, S. M. (2022). An Overview of Diabetes Mellitus in Egypt and the Significance of Integrating Preventive Cardiology in Diabetes Management. *Cureus*, *14*(7), 1-6. https://doi.org/10.7759/cureus.27066
3. Almurdhi, M. M., Reeves, N. D., Bowling, F. L., Boulton, A. J., Jeziorska, M., & Malik, R. A. (2016). Reduced Lower-Limb Muscle Strength and Volume in Patients with Type 2 Diabetes in Relation to Neuropathy, Intramuscular Fat, and Vitamin D Levels. *Diabetes Care*, *39*(3), 441–447. https://doi.org/10.2337/dc15-0995
4. Bellary, S., Kyrou, I., Brown, J. E., & Bailey, C. J. (2021). Type 2 diabetes mellitus in older adults: clinical considerations and management. *Nature reviews. Endocrinology*, *17*(9), 534–548. https://doi.org/10.1038/s41574-021-00512-2
5. Bilajac, L., Juraga, D., & Zuljevic, H. (2019). The influence of physical Activity on handgrip strength of elderly. *Archive of Gerontology and Geriatrics Research, 4(*1), 20–24. https://doi.org/10.17352/aggr.000011
6. Bursać, S. N., Jandrić, S., Talić, G., & Ljubojević, G. (2018). Complications of diabetes mellitus on muscles and joints of lower extremities. Scripta Medica, 49(2), 1-7. https://doi.org/10.7251/scmed1802105b
7. Chia, C. W., Egan, J. M., & Ferrucci, L. (2018). Age-Related Changes in Glucose Metabolism, Hyperglycemia, and Cardiovascular Risk. *Circulation Research*, *123*(7), 886–904. https://doi.org/10.1161/CIRCRESAHA.118.312806
8. Elgayar, S. L, Hagag, A. A., & Ghazi, H. A. (2019). Active versus Passive Stretching Exercises on Blood Glucose and Functional Capacity in Elderly Diabetic Patients: Comparative Study. *IOSR Journal of Nursing and Health Science*, *8*(2), 61-67.
9. Elhamrawy, M. Y., Mohamed, S., Bahnasy, W., Saif, M. Y., Elkholy, A., & Said, M. (2021). Effect of vestibular rehabilitation therapy on spatio-temporal gait parameters in elderly patients with post-stroke hemineglect. *Advances in Rehabilitation*, *35*(3), 17–24. https://doi.org/10.5114/areh.2021.107421
10. Freire, L. B., Brasil-Neto, J. P., da Silva, M. L., Miranda, M. G. C., de Mattos Cruz, L., Martins, W. R., & da Silva Paz, L. P. (2024). Risk factors for falls in older adults with diabetes mellitus: systematic review and meta-analysis. *BMC Geriatrics*, *24*(1), 1-12. https://doi.org/10.1186/s12877-024-04668-0
11. Gil-Calvo, M., de Paz, J. A., Herrero-Molleda, A., Zecchin, A., Gómez-Alonso, M. T., Alonso-Cortés, B., & Boullosa, D. (2024). The 2-Minutes Walking Test Is Not Correlated with Aerobic Fitness Indices but with the 5-Times Sit-to-Stand Test Performance in Apparently Healthy Older Adults. *Geriatrics (Basel, Switzerland)*, *9*(2), 1-8. https://doi.org/10.3390/geriatrics9020043
12. Haddad, C., Sacre, H., Obeid, S., Salameh, P., & Hallit, S. (2021). Validation of the Arabic version of the "12-item short-form health survey" (SF-12) in a sample of Lebanese adults. *Archives of Public Health*, *79*(1), 1-8. https://doi.org/10.1186/s13690-021-00579-3.
13. Herman, T., Giladi, N., & Hausdorff, J. M. (2011). Properties of the 'timed up and go' test: more than meets the eye. *Gerontology*, *57*(3), 203–210. https://doi.org/10.1159/000314963
14. Huang, L., Liu, Y., Lin, T., Hou, L., Song, Q., Ge, N., & Yue, J. (2022). Reliability and validity of two hand dynamometers when used by community-dwelling adults aged over 50 years. *BMC Geriatrics*, *22*(1), 1-8. https://doi.org/10.1186/s12877-022-03270-6
15. IJzerman, T. H., Schaper, N. C., Melai, T., Meijer, K., Willems, P. J., & Savelberg, H. H. (2011). Lower extremity muscle strength is reduced in people with type 2 diabetes, with and without

polyneuropathy, and is associated with impaired mobility and reduced quality of life. *Diabetes Research and Clinical Practice*, *95*(3), 345–351. https://doi.org/10.1016/j.diabres.2011.10.026

16. İmre, E., Koçakgöl, N., & İmre, E. (2022). Low handgrip strength is associated with diabetic foot disease in geriatric patients with type 2 diabetes. *Turkish Journal of Medical Sciences*, *52*(6), 1854–1862. https://doi.org/10.55730/1300-0144.5532
17. Jang, H. C. (2019). Diabetes and Muscle Dysfunction in Older Adults. *Annals of Geriatric Medicine and Research*, *23*(4), 160–164. https://doi.org/10.4235/agmr.19.0038
18. Kaur, P., Bansal, R., Bhargava, B., Mishra, S., Gill, H., & Mithal, A. (2021). Decreased handgrip strength in patients with type 2 diabetes: A cross-sectional study in a tertiary care hospital in North India. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *15*(1), 325–329. https://doi.org/10.1016/j.dsx.2021.01.007
19. Langhammer, B., & Stanghelle, J. K. (2015). The Senior Fitness Test. *Journal of Physiotherapy*, *61*(3), 1-2. https://doi.org/10.1016/j.jphys.2015.04.001
20. Lee, P. G., & Halter, J. B. (2017). The Pathophysiology of Hyperglycemia in Older Adults: Clinical Considerations. *Diabetes Care*, *40*(4), 444–452. https://doi.org/10.2337/dc16-1732
21. Li, K., Wei, N., Cheng, M., Hou, X., & Song, J. (2018). Dynamical coordination of hand intrinsic muscles for precision grip in diabetes mellitus. Scientific *Reports*, *8*(1), 1-14. https://doi.org/10.1038/s41598-018-22588-z
22. Lien, A. S., Hwang, J. S., & Jiang, Y. D. (2018). Diabetes related fatigue sarcopenia, frailty. *Journal of Diabetes Investigation*, *9*(1), 3–4. https://doi.org/10.1111/jdi.12752
23. Munshi, M. N., Meneilly, G. S., Rodríguez-Mañas, L., Close, K. L., Conlin, P. R., Cukierman-Yaffe, T., Forbes, A., Ganda, O. P., Kahn, C. R., Huang, E., Laffel, L. M., Lee, C. G., Lee, S., Nathan, D. M., Pandya, N., Pratley, R., Gabbay, R., & Sinclair, A. J. (2020). Diabetes in ageing: pathways for developing the evidence base for clinical guidance. *The Lancet. Diabetes & Endocrinology*, *8*(10), 855–867. https://doi.org/10.1016/S2213-8587(20)30230-8
24. Naushin, Q., Shweta, M., & Annamma, V. (2017, June 1). Physical Fitness in Community Dwelling Elderly and Institutionalized Elderly Using Senior Fitness Test (SFT). *International Journal of Physiotherapy*, *4*(3), 152-159. https://doi.org/10.15621/ijphy/2017/v4i3/149066
25. Nesti, L., Pugliese, N. R., Sciuto, P., & Natali, A. (2020). Type 2 diabetes and reduced exercise tolerance: a review of the literature through an integrated physiology approach. *Cardiovascular Diabetology*, *19*(1), 1-17. https://doi.org/10.1186/s12933-020-01109-1
26. Nomura, T., Kawae, T., Kataoka, H., & Ikeda, Y. (2018). Aging, physical activity, and diabetic complications related to loss of muscle strength in patients with type 2 diabetes. *Physical Therapy Research*, *21*(2), 33–38. https://doi.org/10.1298/ptr.R0002
27. Nugraha M. H. S. (2024). Balance Problems in the Elderly with Diabetes Mellitus: A Literature Review. *Journal of Mid-life Health*, *15*(2), 55–61. https://doi.org/10.4103/jmh.jmh_29_23
28. Nylen, E. S., Kokkinos, P., Myers, J., & Faselis, C. (2010). Prognostic effect of exercise capacity on mortality in older adults with diabetes mellitus. *Journal of the American Geriatrics Society*, *58*(10), 1850–1854. https://doi.org/10.1111/j.1532-5415.2010.03068.x
29. Pettersson-Pablo, P., Nilsson, T. K., & Hurtig-Wennlöf, A. (2024). Relative handgrip strength correlates inversely with increased body fat, inflammatory markers and increased serum lipids in young, healthy adults - The LBA study. *Diabetes Research and Clinical Practice*, *207*, 1-4. https://doi.org/10.1016/j.diabres.2023.111057
30. Shao, L., Shi, Y., Xie, X. Y., Wang, Z., Wang, Z. A., & Zhang, J. E. (2023). Incidence and risk factors of falls among older people in nursing homes: Systematic review and meta-analysis. *Journal of the American Medical Directors Association*, *24*(11), 1708-1717. https://doi.org/10.1016/j.jamda.2023.06.002
31. Sinclair, A. J., Conroy, S. P., & Bayer, A. J. (2008). Impact of diabetes on physical function in older people. *Diabetes Care*, *31*(2), 233–235. https://doi.org/10.2337/dc07-1784

32. United Nations, Department of Economic and Social Affairs, Population Division. (2022). *World population prospects 2022: Summary of results* (UN DESA/POP/2022/TR/NO. 3). https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf
33. Vagetti, G. C., Gomes, F. R. H., Silva, M. P. da, Gasparotto, G. da S., Oliveira, V. de, & Campos, W. de. (2020). Association between functional fitness and quality of life of elderly participants of a program of physical activity of Curitiba, Brazil. *Journal of Physical Education*, *31*(1), 1-15. https://doi.org/10.4025/jphyseduc.v31i1.3115
34. Valenzuela, P. L., Saco-Ledo, G., Morales, J. S., Gallardo-Gómez, D., Morales-Palomo, F., López-Ortiz, S., Rivas-Baeza, B., Castillo-García, A., Jiménez-Pavón, D., Santos-Lozano, A., Del Pozo Cruz, B., & Lucia, A. (2023). Effects of physical exercise on physical function in older adults in residential care: a systematic review and network meta-analysis of randomised controlled trials. *The Lancet. Healthy Longevity*, *4*(6), 247–256. https://doi.org/10.1016/S2666-7568(23)00057-0
35. Volpato, S., Bianchi, L., Lauretani, F., Lauretani, F., Bandinelli, S., Guralnik, J. M., Zuliani, G., & Ferrucci, L. (2012). Role of muscle mass and muscle quality in the association between diabetes and GAIT speed. *Diabetes Care*, *35*(8), 1672–1679. https://doi.org/10.2337/dc11-2202
36. Wen, C. Y., Lien, A. S., & Jiang, Y. D. (2022). Sarcopenia in elderly diabetes. *Journal of Diabetes Investigation*, *13*(6), 944–946. https://doi.org/10.1111/jdi.13752
37. Wiśniowska-Szurlej, A., Ćwirlej-Sozańska, A., Kilian, J., Wołoszyn, N., Sozański, B., & Wilmowska-Pietruszyńska, A. (2021). Reference values and factors associated with hand grip strength among older adults living in southeastern Poland. *Scientific Reports*, *11*(1), 1-8. https://doi.org/10.1038/s41598-021-89408-9
38. Kovalchuk, A., Zinych, O., Kushnarova, N., Prybyla, O., & Shyshkan-Shyshova, K. (2022). Pathophysiological basis of sarcopenia— a chronic complication of diabetes. *International Journal of Endocrinology*, *18*(6), 343–350. https://doi.org/10.22141/2224-0721.18.6.2022.1205

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

COPYRIGHT