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Measurement of Handgrip Strength Between Diabetic and Non-Diabetic Patients Attending in a Tertiary Level Hospital – A Comparative Study

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Abstract

Background: Diabetes mellitus is a chronic metabolic disorder that adversely affects multiple organ systems, including muscle function. Handgrip strength (HGS) is a reliable indicator of overall muscle strength and is often reduced in diabetic individuals. This study aimed to compare HGS between diabetic and non-diabetic patients and analyze the impact of age, BMI, and gender on HGS.

Methods: This cross-sectional comparative study was conducted at the Department of Physical Medicine and Rehabilitation, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, from April 2020 to March 2021. A total of 160 participants were included, with 80 diabetic and 80 non-diabetic individuals aged 36-65 years. Handgrip strength was measured using a hydraulic hand dynamometer, and data on age, BMI, and diabetes duration were collected. Statistical analyses were performed to compare HGS between groups and assess correlations with age, BMI, and diabetes duration.

Results: Diabetic participants had significantly lower right handgrip strength (21.38 kg, SD ± 4.23) compared to non-diabetic participants (30.53 kg, SD ± 8.73) ($p < 0.001$). Left handgrip strength was also lower in diabetics (20.52 kg, SD ± 4.27) compared to non-diabetics (29.32 kg, SD ± 8.59) ($p < 0.001$). The average HGS was 20.95 kg (SD ± 4.25) in diabetics and 29.92 kg (SD ± 8.65) in non-diabetics ($p < 0.001$). Male participants exhibited higher HGS than females in both diabetic and non-diabetic groups. A significant negative correlation was observed between diabetes duration and average HGS in both male ($r = -0.709$, $p < 0.001$) and female ($r = -0.672$, $p < 0.001$) diabetic participants. Age and BMI were negatively correlated with HGS in both groups, though not statistically significant.

Conclusion: Diabetes significantly reduces handgrip strength, with a more pronounced effect observed in males. Regular assessment of HGS is crucial for early detection of muscle weakness in diabetic patients, enabling timely interventions to improve muscle function and overall quality of life. Further research is needed to develop targeted strategies to enhance muscle strength in the diabetic population.

Keywords: Diabetes mellitus; Handgrip strength; Muscle function

Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. It is primarily classified into two main types: Type 1 diabetes mellitus

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(T1DM) and Type 2 diabetes mellitus (T2DM). T1DM is an autoimmune condition leading to the destruction of insulin-producing beta cells in the pancreas, whereas T2DM is largely attributed to insulin resistance coupled with an eventual decline in insulin production. The global prevalence of diabetes has risen dramatically, with approximately 462 million individuals affected by T2DM in 2017, and projections indicating a continued rise [1]. The World Health Organization (WHO) reports that as of 2019, diabetes was the direct cause of 1.5 million deaths globally, highlighting its significant impact on global health [2]. Diabetes is associated with a myriad of complications that affect multiple organ systems. These complications include neuropathy, retinopathy, nephropathy, and cardiovascular diseases, all of which significantly impair the quality of life and increase the risk of mortality among diabetic patients. Diabetic neuropathy, in particular, is a common and debilitating complication that can lead to muscle weakness and decreased functional capacity [4]. Muscle strength is a critical component of overall health, contributing significantly to functional independence, physical performance, and quality of life. Handgrip strength (HGS) is widely recognized as a reliable indicator of overall muscle strength and function. It is simple, non-invasive, and cost-effective to measure, making it a valuable tool in both clinical and epidemiological studies. HGS has been shown to predict various health outcomes, including morbidity, disability, and mortality, particularly in older adults [4]. Lower HGS is associated with an increased risk of chronic diseases, functional limitations, and poorer recovery outcomes, making it an important marker for assessing health and physical capability [5]. Studies have consistently demonstrated that diabetic patients exhibit lower handgrip strength compared to non-diabetic individuals. This reduction in muscle strength can be attributed to several factors, including diabetic neuropathy, poor glycemic control, and muscle atrophy. For instance, individuals with long-standing T2DM were found to have significantly lower HGS, indicating the detrimental effect of prolonged hyperglycemia on muscle function [6]. Moreover, complications such as neuropathy further exacerbate muscle weakness, contributing to the observed differences in HGS between diabetic and non-diabetic populations [7]. The impact of these complications underscores the importance of monitoring muscle strength in diabetic patients to facilitate early intervention and prevent further decline in physical function. Gender differences in muscle strength are well-documented, with males typically exhibiting higher HGS than females. This difference is largely due to physiological factors such as greater muscle mass and differences in hormonal influences [8]. In diabetic populations, these gender differences may further influence the comparison of HGS between diabetic and non-diabetic groups. Studies have shown that while both male and female diabetic patients have lower HGS compared to their non-diabetic counterparts, the extent of this reduction may vary between genders [9]. For instance, diabetic men were found to have a more pronounced reduction in HGS compared to diabetic women, suggesting that gender-specific factors may modulate the impact of diabetes on muscle strength [10]. The assessment of handgrip strength in clinical practice offers significant benefits for the management of diabetic patients. As a predictive marker of health outcomes, HGS measurement can aid in the early detection of muscle weakness, enabling timely intervention and tailored rehabilitation strategies. This is particularly crucial in diabetic care, where early intervention can mitigate the progression of complications and improve overall health outcomes [11]. Incorporating HGS assessment into routine diabetic care can enhance the comprehensive management of diabetes, addressing both metabolic control and physical function to improve the quality of life for diabetic patients [12]. In conclusion, the measurement of handgrip strength provides valuable insights into the physical health and functional capacity of individuals with diabetes. Given the lower HGS observed in diabetic patients and the associated gender differences, routine assessment of muscle strength should be integrated into diabetic care protocols. This approach will enable early detection of muscle weakness, facilitate timely interventions, and ultimately enhance the overall management and quality of life for diabetic patients. The present study aims to further investigate the differences in handgrip strength between diabetic and non-diabetic patients, with a particular focus on gender differences, to inform better clinical practices and interventions.

Methods

This cross-sectional comparative study was conducted at the Department of Physical Medicine and Rehabilitation, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh. The study duration was from April 2020 to March 2021. The study population comprised individuals aged 36–65 years, including both type 2 diabetes mellitus (T2DM) patients with a diabetes duration of more than five years and non-diabetic individuals attending the department. Participants were selected based on specific inclusion and exclusion criteria to ensure the reliability of the study. For the diabetic group, inclusion criteria included subjects of either gender aged 36–65 years, diagnosed with T2DM according to the American Diabetes Association criteria, with a diabetes duration of more than five years, and being right-hand dominant [13]. Non-diabetic participants were required to be within the same age range, right-hand dominant, and free from diabetes. Exclusion criteria for both groups encompassed individuals with type 1 diabetes mellitus, T2DM patients with a duration of less than five years, those with musculoskeletal or neurological disorders, inflammatory joint diseases, connective tissue diseases, any history of trauma within the

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six months preceding the study, and individuals engaged in occupations or sports that could enhance handgrip strength. A total sample size of 160 participants was determined, with 80 individuals in each group. Purposive sampling technique was used to select participants from the outpatient department of Physical Medicine and Rehabilitation at BSMMU. Diabetic status was confirmed through self-report, physician diagnosis, use of anti-diabetic medication, fasting plasma glucose (FPG) levels of ≥126 mg/dL (7.0 mmol/L), 2-hour post-prandial plasma glucose levels of ≥200 mg/dL (11.1 mmol/L), or HbA1C levels of ≥6.5% (48 mmol/mol). In cases of hyperglycemia or hyperglycemic crisis, random plasma glucose levels of ≥200 mg/dL (11.1 mmol/L) were also considered diagnostic, requiring two abnormal test results from the same or separate samples in the absence of unequivocal hyperglycemia. Anthropometric measurements were conducted using calibrated weight scales and metal measuring tapes. Handgrip strength was assessed using the Baseline Lite Hydraulic Hand Dynamometer. Participants were seated in a straight-back chair without armrests, with feet flat on the floor. The shoulder was adducted and neutrally rotated, elbow at 90° flexion, and forearm and wrist in a neutral position. Standard verbal encouragement was provided uniformly during measurements, which were taken thrice for each hand at 30-second intervals. The average of the three measurements for each hand was calculated, and the overall handgrip strength was determined by averaging the strength of both hands. Ethical considerations were meticulously observed in accordance with the Helsinki Declaration for Medical Research Involving Human Subjects (1964). Written informed consent was obtained from all participants after thoroughly explaining the study protocol and ensuring their understanding and voluntary participation. Ethical clearance was secured from the Institutional Review Board (IRB) of BSMMU. Participants were informed of their rights to participate, refuse, or withdraw from the study at any time, and measures were taken to maintain the privacy, anonymity, and confidentiality of the data collected.

Results

The age distribution shows that within the diabetic group, 17.5% were aged 36-45, 41.3% were aged 46-55, and 41.3% were aged 56-65, with a mean age of 53.22 years (SD ± 8.08). In the non-diabetic group, 23.8% were aged 36-45, 43.8% were aged 46-55, and 32.5% were aged 56-65, with a mean age of 51.51 years (SD ± 7.41). Regarding BMI, among the diabetic participants, 28.7% had a normal BMI (18.5-24.9 kg/m²), 61.3% were overweight (25.0-29.9 kg/m²), and 10.0% were obese (≥30.0 kg/m²), with a mean BMI of 26.12 kg/m² (SD ± 2.34). For the non-diabetic participants, 37.5% had a normal BMI, 55.0% were overweight, and 7.5% were obese, with a mean BMI of 25.87 kg/m² (SD ± 2.34). The gender distribution was identical in both groups, with 50% male and 50% female participants in each group (Table 1).

Table 1: Distribution of baseline characteristics among the participants (N=160).

Baseline Characteristics	Diabetic	Non-Diabetic
	n (%)	n (%)
Age		
36-45	14 (17.5)	19 (23.8)
46-55	33 (41.3)	35 (43.8)
56-65	33 (41.3)	26 (32.5)
Mean±SD	53.22 ± 8.08	51.51 ± 7.41
BMI		
Normal (18.5-24.9 kg/m²)	23 (28.7)	30 (37.5)
Over weight (25.0-29.9 kg/m²)	49 (61.3)	44 (55.0)
Obese (≥30.0 kg/m²)	8 (10.0)	6 (7.5)
Mean±SD	26.12 ± 2.34	25.87 ± 2.34
Gender		
Male	40 (50.0)	40 (50.0)
Female	40 (50.0)	40 (50.0)

The mean fasting blood sugar level among the diabetic participants was 10.20 mmol/L (SD ± 3.45), and the mean postprandial blood sugar level was 14.80 mmol/L (SD ± 4.57). The mean HbA1c level was 8.28% (SD ± 1.55), indicating poor glycemic control among the participants. Regarding the duration of diabetes, 52.5% of the diabetic participants had been diagnosed with diabetes for 5-10 years, 18.8% for 11-15 years, 12.5% for 16-20 years, and 16.2% for more than 20 years. This distribution highlights that a significant proportion of the participants had long-standing diabetes, which may contribute to complications and impact muscle strength (Table 2).

Table 2: Distribution of diabetic participants by glycemic status and duration of diabetes (n=80).

Variables	Mean±SD/n (%)
Glycemic status	
Fasting blood sugar (in mmol/L)	10.20 ±3.45
Postprandial (in mmol/L)	14.80 ±4.57
HbA1c (in %)	8.28 ±1.55
Duration of Diabetes	
5-10 years	42 (52.5)
11-15 years	15 (18.8)
16-20 years	10 (12.5)
>20 years	13 (16.2)

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For the right hand, the mean handgrip strength among diabetic participants was 21.38 kg (SD ± 4.23), significantly lower than the non-diabetic participants, who had a mean handgrip strength of 30.53 kg (SD ± 8.73) ($p < 0.001$). Similarly, for the left hand, the diabetic group had a mean handgrip strength of 20.52 kg (SD ± 4.27), whereas the non-diabetic group had a mean handgrip strength of 29.32 kg (SD ± 8.59) ($p < 0.001$). The average handgrip strength, calculated as the mean of the right and left handgrip strengths, was also significantly lower in diabetic participants at 20.95 kg (SD ± 4.25) compared to 29.92 kg (SD ± 8.65) in non-diabetic participants ($p < 0.001$) (Table 3).

For male participants, diabetic patients had a mean right handgrip strength of 25.02 kg (SD ± 2.62), significantly lower than non-diabetic males who had a mean of 38.59 kg (SD ± 4.07) ($p < 0.001$). Similarly, the left handgrip strength for diabetic males was 24.15 kg (SD ± 2.72), compared to 37.19 kg (SD ± 4.22) for non-diabetic males ($p < 0.001$). The average handgrip strength for diabetic males was 24.58 kg (SD ± 2.66), while for non-diabetic males it was 37.89 kg (SD ± 4.13) ($p < 0.001$). For female participants, diabetic patients had a mean right handgrip strength of 17.75 kg (SD ± 1.54), significantly lower than non-diabetic females who had a mean of 22.47 kg (SD ± 2.07) ($p < 0.001$). The left handgrip strength for diabetic females was 16.90 kg (SD ± 1.59), compared to 21.43 kg (SD ± 2.05) for non-diabetic females ($p < 0.001$). The average handgrip strength for diabetic females was 17.32 kg (SD ± 1.56), while for non-diabetic females it was 21.95 kg (SD ± 2.04) ($p < 0.001$) (Table 4).

In the diabetic group, there was a negative correlation between average HGS and age ($r = -0.215$, $p = 0.056$), suggesting a trend towards reduced handgrip strength with increasing age, although this was not statistically significant. The correlation between right handgrip strength and age was also negative ($r = -0.212$, $p = 0.059$), as was the correlation for left handgrip strength with age ($r = -0.216$, $p = 0.054$). While these correlations approached statistical significance, they did not reach conventional levels of significance ($p < 0.05$). For the non-diabetic group, the correlations between average HGS and age ($r = -0.053$, $p = 0.639$), right HGS and age ($r = -0.051$, $p = 0.656$), and left HGS and age ($r = -0.056$, $p = 0.623$) were weak and not statistically significant. The correlation between BMI and average HGS in the diabetic group was also negative ($r = -0.210$, $p = 0.062$), indicating

Table 3: Comparison of study participants by handgrip strength in Kg (N=160).

Handgrip strength (Kg)	Diabetic (n=80)	Non-diabetic (n=80)	p value
	Mean ± SD	Mean ± SD	
Right	21.38 ±4.23	30.53 ±8.73	<0.001
Left	20.52 ±4.27	29.32 ±8.59	<0.001
Average	20.95 ±4.25	29.92 ±8.65	<0.001

Table 4: Comparison of handgrip strength in Kg of male and female patients (N=160).

Handgrip strength (Kg)	Diabetic (n=80)	Non-diabetic (n=80)	p value
	Mean ± SD	Mean ± SD	
Male (n=80)			
Right	25.02 ±2.62	38.59 ±4.07	<0.001
Left	24.15 ±2.72	37.19 ±4.22	<0.001
Average	24.58 ±2.66	37.89 ±4.13	<0.001
Female (n=80)			
Right	17.75 ±1.54	22.47 ±2.07	<0.001
Left	16.90 ±1.59	21.43 ±2.05	<0.001
Average	17.32 ±1.56	21.95 ±2.04	<0.001

Table 5: Correlation of average handgrip strength (HGS) in Kg with age, BMI and d of diabetic and non-diabetic study participants (N=160).

Parameter	Diabetic Group (r, p value)	Non-diabetic Group (r, p value)
Correlation with Age (Average HGS)	-0.215, 0.056	-0.053, 0.639
Correlation with Age (Right HGS)	-0.212, 0.059	-0.051, 0.656
Correlation with Age (Left HGS)	-0.216, 0.054	-0.056, 0.623
Correlation with BMI	-0.210, 0.062	-0.187, 0.108
Correlation with Diabetes Duration (Male)	-0.709, <0.001	-
Correlation with Diabetes Duration (Female)	-0.672, <0.001	-

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a trend where higher BMI might be associated with lower handgrip strength, though this was not statistically significant. In the non-diabetic group, the correlation between BMI and average HGS was similarly negative ($r = -0.187$, $p = 0.108$), but again, not statistically significant. A significant negative correlation was found between the duration of diabetes and average HGS in both male ($r = -0.709$, $p < 0.001$) and female ($r = -0.672$, $p < 0.001$) diabetic participants, indicating that longer duration of diabetes was strongly associated with lower handgrip strength in both genders (Table 5).

Discussion

This study aimed to compare handgrip strength (HGS) between diabetic and non-diabetic patients and analyze the impact of age, BMI, and gender on HGS. Our findings indicate that diabetic participants had significantly lower handgrip strength compared to non-diabetic participants. Specifically, diabetic participants had a right handgrip strength of 21.38 kg (SD ± 4.23) compared to 30.53 kg (SD ± 8.73) in non-diabetic participants ($p < 0.001$). Similarly, the left handgrip strength was 20.52 kg (SD ± 4.27) for diabetics compared to 29.32 kg (SD ± 8.59) for non-diabetics ($p < 0.001$). The average handgrip strength was significantly lower in diabetic participants at 20.95 kg (SD ± 4.25) compared to 29.92 kg (SD ± 8.65) in non-diabetic participants ($p < 0.001$). These findings are consistent with previous studies. For instance, Ezema et al. [6] reported that individuals with long-standing type 2 diabetes mellitus had significantly lower HGS, with figures of 23.0 kg in diabetics versus 32.0 kg in non-diabetics [6]. Rajput et al. [14] also found that prediabetic individuals exhibited lower HGS compared to normoglycemic controls, further highlighting the early impact of glucose metabolism disorders on muscle strength. Furthermore, the correlation of HGS with age and BMI was analyzed in our study. In the diabetic group, a negative correlation was observed between average HGS and age ($r = -0.215$, $p = 0.056$), right HGS with age ($r = -0.212$, $p = 0.059$), and left HGS with age ($r = -0.216$, $p = 0.054$), although these did not reach statistical significance. This trend is supported by Joo et al. [15], who found that lower relative handgrip strength was inversely associated with increased insulin resistance in older men without diabetes, indicating that muscle strength declines with age, affecting metabolic health [15]. In the non-diabetic group, the correlations of average HGS with age ($r = -0.053$, $p = 0.639$), right HGS with age ($r = -0.051$, $p = 0.656$), and left HGS with age ($r = -0.056$, $p = 0.623$) were weak and not statistically significant. The correlation of BMI with average HGS in the diabetic group was negative ($r = -0.210$, $p = 0.062$), as was the correlation in the non-diabetic group ($r = -0.187$, $p = 0.108$), neither reaching statistical significance. This aligns with findings by Suda et al. [16], who reported that higher BMI was associated with lower handgrip strength and increased diabetes prevalence [16]. A significant negative correlation was found between diabetes duration and average HGS in both male ($r = -0.709$, $p < 0.001$) and female ($r = -0.672$, $p < 0.001$) diabetic participants, indicating that longer diabetes duration is associated with greater muscle strength decline. This asymmetry is likely due to the greater use and training of the dominant hand in daily activities. Overall, our findings emphasize the impact of diabetes on muscle strength and the importance of monitoring handgrip strength as a simple, non-invasive indicator of muscle function. Regular assessment of handgrip strength can aid in the early detection of muscle weakness and prompt interventions to mitigate the adverse effects of diabetes on muscle health. These results underscore the need for integrated care approaches that include muscle strength assessment and tailored exercise programs to improve the quality of life for diabetic patients. This study adds to the growing body of evidence that underscores the critical role of muscle strength in managing diabetes and highlights the need for further research to develop targeted interventions that address muscle weakness in diabetic populations.

Limitations of the Study

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community.

Conclusion

This study highlights significant differences in handgrip strength between diabetic and non-diabetic individuals, underscoring the adverse impact of diabetes on muscle function. Diabetic participants exhibited significantly lower handgrip strength compared to non-diabetic counterparts, with this reduction more pronounced in males. Additionally, age and BMI were negatively correlated with handgrip strength in both groups, with diabetes duration showing a significant negative correlation with muscle strength. These findings emphasize the importance of regular assessment of handgrip strength as a simple, non-invasive tool for early detection of muscle weakness in diabetic patients. Integrating muscle strength evaluations into routine diabetic care can facilitate timely interventions, helping to mitigate muscle decline and improve overall quality of life. Further research is needed to develop targeted strategies to enhance muscle strength and functional outcomes in the diabetic population.

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References

1. Khan MAB, Hashim MJ, King JK, et al. Epidemiology of Type 2 Diabetes – Global Burden of Disease and Forecasted Trends. Journal of Epidemiology and Global Health 10 (2019): 107-11.

Nazmin S, et al., J Ortho Sports Med 2024
DOI:10.26502/josm.511500174

2. World Health Organization. Diabetes. 2023 [cited 2024 Jun 22]. Diabetes. Available from: https://www.who.int/news-room/fact-sheets/detail/diabetes

3. Kanter JE, Bornfeldt KE. Impact of Diabetes Mellitus. Arteriosclerosis, Thrombosis, and Vascular Biology 36 (2016): 1049-53.

4. McGrath RP, Kraemer WJ, Snih SA, et al. Handgrip Strength and Health in Aging Adults. Sports Med 48 (2018): 1993-2000.

5. Hetherington-Rauth M, Magalhães JP, Alcazar J, et al. Relative Sit-to-Stand Muscle Power Predicts an Older Adult's Physical Independence at Age of 90 Yrs Beyond That of Relative Handgrip Strength, Physical Activity, and Sedentary Time: A Cross-sectional Analysis. American Journal of Physical Medicine & Rehabilitation 101 (2022): 995.

6. Ezema CI, Iwelu EV, Abaraogu UO, et al. Handgrip Strength in Individuals with Long- Standing Type 2 Diabetes Mellitus: A preliminary report. African Journal of Physiotherapy and Rehabilitation Sciences 4 (2012): 67-71.

7. Bautmans I, Gorus E, Njemini R, et al. Handgrip performance in relation to self-perceived fatigue, physical functioning and circulating IL-6 in elderly persons without inflammation. BMC Geriatrics 7 (2007): 5.

8. Vianna L, Oliveira R, Araujo CG. Age-Related Decline in Handgrip Strength Differs According to Gender. Journal of strength and conditioning research / National Strength & Conditioning Association 21 (2007): 1310-4.

9. Kwak Y, Kim Y, Chung H. Sex-Associated Differences in the Handgrip Strength of Elderly Individuals. West J Nurs Res 42 (2020): 262-8.

10. Davies BN, Greenwood EJ, Jones SR. Gender difference in the relationship of performance in the handgrip and standing long jump tests to lean limb volume in young adults. Europ J Appl Physiol 58 (1988): 315-20.

11. Sipers WMWH, Verdijk LB, Sipers SJE, et al. The Martin Vigorimeter Represents a Reliable and More Practical Tool Than the Jamar Dynamometer to Assess Handgrip Strength in the Geriatric Patient. Journal of the American Medical Directors Association 17 (2016): 466.e1-466.e7.

12. Nagaoka S, Yoshimura Y, Eto T, et al. Low handgrip strength is associated with reduced functional recovery and longer hospital stay in patients with osteoporotic vertebral compression fractures: a prospective cohort study. Eur Geriatr Med 12 (2021): 767-75.

13. American Diabetes Association. 2. Classification and Diagnosis of Diabetes: Standards of Medical Care in Diabetes—2020. Diabetes Care 43 (2019): S14-31.

14. Rajput R, Garg R, Rajput M, et al. Body composition and handgrip strength in patients with prediabetes: A case-control study from Haryana, North India. Diabetes & Metabolic Syndrome: Clinical Research & Reviews 15 (2021): 823-7.

15. Joo KC, Son DH, Park JM. Association between Relative Handgrip Strength and Insulin Resistance in Korean Elderly Men without Diabetes: Findings of the 2015 Korea National Health Nutrition Examination Survey. Korean J Fam Med 43 (2022): 199-205.

16. Suda N, Manda C, Gallagher J, et al. Observational study: handgrip strength, body composition and diabetes mellitus. BMC Research Notes 14 (2021): 332.