Systematic Review of the Relationship Between Handgrip Strength and Blood Glucose Levels in Young Adults and the Elderly

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https://doi.org/10.56893/ajhes2024v03i02.08

Abstract

Background: Handgrip strength (HGS) is an indicator of overall muscle health and is affected by impaired blood glucose levels. This review discusses the relationship between HGS and blood glucose levels and provides solutions to the known problems of HGS and blood glucose regulation.

Methods: This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines. The articles were sourced from Google Scholar and PubMed. A total of 418 studies were screened, of which 19 articles were included in this study. The Newcastle–Ottawa Scale was used to assess the risk of bias.

Results: A relationship was observed between low HGS and high blood glucose levels. The suggested mechanisms involve insulin resistance, Caspase-3 activation, and the mitochondrial impact. Sarcopenia emerged as an independent risk factor for impaired glucose control. Interventions including insulin administration and exercise have been proposed to preserve muscle mass.

Conclusion: Resistance training and HGS exercises can be added to the rehabilitation practices for managing diabetes mellitus. HGS measurements are vital for predicting muscle mass loss in clinical practice.

Keywords: Handgrip strength, blood glucose, young adults, elderly, systematic review

Introduction

Handgrip strength measures the maximum force used to grip, hold, and suspend an object in one's hand (Nakandala *et al.,* 2019). It is the basis of our daily function as human beings. We use our hands daily. Blood glucose is an essential substrate for metabolism that can affect the grip strength of one's hand when not regulated or left in an uncontrollable state. Only a few attempts to link blood glucose levels with HGS have been reported. However, it is now apparent that blood glucose levels affect HGS in one way or another. An increase in blood glucose levels above the normal range can lead to hyperglycemia and subsequently diabetes mellitus.

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In contrast, an extreme decrease in blood glucose levels can lead to hypoglycemia, which is far more dangerous than hyperglycemia (Lopez *et al.,* 2014). This decrease or increase in blood glucose levels can affect HGS negatively. Handgrip strength is a significant biomarker of various diseases, including diabetes mellitus, especially type two diabetes mellitus (Van der Kooi *et al.,* 2015).

Individuals with chronic or acute diseases, such as sarcopenia, diabetes mellitus, and hypertension, may find it very difficult to perform normal day-to-day activities with their hands due to loss or reduction in muscle function. Elderly individuals are susceptible to a severe decrease in HGS with increasing age. This susceptibility is no surprise, as one is expected to lose strength as one ages. However, the symptom of low grip strength in the elderly may serve as a biomarker for underlying diseases, many of which are related to obesity and diabetes mellitus (Lee *et al.,* 2018).

Interventions such as regular physical exercise and effective blood glucose monitoring systems have been demonstrated to enhance handgrip strength (HGS) and aid in the management of conditions such as diabetes mellitus, thereby contributing to the maintenance of a normal and healthy lifestyle. Gender and dominant handedness also affect the HGS of an individual; studies show that males are likely to have a stronger HGS than females, most likely because females have more fat stores, while males have more muscle mass. The dominant hand of an individual is said to represent HGS; most times, the dominant hand of an individual has a firmer grip than the less dominant hand because the dominant hand has adapted to more work than the less dominant hand (Bardo *et al.*, 2021). This systematic review aims to link the relationship between handgrip strength and blood glucose levels.

Methods

In line with the PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 recommendations, a preliminary literature review and needs assessment were conducted using Google Scholar, PubMed, and the Prospective Register of Systematic Reviews (PROSPERO identifier: CRD42023476121), which confirmed that a similar systematic review had not been conducted in the last five years.

To assess the relationship between hand grip strength and blood glucose levels, the literature search was limited to articles selected from Google Scholar and PubMed databases. This literature search commenced on February 24, 2023, and ended on February 28, 2023. The search terms included: “association,” “correlation,” “link,” “relation,” “relationship handgrip strength,” “strength handgrip,” “hand grasps,” “muscle strength,” “hand strength,” “hypoglycemia,” “hyperglycemia,” “glycemic index,” “diabetes glycemic levels,” “blood glucose” and “blood glucose levels.” These terms were used as keywords in Google Scholar and Mesh terms in PubMed. In both databases, standard search input and advanced search input were used. Studies were selected for inclusion in this systematic review based on predetermined criteria. Articles identified through the literature search were included if they met the inclusion criteria, specifically examining the relationship between handgrip strength and blood glucose levels, either directly or indirectly, in adult populations aged ≥ 18 years. Eligible studies comprised observational reviews, original research articles, and clinical trials involving adults and elderly individuals, provided they were not duplicates.

The exclusion criteria included studies involving children or animals, absence of relevant outcomes (i.e., no stated association between handgrip strength and blood glucose levels), meta-analyses, books, and duplicate publications.

Article Screening and Selection Process

Two screening levels were used. The first was conducted by one author (S.S) with ZOTERO using (1) article title and (2) abstract review sequentially. The second was a full-text article review using predetermined Participant, Intervention, Comparison, Outcome, and Time (PICOT) criteria performed by two authors (S.S and S.O). The PICOT criteria are:

1. Participants/population: Patients or individuals with or without diabetes mellitus aged 18 and above.
2. Intervention: Handgrip strength and blood glucose level measurements.
3. Comparison: Individuals with normal glycemic levels compared to those with impaired glycemic levels.
4. Outcome: Correlation or association between handgrip strength and blood glucose level.
5. Time: Articles published between 2000 and 2023 were reviewed.

The study design is a cross-sectional, questionnaire-based, face-to-face survey case series with a sample size of≥ 10. The authors thoroughly inspected the full text of these articles to ensure that they were qualified based on the inclusion criteria. PRISMA flowchart is used to show the study selection process in Figure 1.

Quality Assessment of Studies

The Newcastle-Ottawa Scale (NOS) is used to evaluate the quality of observational research in systematic reviews and meta-analyses (such as cohort and case-control studies) (Lo *et al.*, 2014). This scale was chosen for this systematic review because the included articles were mainly observational studies. In this systematic review, 19 articles were assessed using NOS in the following domains: selection, comparability, and outcome.

For the selection domain, articles were assessed under the following subgroups: adequacy of case definition, representativeness of cases, definition, and use of controls. The maximum number of stars that could be awarded was four. The articles were critically assessed and awarded the appropriate stars. Only two stars can be obtained in the comparability domain. The 19 articles were evaluated based on the comparability of cohorts based on the study design; for most articles, the adequacy of confounding factors was graded.

In the outcome domain, where the attainment of stars is a maximum of three, the assessment of outcome (independent blind assessment, record linkage, no description), duration of follow-up for outcome to occur, and adequacy of follow-up of cohorts were assessed.

Results

An online search returned 418 citations (Figure 1). After duplicates, date, title, and abstract review, 156 articles were excluded. A full-text review of the remaining 98 publications revealed that 19 publications were eligible for inclusion. No additional articles were eligible after manual searching or snowballing. Table 1 summarizes the characteristics of the study.

Figure 1

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram showing article selection process

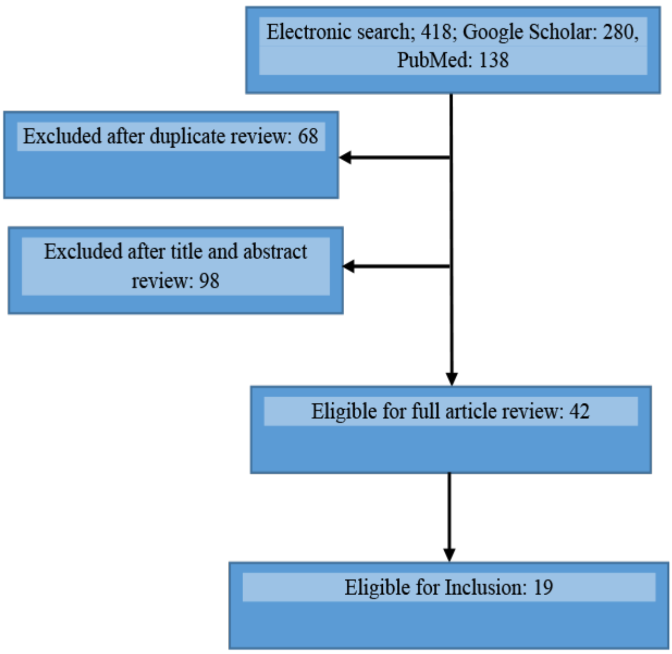

Table 1

Articles included in the Systematic Review, Characteristics, Outcome and Distribution

Reference	Country	Study design	Age	Parameters	Outcome
Aziapono et al	Nigeria	Cross-sectional	>/=18	GMS, FBS	HGS and FBS< after alcohol intake
Badawi et al	Qatar	Cross-sectional	>18	HGS. HbA1c	Relation with BG control &HGS
Darmawan et al	Indonesia	Cross-sectional	19-80	FBS, BMI , HGS	>FBS leads to a decline in HGS
Giglio et al	Brazil	Cross-sectional	18-89	HGS, BMI , BG	No HGS and FBS
Haro et al	Brazil	Cross-sectional	18-70	HGS ,ACE,AGT	-VE BG and HGS
Kaylani et al	USA	Prospective cohort	>18	FBS,OGTT,HGS	>FBS leads to a decline in HGS
Koo et al	Korea	Prospective cohort	60	HGS, HbA1c,OGTT	HGS predicts aggravated BG
Kim et al	Korea	Cross-sectional	40-92	RGS	T2DM is >in the obese and weak
Sugimoto et al	Japan	Longitudinal	>/=40	HbA1c, HGS	<in HbA1c leads to > SMI
Tianen et al	Finland	Longitudinal	>/=55	HGS,BMI,BG	T2DM predicts muscle strength
Verli et al	Brazil	NS	>18	HGS,BG	Rel between HGS &BG
Wallymahmed et al	UK	NS	18-70	HGS,HbA1c,BMI	HGS rel –VE with HbA1c
Astrom et al	Finland	Cross-sectional	62	OGTT,HGS	Low HGS in T2DM
Chang et al	Taiwan	Cross-sectional	65	HGS,BG	>HGS <risk of DM
Guiderez et al	USA	NS	>18	HGS,FBS	Low HGS predicts T2DM
Lee et al	Korea	Cross-sectional	19-80	HGS, hs-CRP	HGS relates -VE with HbA1c&BG
Liang et al	China	Cohort	>18	2HPG,HGS,BMI, RGS	FBS –VE with HGS
Qiu et al	China	Prospective cohort	>/=40	hs-CRP, HGS, HbA1C	<HGS rel hs-CRP in T2DM
Wong et al	Singapore	Cross-sectional	45-69	HGS,MSI,BMI	<MSI predicts DM

Abbreviations; NS; Not specified ,HGS; Handgrip strength, GMS; Grp muscular strength, FBS; Fasting blood sugar, OGTT; Oral glucose tolerance test, RGS; Relative grip strength ,Hs-CRP;C-reactive protein test, 2HPG;2hour postprandial glucose, BMI; Body mass index, MSI; Muscular strength index, BG; Blood glucose,HbA1c;Glycated hemoglobin, SMI: Skeletal muscle index, T2DM: Type 2 diabetes mellitus, REL: Relates.

The reviewed studies predominantly focused on individuals with diabetes because of their sustained elevation of blood glucose levels. While most agreed on the association between grip strength and blood glucose, Giglio *et a*l. introduced a conflicting view, suggesting that physical activity might modify the expected link. However, limitations, such as age adjustments and testing environment, could impact these results.

Association Between Handgrip Strength and Blood Glucose Levels

The findings consistently demonstrated a strong association between low HGS and elevated blood glucose levels, with mechanisms such as insulin resistance, mitochondrial dysfunction, and increased glycogenolysis identified as the key contributors. Sarcopenia also emerged as an independent risk factor for impaired glucose control.

Gender Disparities in Handgrip Strength and Diabetes Risk

Gender differences were evident in the studies, with men transitioning to diabetes showing marked declines in HGS, while women with lower HGS exhibited a higher risk of developing diabetes. These disparities were attributed to variations in muscle-to-fat composition and socioeconomic factors.

Interventions to Preserve Muscle Mass and Improve Glycemic Control

Resistance training and glucose-lowering therapies, including insulin administration, showed significant potential in preserving muscle mass and improving glycemic regulation. Additionally, high-sensitivity C-reactive protein (HS-CRP) was identified as a mediator in the relationship between muscle strength and T2DM.

Mechanisms Underlying the Relationship

Potential mechanisms linking HGS to blood glucose levels include Caspase-3 activation, ubiquitin-proteasome activity, and the impact of inflammatory cytokines, such as TNF-α and IL-6. These mechanisms are associated with muscle degradation and insulin resistance.

Predictive Value of Handgrip Strength

A greater HGS is associated with reduced progression from prediabetes to diabetes. Conversely, low HGS is predictive of T2DM and poor glycemic control, underscoring the utility of HGS as a biomarker for metabolic and muscular health.

Discussion

This systematic review, which was based on 19 articles, investigated the relationship between handgrip strength and blood glucose levels. The results showed a significant association.

This study illustrated the correlation between blood glucose levels and HGS, a recognized biomarker of muscle health and morbidity (Bohanon *et al.,* 2019). Most studies in this review focused on individuals with diabetes mellitus, which is characterized by persistently high blood glucose levels. This context helps to explain the observed link between blood glucose levels and handgrip strength. While most studies support a positive association between these variables, a few studies present contrasting findings. It is important to consider these different viewpoints to fully understand the complexities of the relationship between blood glucose levels and handgrip strength.

Frequent and consistent physical activity positively affects muscle health and glucose regulation (Liang *et al.,* 2020). This might explain the absence of a causal relationship between low grip strength and hyperglycemia reported by Giglio *et al.*, who did not account for age and conducted glycemic testing in parks. These factors may have contributed to the need for additional correlations.

In contrast, Astrom *et a*l. found an indirect correlation between blood glucose levels and handgrip strength, indicating that low grip strength is associated with newly diagnosed and long-term diabetes mellitus patients. This finding aligns with that of Liang *et al.* (2020), who reported decreased grip strength levels in men transitioning from normoglycemia to prediabetes and diabetes.

This review suggests that higher fasting blood glucose levels are stronger predictors of lower muscle strength than 2-hour post-challenge glucose levels, which is consistent with earlier findings by Kaylani *et al.* (2015). Gender differences were observed, as women demonstrated higher insulin sensitivity and body fat, potentially influencing BMI changes related to hyperglycemia (Liang *et al.*, 2020). Although BMI may affect blood glucose levels, Kim *et al.*[10] found that low grip strength in patients with type 2 diabetes is independent of BMI and more closely associated with lower relative grip strength, which is consistent with Karvonen-Gutierrez *et al*. (2018).

The proportion of muscle mass to fat mass that constitutes body weight is likely to be more closely associated with relative handgrip strength in this study. Relative HGS is proposed to be a more accurate evaluation of overall muscle strength, calculated by dividing absolute HGS (kg) by body weight (kg) (Kim *et al*., 2021).

Various mechanisms have been proposed to explain the link between glucose metabolism and grip strength, including Caspase-3 activation and proteolytic activation of the ubiquitin-proteasome. These are two mechanisms by which insulin resistance, a significant underlying metabolic imbalance in hyperglycemia, may cause muscle breakdown and correlate with previous findings by Li *et al.,* (2018). Second, increased glycogenolysis, which is the breakdown of glycogen stores to glucose, mainly occurring in the liver and kidney, leads to increased fasting glucose levels, which may partly contribute to the loss of muscular strength. Hyperglycemia may reduce muscular strength due to its impact on skeletal muscle mitochondria, as seen in patients with type 2 diabetes mellitus (Liang *et al*., 2020), which is consistent with the findings of Lee *et al*. (2018). Patients with type 2 diabetes have a defective bioenergetic capacity of their muscle mitochondria, and increased insulin resistance is correlated with extreme mitochondrial damage. Krüppel-like factor 15 protein, which has been shown to control skeletal muscle lipid flow and exercise adaptation, may cause hyperglycemia, resulting in a loss in muscular strength (Liang *et al.,* 2020). The link between diabetes and low muscle strength may also be caused by increased intramuscular adipose tissue and muscle atrophy, which causes insulin resistance in the skeletal muscle and adverse effects on mitochondrial activity. Reactive oxygen species are released when intramuscular adipose tissue and muscle atrophy lower skeletal muscle mitochondrial oxidative and phosphorylation activities (Li *et al*., 2018). This activity damages the muscle and impairs glucose metabolism and disposal, leading to intramuscular triglyceride accumulation due to mitochondrial damage blockade of the insulin receptor by interfering with insulin signalling pathways. The increased levels of inflammatory cytokines in hyperglycemic individuals cause irreparable damage to skeletal muscle mass, which can lead to impaired grip strength (Liang *et al*., 2020).

The findings of Chang *et al.* (2022) align with those of Liang *et al.* (2020) by demonstrating that individuals with higher grip strength tend to have lower blood glucose levels. However, Chang *et al.* specifically compared obese and non-obese individuals while also considering other metabolic factors such as lipid profiles. Notably, this study suggests that handgrip strength may have a complex relationship with lipid profiles. For instance, individuals with meager handgrip strength could exhibit a "deleterious low" lipid profile due to poor nutritional status, which is mainly observed in women. Thus, nutritional status is an essential factor that influences grip strength and blood glucose levels, potentially elucidating sex differences in these metrics.

Furthermore, a nationwide survey by Lee *et al.* corroborated the inverse correlation between low HGS and fasting glucose and insulin levels, which is consistent with the findings of Li *et al*. and Liang *et al*. The mechanisms underlying diminished muscle strength may involve elevated levels of inflammatory markers such as tumor necrosis factor-alpha (TNF-α) and IL-6 (Interleukin-6). This study corresponds to studies by Liang *et al.,* 2020, Li *et al.,* 2018, and Darmawan *et al.,* 2022.

Lee *et al.* (2018) also highlighted that hs-CRP mediates the relationship between muscle strength and type 2 diabetes, accounting for approximately 10% of the overall effect. To further elucidate this relationship, recent findings from Qiu *et al.* (2022) support the association between low HGS and hs-CRP levels in patients with T2DM. Elevated hs-CRP levels produced in the liver as an inflammation marker may indicate reduced physical activity and muscle mass due to age-related skeletal muscle impairment (Son *et al*., 2022).

Koo *et al*. (2021) identified additional risk factors for impaired glycemic control in elderly patients with long-standing

T2DM, beyond insulin resistance and low HGS. Notably, sarcopenia, a disorder characterized by reduced muscle mass, quality, and physical function, was found to be an independent risk factor for poor glycemic control. As aging further deteriorates muscle health, T2DM can exacerbate sarcopenia symptoms. These results align with the findings of Sugimoto *et al.* (2021), who demonstrated that better control of blood glucose and insulin levels can improve muscle mass and gait speed in T2DM patients. The study suggests that combining antihyperglycemic therapy and exercise may be more effective in preserving muscle mass than alone.

Medications such as GLP-1 analogs, insulin, thiazolidinediones, and DPP-4 inhibitors may help to maintain muscle mass, although their effects vary (Sugimoto *et al.,* 2021). Insulin not only aids muscle protein synthesis in the presence of amino acids, but also reduces muscle protein breakdown, helping to prevent or slow the progression of sarcopenia in diabetic individuals (Sugimoto *et al.,* 2021). These findings highlight the need for further research on the role of insulin in enhancing skeletal muscle health. A low HGS in T2DM patients is also associated with reduced muscle quality and poor glycemic control, as noted in recent studies (Tiainen *et al.,* 2022), whereas a stronger HGS has been shown to reduce the risk of developing T2DM in non-diabetic individuals (Wander *et al.,* 2011), emphasizing the importance of muscle strength in diabetes prevention.

Koo *et al.* (2021) found that the impact of muscle power on elevated glycemic levels was more pronounced in women than in men, and suggested that this may be attributed to the higher fat composition in women compared to the greater muscle mass seen in men, which aligns with the findings of Liang *et al*. They also implied that lower economic status might contribute to these sex differences, adding that women with lower economic status are more likely to develop obesity, which is a known risk factor for insulin resistance and poor glycemic control. A recent study (Wong *et al.,* 2022) also reported that women with a lower HGS had a nearly 2% higher risk of developing diabetes. Both studies (Koo *et al.,* 2021; Wong *et al.,* 2022) emphasized that resistance training could enhance muscle mass and improve insulin sensitivity by increasing GLUT-4 protein expression and insulin receptors in muscle cells, which play a crucial role in glucose metabolism.

In contrast to previous studies, Wong *et al*. found correlations between lower muscle strength and a combined ratio of upper and lower muscle strength (muscle mass index) correlated more with HGS than when assessed independently in midlife women, implying that not only the upper limbs are affected but also the lower limbs in women and may serve as an explanation for why sex differences are noted between males with impaired glucose regulation and poor grip strength (Wong *et al.,* 2022).

Qiu *et al*. (2022) investigated the relationship between muscle strength (HGS and chair rising time) and changes in glycemic status among middle-aged and older women. Specifically, they examined the likelihood of progression from prediabetes to diabetes and the potential for regression to normoglycemia. Prediabetes, characterized by elevated blood glucose levels that do not meet the threshold for diabetes, was assessed using glycated hemoglobin (HbA1c) levels (Tiainen *et al.,* 2022). The study found that higher HGS was associated with lower odds of progression from prediabetes to diabetes. However, increased HGS did not significantly enhance the likelihood of regression from prediabetes to normoglycemia. These results align with previous research, which suggest that greater muscle strength may support better glucose regulation and metabolic health.

Qiu *et al.* (2022) highlighted the progression of muscle strength loss in older adults with T2DM and prediabetes, showing a decline from normoglycemia to prediabetes and diabetes. These results align with the study by Tianien *et al.* However, unlike Qiu *et al*., Tianien *et al.* observed that women do not experience a significant decline in muscle strength across these stages. This difference may be attributed to women with diabetes being more likely to adopt effective lifestyle modifications such as dietary changes and exercise, which can mitigate muscle strength loss. Additionally, physiological changes associated with menopause, such as alterations in the metabolic profile, body composition, and fat distribution, might also influence muscle mass and strength in older women, indicating that menopause could be critical in maintaining HGS among older women with glycemic impairments, warranting further investigation.

Most studies in this systematic review provided evidence linking blood glucose levels and HGS, mainly through mechanisms associated with T2DM without much emphasis on T1DM. Wallymahmed *et al*. (2007) suggested a relationship between T1DM, aerobic exercise, and glycemic control, indicating that individuals with better aerobic capacity sometimes experience poorer glycemic control. This could be because individuals with T1DM may intentionally maintain higher blood glucose levels during exercise to avoid hypoglycemia, which can occur during or after physical activity. In contrast, studies on T2DM, such as that by Kim *et al*. (2021), have shown a positive correlation between aerobic capacity and glycemic control. This discrepancy underscores the complexity of managing glycemic levels through physical activity in different types of diabetes. While physical activity is generally recommended for weight loss and metabolic management in patients with diabetes, it is important to clarify how it affects glycemic control, especially in T1DM. Given the observational nature used by Wallymahmed *et al*. (2007), interpretations should be cautious. Nonetheless, it highlights the need for further research on the interaction between physical activity and glycemic control in T1DM patients.

An important finding by Verli *et al*. (2021) suggested that carbohydrate

(CHO) intake before exercise reduced perceived fatigue in Brazilian Jiu-Jitsu (BJJ) athletes. Specifically, CHO consumption thirty minutes before exercise led to higher blood glucose levels, positively impacting HGS. This timing may be optimal for CHO absorption, particularly for short, intense physical activities, such as BJJ. CHO serves as a key energy source for muscle contractions, enhancing glycogen stores and maintaining metabolic balance. The study also suggested a positive relationship between blood glucose levels and HGS, potentially due to increased glucose availability. These findings could guide future research and have practical applications in clinical settings such as hypoglycemia management during exercise. However, further studies are needed to determine the precise mechanisms underlying this relationship and confirm the benefits of CHO intake on HGS in different contexts.

Conclusion

Although several studies have shown a link between handgrip strength and diabetes mellitus, the exact causal connection remains unknown. Insulin resistance caused by lipids is reduced by sustained exercise and training, which may be associated with greater muscular strength. However, inflammation, which is also a significant element brought about by insulin resistance, may be the cause of decreased muscular strength. To ascertain the causal connection between handgrip strength and blood glucose levels, further mechanistic research and experiments are required. Prospective trials are also required to determine the efficacy of strength training as a T2DM prevention and treatment strategy. We recommend incorporating rehabilitation interventions for individuals with T2DM and hand dysfunction. These interventions may target and improve grip strength and overall glucose regulation.

Study Limitations

This systematic review sheds new light on the relationship between handgrip strength and blood glucose level. Covering studies from 2007 to 2022, our findings confirm a significant link between handgrip strength and blood glucose levels. This review has implications for clinical practice and suggests avenues for further research, particularly for managing conditions such as diabetes and sarcopenia.

Despite its strengths, our study has several limitations. The use of the NOS method revealed some studies with fair ratings, indicating a degree of bias risk. The focus on adults and the elderly restricts broad generalizations about age groups, and reliance on small sample sizes and questionnaires introduces potential inaccuracies.

Nevertheless, this review underscores the importance of maintaining blood glucose levels and lays the groundwork for future investigations into improving muscle strength and glucose regulation in patients with dysglycemia or low muscle strength. It also offers valuable insights for clinicians, physiotherapists, and nutritionists to enhance clinical practice and overall health outcomes.

Suggestions for Future Research

We suggest that more studies should use diabetic animal models to study this correlation, followed by a muscle-strengthening intervention using limb exercise aimed at increasing grip strength in mice while maintaining blood glucose levels. In addition, a longitudinal study spanning more than 10 years is recommended to investigate the handgrip strength of children aged 5–10 years with both T1DM and T2DM.

Declaration

We used Grammarly and ChatGPT to improve the grammar, style, clarity, and readability of this manuscript. These tools assisted in the drafting and editing process; however, all final interpretations, conclusions, and editorial decisions are the authors' sole responsibility.

Conflict of Interest: None declared

Financial Support: None

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