African Scientist Vol. 25, No. 1 March 31, 2024
Printed in Nigeria

1595-6881/2023 $80.00 + 0.00

https://africansciientistjournal.org

AFS2024008/25105

Handgrip Strength as a Screening Tool for Diabetes in Resource-Constrained Settings: A Potential Solution to Overcome Barriers to Diagnosis

Lekan Sheriff Ojulari[1*], Swabirah Enimire Sulaiman[1], Taofeek Olanrewaju Ayinde[1], Eniola Riskat Kadir[2], Aishah Abubakar[3]

[1]Department of Physiology, University of Ilorin, Ilorin, Nigeria.
[2]Department of Anatomy, University of Ilorin, Ilorin, Nigeria.
[3]Department of Physiology, University of Maiduguri, Nigeria.

*Corresponding author Email: ojulari.ls@unilorin.edu.ng, Tel: +234 (0) 803 242 9067

(Received February 23, 2024; Accepted in revised form March 12, 2024)

ABSTRACT: Diabetes mellitus is an escalating global health concern, especially in low and middle-income countries. Handgrip strength (HGS), a measure of muscle strength, emerges as a potential non-invasive and affordable screening tool for diabetes, particularly in areas with limited healthcare access. This study aimed to investigate the relationship between HGS and blood glucose regulation in non-diabetic young adults and to provide valuable insights into the potential of HGS as a preventive and affordable approach to managing diabetes. An observational study was conducted on a group of Nigerian students aged 18-21 using cross sectional design. HGS was measured with a dynamometer, and its links to blood glucose markers (fasting blood glucose, 2 hour postprandial glucose, and HbA1c) were explored using multiple regression models. Findings revealed significant associations between HGS and glucose regulation markers, particularly FBS, among males. The relationship was evident in females after adjusting for body mass index (BMI). A notable relationship between HGS and 2 hour postprandial glucoselevels was observed in females but not in males. No significant associations were found between HGS and serum insulin levels across genders. Our study introduces HGS as a practical, cost-effective screening tool for blood glucose regulation disorders in resource-constrained settings.

Keywords: Handgrip strength, Blood glucose regulation, Diabetes, 2 hour postprandial glucose

Introduction

Diabetes mellitus is a global health concern, with a rapid increase in diagnosed cases and a projected rise to 625 million adults affected by 2045, primarily in low and middle-income countries (Laukkanen *et al.*, 2020; Kunutsor *et al.,* 2020; Cho *et al.,* 2018). Managing diabetes comes with substantial lifetime medical costs, especially for complications, with Africa expected to bear a significant burden despite low contributions to global diabetes care expenses (Mapa-Tassou *et al.*, 2019). In 2017, the International Diabetes Federation estimated diabetes-related health expenditure at $3.3 billion, with Nigeria alone incurring direct costs ranging from $1.071 billion to $1.639 billion (Mapa-Tassou *et al.,* 2019). In the United States, diabetes is a leading cause of death, contributing to 69,091 deaths and impacting an additional 234,051 deaths (Kunutsor and Laukkanen, 2016).

In resource-constrained settings, obstacles like difficult access to healthcare and expensive transportation frequently cause patients to put off receiving treatment. To close this gap, trained volunteers known as Community Health Workers (CHWs) provide vital healthcare and education to underserved rural communities in developing countries (Newman *et al.*, 2006). As expensive tools like blood glucometers may go unused owing to budget restrictions and safety concerns surrounding blood samples, CHWs require accessible and inexpensive biomedical tools for effective sickness detection and diagnosis (Eckman *et al.*, 2016). An alternative screening tool that shows promise in resource-constrained settings is handgrip strength, a simple measure of muscle strength that correlates well with other strength measures, such as quadriceps strength (Newman *et al.*, 2006). Handgrip strength has been associated with metabolic syndrome, type 2 diabetes mellitus, and overall mortality (Kawamoto *et al.*, 2016, Leong *et al.*, 2015, Celis-Morales *et al.*, 2018). It indicates overall strength and physical activity level, as it measures the force produced by the muscles controlling the hand using a hand dynamometer (Chang *et al.,* 2010).

Studies have investigated resistance exercises' positive impact on glucose metabolism, improving muscle function and insulin-mediated glucose uptake in skeletal muscle, although the exact mechanism is not fully understood (Reichkendler *et al.,* 2013). Considering its relevance to diseases like diabetes, malnutrition, and functional disability, handgrip strength testing with affordable and durable hand dynamometers has gained prominence. With limited access to healthcare in nations like Nigeria, this strategy offers a preventive and economical way to control diabetes (Eckman *et al.*, 2016). By utilizing handgrip strength as a screening tool, barriers to diagnosis, such as high costs and limited access to healthcare professionals, can be overcome, facilitating early identification and intervention in high-risk populations.

Materials and methods

Participants: One hundred students from the University of Ilorin, Nigeria, were initially recruited for this study. Recruitment was conducted through advertisements on social platforms, and participants were selected on a "first come" basis. Due to incomplete data, information from only fifty-nine recruited students was used for the final computation and analysis of results.

Inclusion criteria: The data collected for this study included currently enrolled students aged 18-30 years who exhibited normoglycemia, with fasting blood glucose levels ranging from 70-100 mg/dL. Participants were also required to have no significant health conditions or physical impairments that could affect their grip strengths or fasting blood glucose levels.

Exclusion criteria: Students with missing information, a history of elevated blood glucose or a diagnosis of diabetes, and those who were unwilling or unable to undergo handgrip strength measurements as part of the study protocol were excluded from the analysis.

Ethical approval: Ethical approval was obtained from the University of Ilorin Teaching Hospital Research Ethics Committee**,** Ilorin, Kwara State, with the reference number UITH/CAT/189/VOL.21^{B} /486. An informed consent was also obtained from each of the research subjects.

Dependent variables: This study's dependent variables were glycaemic control and insulin resistance among non-diabetic students. As indicators, glycaemic control was assessed using glycated haemoglobin (HbA1C), fasting blood glucose, and 2-hour postprandial blood glucose. Plasma glucose was measured using a modified hexokinase enzymatic method, serum insulin was determined by radioimmunoassay, and glycated haemoglobin was assayed using high-performance liquid chromatography (Ruhl and Everhart, 2000). An HbA1C above 7% and a 2 hour postprandial glucose greater than 140 mg/dL indicate poor glycaemic control (Bell, 2001). A fasting serum insulin above 10 µIU/mL was diagnostic of insulin resistance (ADA, 2014).

Independent variables: Handgrip strength was measured using a Jamar J00105 hydraulic hand dynamometer. Isometric grip force was assessed from single maximal grip efforts of the right and left sides with participants seated upright with their elbow by their side flexed at 90° so that their forearm was facing forward and resting on an armrest. The dynamometer was adjusted to the participant's hand size. Moreover, if participants could not perform the grip strength test due to existing health issues, these data were excluded from the analyses. The average value recorded from the right and left hand was expressed in absolute (kilograms) and relative units (kilogram of grip strength divided by kilogram of body weight) and used for subsequent analyses (Boonpor *et al.,* 2021).

Anthropometric measurements were obtained by trained personnel following standard operating procedures and using calibrated equipment (UK-Biobank, 2007). Weight was measured without shoes and outdoor clothing using the Tanita BC 418 body composition analyser. Height was measured without shoes using the wall-mounted SECA 240 height measure. Body mass index (BMI) was calculated from weight (in kilograms) divided by the square of height (in meters). Using a non-elastic SECA 200 tape measure, waist circumference was measured midway between the lowest rib margin and the iliac crest in a horizontal plane, while hip circumference was measured at the point where the buttocks extended the most (Boonpor *et al.,* 2021).

Co-variates: The covariates in this study included sociodemographic characteristics, lifestyle factors, and self-reported family history of diseases. Sociodemographic characteristics covered age (years, continuous), gender (male/female), country, and ethnicity. Lifestyle factors included self-reported exercise, drinking and smoking status.

Statistical analysis: A cross-sectional analysis was conducted and recorded as means (standard deviations) for continuous variables and frequencies for categorical variables. Differences between groups were assessed using ANOVA or chi-square tests for continuous or categorical variables. Multiple linear regression models were used to examine the association between glucose regulation and grip strength. IBM SPSS Statistics Version 25.0 (IBM Corp., Armonk, New York, USA) was used for all statistical analyses.

Results

General clinical characteristics of the study population: Overall, data of 59 subjects (30 males = 50.8 % and 29 females = 49.2%, with a mean age of 18 to 21 years) were used for this study. Dominant HGS ranged from 11.5 - 29.8 kg with an interquartile range (IQR) of 18.4 – 25.1 kg (6.7 kg) in females and from 15.0 – 33.2 kg with an IQR of 21.6 – 27.4 kg (5.8 kg) in males (Table 1).

Table 1: Sample clinical characteristics and biomarkers showing mean, quartiles, interquartile range and standard deviation of continuous variables and percent (%) if categorical variables (n=59).

	Mean	**Median**	**Min**	**Max**	**25%**	**75%**	**Interquartile Range (%)**	**Std Dev**
HGS Right Hand (kg)	22.95	22.70	11.50	33.2	20.1	26.2	6.1	4.534
HGS Left Hand (kg)	21.46	21.20	13.80	31.80	18.2	24.9	6.7	4.543
Absolute HGS (kg)	46.22	45.60	28.40	67.80	41.4	52.4	11.0	8.706
Relative HGS (m^2)	2.13	2.12	0.98	3.81	1.82	2.39	0.57	0.520
BMI (Kg/m^2)	22.32	22.00	15.40	38.6	19.4	23.8	4.4	4.304
Waist/Hip Ratio	0.79	0.80	0.70	1.1	0.7	0.80	0.1	0.078
Pulse Pressure (mmHg)	49.34	49.00	30.0	68	43.0	57.0	14.0	9.278
Fasting Blood Glucose (mmol/L)	4.86	4.80	3.60	6.4	4.5	5.3	0.8	0.560
HbA1C (%)	3.73	3.42	0.51	8.58	2.87	4.59	1.72	1.396
2 hour postprandial glucose (mmol/L)	5.20	5.20	3.90	7.6	4.5	5.7	1.2	0.779
Serum Insulin (µIU/L)	18.86	14.09	5.88	158.55	10.58	19.59	9.01	20.522
	N	**(%)**						
Gender								
Male	30	50.8						
Female	29	49.2						
Age								
18-21	19	32.2						
22-25	38	64.4						
26-30	2	3.4						
Smokes								
Yes	0	0.0						
No	59	100.0						
Alcohol Intake								
Yes	6	10.2						
No	53	89.8						
Does Exercise								
Yes	29	49.2						
No	30	50.8						
Hand Dominance								
Right	51	86.4						
Left	8	13.6						

BMI denotes body mass index
HbA1C denotes glycated haemoglobin
HGS denotes Handgrip strength

Clinical characteristics and biomarkers by sex: In this study, HGS < 18kg was defined as low while HGS >18kg was defined as normal, fasting blood sugar between 3.9-5.9mmom/l and 2HPG < 7.8 mmol/l was defined as the normal range of blood glucose levels. HGS values recorded from study subjects were within the normal range, with a mean of 21.07 kg and 18.70 kg for dominant and non-dominant hands, respectively.

The dominant HGS in females (mean = 21.4 ± 4.53) was significantly reduced (p = 0.005) when compared to males (mean = 24.6 ± 4.06; Table 2). Non-dominant HGS ranged from 13.8 - 25.8 kg with an interquartile range (IQR) of 15.7 – 21.2 kg (5.5 kg) in females and from 14.7 – 31.8 kg with an IQR of 20.5 – 26.1 kg (5.6 kg) in males. The non-dominant HGS in females (mean = 18.9 ± 3.61) was significantly reduced (*p* = 0.001) when compared to males (mean = 24.0 ± 4.09; Table 2).

Table 2: Clinical characteristics and biomarkers by sex

	Males		**Females**		
	Mean	**Std Dev**	**Mean**	**Std Dev**	***p* value**
HGS Right Hand (kg)	24.62	4.06	21.37	4.53	0.008
HGS Left Hand (kg)	24.01	4.09	18.97	3.61	0.000
Absolute HGS (kg)	4975	8.27	42.87	7.99	0.003
Relative HGS (m^2)	2.37	0.61	1.93	0.40	0.003
BMI (Kg/m^2)	21.59	3.47	22.85	5.13	0.357
Waist/Hip Ratio	0.82	0.06	0.77	0.09	0.020
Pulse Pressure (mmHg)	53.65	8.02	44.55	8.14	0.000
Fasting Blood Glucose (mmol/L)	4.69	0.64	5.01	0.44	0.042
HbA1C (%)	3.81	1.24	3.61	1.56	0.519
2 hour postprandial glucose (mmol/L)	5.15	0.75	5.22	0.83	0.818
Serum Insulin (µIU/L)	17.40	8.76	15.65	9.01	0.449
	N = 30	**%**	**N = 29**	**%**	
Age					
18-21	6	20.0	13	44.83	
22-25	23	77.0	15	51.72	
26-30	1	3.0	1	3.45	
Smokes					
Yes	0	0.0	0	0.00	
No	30	100.0	29	100.00	
Alcohol Intake					
Yes	1	3.3	5	17.24	
No	28	93.4	24	82.76	
Missing	1	3.3	0	0.00	
Does Sports					
Yes	19	63.3	10	34.48	
No	11	36.7	19	65.52	
Hand Dominance					
Right	27	90.0	25	86.21	
Left	3	10.0	4	13.79	

BMI denotes body mass index
HbA1C denotes glycated haemoglobin
HGS denotes handgrip strength
Values of absolute handgrip strength were calculated by summation of dominant and non-dominant handgrip strength.
Values of relative handgrip strength were calculated from absolute handgrip strength divided by body mass index.

Gender disparities in handgrip strength within the study population: In both sexes, there was significant differences (female *p* = 0.03 & male *p* = 0.04) (Figure 1) in HGS between in both hands, suggesting that hand dominance could be a relevant factor in this study. Therefore, the results of dominant and non-dominant HGS were also considered independently (Table 3).

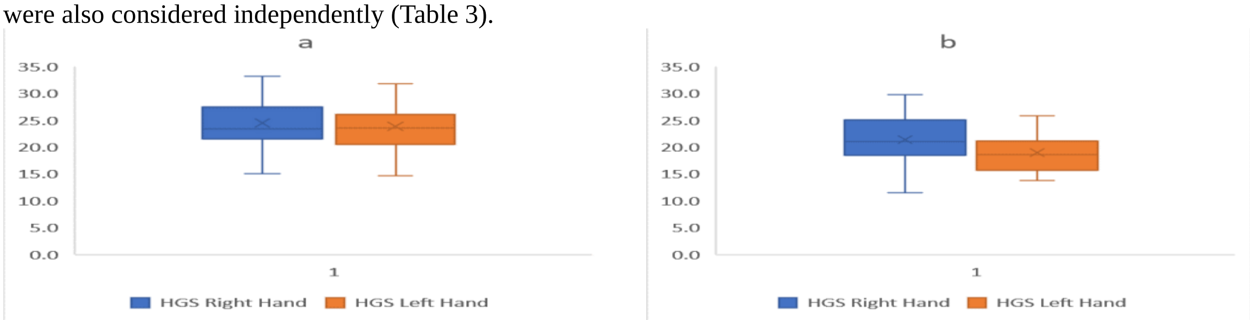

Figure 1: Boxplots comparing handgrip strength in both dominant and non-dominant hands in both male (a) and female (b) subjects. Mean HGS in males was 24.47 ± 4.05 and 23.86 ± 4.07 in both right and left hands, respectively; and in females was 21.37 ± 4.53 and 18.97 ± 3.61 in both right and left hands, respectively. The difference was statistically significant at *p*-value 0.03 and 0.04 between hands in females and males, respectively.

Table 3: Results of multiple linear regression of handgrip strength (dominant and non-dominant) on blood glucose regulation biomarkers

	Male Handgrip Strength				**Female Handgrip Strength**			
	Dominant		**Non-dominant**		**Dominant**		**Non-dominant**	
	Estimate (SE)	***P***	**Estimate (SE)**	***P***	**Estimate (SE)**	***P***	**Estimate (SE)**	***P***
Fasting Blood Glucose	0.3758 (0.59)	0.04	0.3941 (0.61)	0.07	0.3218 (0.42)	0.09	0.2330 (3.58)	0.22
2 Hour Postprandial Glucose	0.1117 (0.76)	0.55	0.1049 (0.76)	0.57	0.3407 (0.78)	0.07	0.3887 (3.39)	**0.04**
HbA1C	0.0184 (1.26)	0.92	0.1277 (1.25)	0.57	0.0587(1.58)	0.76	0.2090 (3.60)	0.28
Serum Insulin	0.2303 (8.82)	0.22	0.2226 (8.83)	0.22	0.0846 (9.14)	0.66	0.0678 (28.48)	0.73

Multiple regression analysis examined the relationships between handgrip strength and the blood glucose regulatory markers, specifically fasting blood glucose, 2 hours postprandial glucose, HbA1C and serum insulin levels. Four different models were tested to account for potential confounders: Model 1 (no adjustments), Model 2 (adjusted for Waist Hip Ratio), Model 3 (adjusted for BMI), and Model 4 (adjusted for both WHR and BMI) (Tables 4, 5 and 6).

Table 4: Results of multiple regression of absolute handgrip strength and relative handgrip strength on blood glucose regulation biomarkers

	Absolute Handgrip Strength				**Relative Handgrip Strength**			
	Male		**Female**		**Male**		**Female**	
	Estimate (SE)	*P*	Estimate (SE)	*P*	Estimate (SE)	*P*	Estimate (SE)	*P*
Fasting Blood Glucose	0.322 (0.62)	0.09	0.319 (0.42)	0.08	0.139 (0.64)	0.46	0.08 (0.45)	0.68
2 hour postprandial glucose	0.067 (0.76)	0.72	0.396 (0.77)	0.03	0.287 (0.73)	0.12	0.284 (0.80)	0.14
HbA1C	0.088 (1.25)	0.64	0.085 (1.58)	0.66	0.335 (1.19)	0.07	0.303 (1.51)	0.11
Serum Insulin	0.232 (8.67)	0.21	0.102 (9.12)	0.59	0.227 (8.68)	0.22	0.079 (9.14)	0.68

SE denotes standard error. HbA1C denotes glycated haemoglobin

Table 5: Adjusted relationships of handgrip strength with blood glucose regulatory markers (males n=29).

	Fasting Blood Glucose		**2-Hour Postprandial**		**HbA1C**		**Serum Insulin**	
	Estimate (SE)	***P***	**Estimate**	***P***	**Estimate**	***P***	**Estimate**	***P***
Absolute HGS								
Model 1[a]	0.3755 (0.59)	0.04	0.1133 (0.76)	0.55	0.0560 (1.26)	0.77	0.2318 (8.82)	0.22
Model 2[b]	0.4543 (0.58)	0.04	0.2511 (0.75)	0.42	0.2165 (1.26)	0.52	0.3694 (8.58)	0.14
Model 3[c]	0.5311 (0.56)	0.01	0.4231 (0.70)	0.07	0.3239 (1.22)	0.22	0.2435 (8.95)	0.44
Model 4[d]	0.5465 (0.56)	0.03	0.4311 (0.71)	0.14	0.3392 (1.23)	0.36	0.3707 (8.74)	0.27
Relative HGS								
Model 1[a]	0.0436 (0.64)	0.82	0.2223 (0.74)	0.24	0.2947 (1.21)	0.11	0.2408 (8.79)	0.20
Model 2[b]	0.2408 (0.64)	0.45	0.2769 (0.75)	0.34	0.3248 (1.22)	0.22	0.3406 (8.68)	0.19

Note: Boldface indicates statistical significance (p<0.05). SE denotes standard error. HbA1C denotes glycated haemoglobin

[a] Multiple Linear regression analysis [b] Adjusted for Waist hip ratio (WHR)

[c] Adjusted for Body mass index (BMI) [d] Adjusted for WHR and BMI

Table 6: Adjusted relationships of handgrip strength with blood glucose regulatory markers (females n=30).

	Fasting Blood Glucose		**2 Hour Postprandial Glucose**		**HbA1C**		**Serum Insulin**	
	Estimate (SE)	P	Estimate	P	Estimate	P	Estimate	P
Absolute HGS								
Model 1[a]	0.319 (0.42)	0.08	0.396 (0.77)	**0.03**	0.085 (1.58)	0.66	0.102 (9.12)	0.59
Model 2[b]	0.3683 (0.42)	0.15	0.4243 (0.77)	0.08	0.1553 (1.59)	0.73	0.1671 (9.21)	0.69
Model 3[c]	0.4641 (0.40)	**0.04**	0.4336 (0.77)	0.07	0.4801 (1.42)	**0.03**	0.1037 (9.29)	0.87
Model 4[d]	0.4872 (0.41)	0.08	0.4541 (0.78)	0.12	0.4866 (1.44)	0.08	0.1672 (9.39)	0.87
Relative HGS								
Model 1[a]	0.0800 (0.45)	0.68	0.2840 (0.80)	0.14	0.3030 (1.51)	0.11	0.0790 (9.14)	0.68
Model 2[b]	0.1626 (0.45)	0.71	0.3291 (0.81)	0.23	0.3176 (1.53)	0.25	0.1567 (9.23)	0.72

Note: Boldface indicates statistical significance (p<0.05). SE denotes standard error. HBA1c denotes glycated haemoglobin

[a] Multiple Linear regression analysis [b] Adjusted for Waist hip ratio (WHR)

c Adjusted for Body mass index (BMI) d Adjusted for WHR and BMI

Summary Description of Findings from Study Population

Findings in males and females: While still maintaining normal ranges in the blood regulatory markers (FBS, 2 hour postprandial glucose and HbA1C) serum insulin levels were slightly elevated in both sexes (male: 17.40 ± 8.76; female: 15.65 ± 9.01).
Fasting blood glucose: In males, a notable finding emerged as absolute handgrip strength was consistently linked to fasting blood glucose levels across all models ($p < 0.05$), irrespective of adjustments made for WHR and BMI (Table 5). This association persisted, highlighting the robustness of the relationship. In contrast, among females, absolute HGS was only found to be associated to blood glucose levels following adjustments to BMI (Model 3; Table 6).
2 hour postprandial glucose: The investigation into the relationships between handgrip strength and 2 hour postprandial glucose levels showed a significant ($p < 0.05$) association in females. Notably, no significant relationships were observed in males.
HbA1C: For females, an interesting finding emerged in Model 3, where adjustments were made for BMI. A significant positive relationship was observed between absolute HGS and HbA1C levels. Of note is that this association was not observed in males or in other models.
Serum insulin: Irrespective of gender, our analyses found no significant associations between HGS and serum insulin levels across all models tested.

Discussion

Our research reveals complex relationships between handgrip strength and blood indicators for diabetes, including fasting glucose, HbA1C, and serum insulin. Notably, even when other regulatory indicators were normal, increased blood insulin levels were seen in both male and female subjects.
Our study highlights a strong and consistent correlation between handgrip strength and fasting blood glucose levels in males, even considering factors like waist-hip ratio and BMI. This suggests handgrip strength is a reliable marker for glucose metabolism in males. However, in females, the connection is evident only after accounting for BMI, indicating that body composition influences this relationship.
The results for males are consistent with previous studies highlighting the impact of enhanced muscle metabolism and testosterone levels on insulin sensitivity (Srikanthan and Karlamangla, 2011; Pitteloud *et al.*, 2005). Testosterone has been shown to promote muscle glucose uptake and function (Griggs *et al.*, 1989), making muscles a vital site for glucose absorption. A stronger handgrip may indicate better neuromuscular junction efficiency, potentially influencing metabolic processes like glucose regulation (Deschenes, 2011).
In females, the relationship between handgrip strength (HGS) and glucose metabolism appears complex. The findings suggest that factors like body fat percentage, typically higher in females (Goodpaster *et al.*, 2006), may confound the HGS-glucose metabolism connection. Increased adiposity has been linked to insulin resistance and glucose disruption (Petersen and Pedersen, 1985). After adjusting for BMI, the relationship becomes significant, highlighting the potential mediation of body composition, especially fat mass, in this connection. Adipose tissue's role as an endocrine organ releasing factor, including adipokines, can influence insulin sensitivity and glucose metabolism (Grontved *et al.*, 2015), with implications for insulin resistance pathogenesis.
In line with Niemann *et al*. (Niemann *et al.*, 2020) our study revealed no direct link between handgrip strength and serum insulin levels. However, Lazarus *et al.* (Lazarus *et al.*, 1997), reported a modest correlation, indicating the variability of this relationship across different populations and methodologies. Although stronger muscles might be expected to enhance glucose uptake and influence insulin levels, our results suggest complex physiological mechanisms are at play. Factors like fasting, trauma, and certain diseases influence skeletal muscle mass balance, which can accelerate muscle protein breakdown. Insulin, a pivotal hormone, regulates this process by influencing key proteins such as FOXO transcription factors (O˙Neil *et al.*, 2010).
We identified a notable association between handgrip strength and 2-hour post-prandial glucose levels, but this was evident only in females and not males. A similar study by Huang in 2023 emphasised that the effect of handgrip strength on Type 2 Diabetes Mellitus could be influenced by factors such as BMI and gender (Huang *et al.,* 2023). This gender divergence in results underlines the need to consider gender-specific physiological pathways when using handgrip strength as a diabetes screening tool.
For females, the significant correlation may be attributed to the role of estrogen, which is known to modulate muscle function and insulin sensitivity. Research conducted by Chidi-Ogbolu and Baar (Chidi-Ogbolu and Baar, 2019) and Camporez *et al*., 2013 (Camporez *et al*., 2013), provides evidence to support this claim, suggesting that oestrogen may have the ability to improve glucose uptake in muscles when insulin is present (Jang *et al*., 2020).

On the other hand, the relationship in males is more intricate due to testosterone's fluctuating effects on insulin sensitivity. While testosterone's influence on muscle strength is well-documented, its impact on insulin sensitivity can vary based on age and general health. This observation aligns with findings by Dhindsa and co-workers (2018) complicating the establishment of a direct link between handgrip strength and post-prandial glucose levels in males.

Our study's salient observation is the link between handgrip strength and HbA1C levels, especially when considering BMI. Similarly, Mainous *et al*. (2015) highlighted that handgrip strength negatively correlated with HbA1C levels, strengthening the credibility of HbA1C as a marker for prolonged glucose control.

The association between muscle, fat tissue, and glucose regulation is persistent, indicating the importance of handgrip strength as a potential indirect indicator of long-term glycemic control in areas with limited resources. This assertion is consistent with the findings of Jang *et al*. (2020) who explored the relationship between relative handgrip strength and prediabetes based on HbA1C levels and emphasised the significance of sex differences.

Conclusion

The results of this study show that handgrip strength can be a useful measure for determining diabetes risk and directing prompt treatment. By incorporating HGS evaluations into healthcare, exercise-based programs can help individuals control their blood sugar levels. HGS is a cheap, non-invasive screening technique that is especially helpful for community health workers in areas with limited resources. In developing nations, it can close diagnostic gaps and reduce budgetary constraints. The study's limitations, including its small sample size and concentration on students, call for more research in order to expand its application.

Acknowledgements

We thank all the participants and research staff of the Physiology Laboratory of the University of Ilorin, Nigeria, for their helpful cooperation in this study.

References

American Diabetes Association (ADA): Diagnosis and classification of diabetes mellitus: Diabetes Care, 37 Suppl 1: S81-90. 2014.

Bell DS: Importance of postprandial glucose control. South Med J, 94(8): 804–9. 2001.

Boonpor J, Parra-Soto S, Petermann-Rocha F, Ferrari G, Welsh P, Pell JP, Sattar N, Gill JM, Ho FK, Gray SR, Celis-Morales C: Associations between grip strength and incident type 2 diabetes: findings from the UK Biobank prospective cohort study. BMJ Open Diabetes Res. Care, 9(1):e001865. 2021.

Camporez JPG, Jornayvaz FR, Lee HY, Kanda S, Guigni BA, Kahn M, Samuel VT, Carvalho CR, Petersen KF, Jurczak MJ, Shulman GI: Cellular mechanism by which estradiol protects female ovariectomized mice from high-fat diet-induced hepatic and muscle insulin resistance. Endocrinology, 154(3): 1021–8. 2013.

Celis-Morales CA, Welsh P, Lyall DM, Steell L, Petermann F, Anderson J, Iliodromiti S, Sillars A, Graham N, Mackay DF, Pell JP: Associations of grip strength with cardiovascular, respiratory, and cancer outcomes and all-cause mortality: prospective cohort study of half a million UK Biobank participants. bmj 361: k1651. 2018.

Chang HY, Chou KY, Lin JJ, Lin CF, Wang CH: Immediate effect of forearm kinesiotaping on maximal grip strength and force sense in healthy collegiate athletes. Phys. Ther. Sport, 11(4): 122–7. 2010.

Chidi-Ogbolu N, Baar K: Effect of estrogen on musculoskeletal performance and injury risk. Front Physiol, 9: 1834. 2019.

Cho NH, Shaw JE, Karuranga S, Huang Y, da Rocha Fernandes JD, Ohlrogge AW, Ohlrogge AW, Malanda BI.IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. Diabetes Res Clin Pract, 138: 271–81. 2018.

Deschenes MR: Motor unit and neuromuscular junction remodeling with aging. Curr Aging Sci, 4(3): 209–20. 2011.

Dhindsa S, Ghanim H, Batra M, Dandona P: Hypogonadotropic hypogonadism in men with diabetes and obesity. Diabetes Care, 41(7): 1516–25. 2018.

Eckman M, Gigliotti C, Sutermaster S, Butler PJ, Mehta K: Using handgrip strength to screen for diabetes in developing countries. J Med Eng Technol, 40(1): 8–14 2016.

Goodpaster BH, Park SW, Harris TB, Kritchevsky SB, Nevitt M, Schwartz AV, Simonsick EM, Tylavsky FA, Visser M, Newman AB: The loss of skeletal muscle strength, mass, and quality in older adults: the health, aging and body composition study. J Gerontol. A Biol Sci Med Sci, 61(10): 1059–64. 2006.

Griggs RC, Kingston W, Jozefowicz RF, Herr BE, Forbes G, Halliday D: Effect of testosterone on muscle mass and muscle protein synthesis. J Appl Physiol Bethesda Md, 1985. 66(1): 498–503. 1989.

Grøntved A, Ried-Larsen M, Møller NC, Kristensen PL, Froberg K, Brage S, Andersen LB: Muscle strength in youth and cardiovascular risk in young adulthood (the European Youth Heart Study). Br J Sports Med, 49(2): 90–4. 2015.

Huang Q, Chen X, Shen HY, Zhou JM, Zhang HQ, Wang L, Chen R, Cheng J, Zhang Y, Zhang DM, Chen GM: Gender-specific association of handgrip strength with type 2 diabetes mellitus in Chinese Han older adults. Diabetes Metab Syndr Obes Targets Ther, 16: 913–23. 2023.

Jang BN, Nari F, Kim S, Park EC: Association between relative handgrip strength and prediabetes among South Korean adults. PLoS ONE, 15(10): e0240027. 2020.

Kawamoto R, Ninomiya D, Kasai Y, Kusunoki T, Ohtsuka N, Kumagi T, Abe M: Handgrip strength is associated with metabolic syndrome among middle-aged and elderly community-dwelling persons. Clin Exp Hypertens N Y N, 1993. 38(2): 245–51. 2016.

Kunutsor SK, Laukkanen JA: Serum zinc concentrations and incident hypertension: new findings from a population-based cohort study. J Hypertens, 34(6): 1055–61. 2016.

Kunutsor SK, Voutilainen A, Laukkanen JA: Handgrip strength improves prediction of type 2 diabetes: a prospective cohort study. Ann Med, 52(8): 471–8. 2020.

Laukkanen JA, Voutilainen A, Kurl S, Araujo CGS, Jae SY, Kunutsor SK: Handgrip strength is inversely associated with fatal cardiovascular and all-cause mortality events. Ann Med, 109. 52: 3–4. 2020.

Lazarus R, Sparrow D, Weiss ST: Handgrip strength and insulin levels: cross-sectional and prospective associations in the normative aging study. Metabolism, 46(11): 1266–9. 1997.

Leong DP, Teo KK, Rangarajan S, Lopez-Jaramillo P, Avezum A, Orlandini A, Seron P, Ahmed SH, Rosengren A, Kelishadi R, Rahman O: Prognostic value of grip strength: findings from the prospective urban rural epidemiology (PURE) study. Lancet Lond Engl, 386(9990): 266–73. 2015.

Mainous AG, Tanner RJ, Anton SD, Jo A: Grip strength as a marker of hypertension and diabetes in healthy weight adults. Am J Prev Med, 49(6): 850–8. 2015.

Mapa-Tassou C, Katte JC, Mba Maadjhou C, Mbanya JC: Economic impact of diabetes in Africa. Curr Diab Rep, 19(2): 5. 2019.

Newman AB, Kupelian V, Visser M, Simonsick EM, Goodpaster BH, Kritchevsky SB, Tylavsky FA, Rubin SM, Harris TB: Strength, but not muscle mass, is associated with mortality in the health, aging and body composition study cohort. J Gerontol. A Biol Sci Med Sci, 61(1): 72–7. 2006.

Niemann MJ, Tucker LA, Bailey BW, Davidson LE: Strength training and insulin resistance: the mediating role of body composition. J Diabetes Res, 2020: 7694825. 2020.

O'Neill ED, Wilding JPH, Kahn CR, Van Remmen H, McArdle A, Jackson MJ, Close GL: Absence of insulin signalling in skeletal muscle is associated with reduced muscle mass and function: evidence for decreased protein synthesis and not increased degradation. Age, 32(2): 209–22. 2010.

Petersen AMW, Pedersen BK: The anti-inflammatory effect of exercise. J Appl Physiol Bethesda Md, 1985. 98(4): 1154–62. 2005.

Pitteloud N, Mootha VK, Dwyer AA, Hardin M, Lee H, Eriksson KF, Tripathy D, Yialamas M, Groop L, Elahi D, Hayes FJ: Relationship between testosterone levels, insulin sensitivity, and mitochondrial function in men. Diabetes Care, 28(7): 1636–42. 2005.

Reichkendler MH, Auerbach P, Rosenkilde M, Christensen AN, Holm S, Petersen MB, Lagerberg A, Larsson HB, Rostrup E, Mosbech TH, Sjödin A: Exercise training favors increased insulin-stimulated glucose uptake in skeletal muscle in contrast to adipose tissue: a randomized study using FDG PET imaging. Am J Physiol Endocrinol Metab, 2013 305(4): E496-506. 2010.

Ruhl CE, Everhart JE: Association of diabetes, serum insulin, and c-peptide with gallbladder disease. Hepatology, 31(2): 299–303. 2000.

Srikanthan P, Karlamangla AS: Relative muscle mass is inversely associated with insulin resistance and prediabetes. Findings from the third national health and nutrition examination survey. J Clin Endocrinol Metab, 96(9): 2898–903. 2011.

UK Biobank: Protocol for a large-scale prospective epidemiological resource. Available: http://www. ukbiobank. ac. uk/ wp-content/ uploads/ 2011/ 11/ UK- Biobank- Protocol. pdf. 2007. 1-112.