

Grip Strength and Anthropometric Characteristics among Hispanic Children and Adolescents with Obesity and Insulin Resistance

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Objective: The objectives of this study were: 1) to describe and evaluate associations between grip strength, and anthropometric characteristics in pediatric patients with obesity and insulin resistance (IR), and 2) to compare IR using the HOMA-IR model and fasting insulin level.

Methods: Secondary data analysis was conducted using results from 41 children and adolescents with obesity and IR (18 boys and 23 girls, mean age: 14.4 ± 3.1 years) enrolled in a clinically supervised weight management program. Independent t-tests were conducted to detect sex differences, and correlation analyses to determine associations between variables.

Results: Mean body mass index (BMI) was above the 99th percentile, with 109.6 ± 19.7 cm waist circumference, $45.6 \pm 6.7\%$ body fat, 59.9 ± 15.7 kg lean mass, 91.8 ± 8.9 mg/dL fasting glucose, 36.9 ± 31.5 μ U/m fasting insulin, 8.6 ± 1.2 HOMA-IR, and 30.2 ± 9.0 kg grip strength. Boys had greater height, fasting glucose, and lean mass compared to girls. There was a significantly high correlation ($r=0.98$, $P<0.0001$) between fasting insulin and HOMA-IR. Grip strength was not associated with insulin and HOMA-IR. However, grip strength relative to lean mass inversely correlated with waist circumference, percent body fat, and BMI percentile.

Conclusion: Fasting insulin and HOMA-IR do not appear to influence grip strength in the group of children and adolescents with obesity and IR in this study. However, grip strength was significantly influenced by anthropometric characteristics. The use of a fasting insulin cutoff at or above 12μ U/mL appears appropriate to detect insulin resistance in this pediatric group.

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Key words: Muscle strength, Insulin resistance, Lean mass, Waist circumference

Adequate muscle strength is associated with improved posture, reduced risk of musculoskeletal injury, greater bone mass, enhanced glucose uptake, potential increases in resting metabolic rate, and better body weight control across children, adolescents, and adults (1). Isometric muscle action assessed with hand-held dynamometers provides evidence of musculoskeletal changes linked to diabetes, frailty, premature mortality, and cognitive impairment (2). Yu et al. (3) reported that grip strength increases with age and that boys aged 12 years and older exhibit greater grip strength than girls of the same age. In pediatric populations, lower grip strength has been observed in children with obesity or excess body fat. Yu et al. (3) also documented that children with high body fat have significantly lower grip strength (18.0 ± 0.5 kg) compared with those with lower body fat (20.3 ± 1.0 kg).

Pediatric obesity is a major global public health concern. According to the World Health Organization (4), in 2022, more than 390 million children and adolescents aged 5-19 years were overweight or obese, with prevalence rising from 8% in 1990 to 20% in 2022. In the United States, approximately one-third of children and youth are overweight and obese, a condition closely linked to insulin resistance (IR) and type 2 diabetes (5).

Skeletal muscle accounts for more than 75% of insulin-mediated glucose disposal, and clinical studies indicate that IR is primarily determined by skeletal muscle responses to insulin (6). When cells

do not respond normally to insulin, the pancreas compensates by producing more insulin, but glucose disposal remains impaired, leading to elevated blood glucose and progression to prediabetes and type 2 diabetes. IR often presents without symptoms, though some children develop acanthosis nigricans, a thick, dark, velvety skin patches typically found on the neck and armpits (5).

IR is strongly associated with body mass index (BMI) and percent body fat, with higher IR observed in youth with obesity compared to normal-weight peers (6). Increased visceral adipose tissue further exacerbates IR and reduces acute insulin response. Although IR is commonly linked to obesity, it can also occur in people without obesity (6).

There is still no consensus on standardized criteria for diagnosing IR in pediatric populations. Physical signs such as acanthosis nigricans increase suspicion but do not confirm IR (6). To assess IR, Carrasco et al. (7) used the homeostasis model assessment (HOMA) with the formula: fasting glucose (mg/dL)

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x fasting insulin ($\mu\text{U}/\text{mL}$) / 405. Although widely used, HOMA-IR lacks universally accepted pediatric cut-off points. McAuley et al. (8) suggested that a fasting insulin level of 12.2 $\mu\text{U}/\text{mL}$ is a practical threshold for IR diagnosis, corresponding to a HOMA-IR of approximately 2.5 when assuming a fasting glucose of 85 mg/dL. IR is recognized as a common pathway for glucose metabolism disorders, dyslipidemia, and hypertension (9).

Grip strength has been inversely correlated with IR and impaired glucose metabolism in adolescents, suggesting that improved muscle fitness may benefit early prevention of IR and type 2 diabetes (10, 11). While studies have examined grip strength in children with obesity, evidence remains limited for those with both obesity and IR, where metabolic and neuromuscular function may be affected (11, 12). Therefore, this study aimed to describe and evaluate the association between grip strength and anthropometric characteristics in pediatric patients with obesity and IR; and to compare the use of the HOMA-IR and fasting insulin levels for detecting IR in this population.

Materials and Methods

This retrospective cohort study included pediatric patients with obesity and IR treated between 2020 and 2024 in the Mi Meta weight and health program at the *Centro de Diabetes y Endocrinología Pediátrica de Puerto Rico* (CDEP) in Bayamón, Puerto Rico. Eligibility criteria for program enrollment were: BMI $\geq 95^{\text{th}}$ percentile, or a BMI $\geq 85^{\text{th}}$ percentile with weight-related comorbidity (e.g., diabetes, thyroid dysfunction, heart disease), and family support, motivation, and commitment to a 12-month intervention. Each new patient provided a physician referral, growth charts, psychosocial questionnaires, documentation of previous weight-control attempts, and laboratory results. After completing all requirements, an initial visit was scheduled. Participants and their parents received detailed explanations of all evaluations.

For this secondary analysis, de-identified data from the CDEP database were used. The final sample included 41 participants (18 boys and 23 girls) aged 8 to 19 years. The study was approved by the Institutional Committee for the Protection of Human Subjects in Research (CIPSHI) of the University of Puerto Rico, Río Piedras Campus.

Anthropometric and physiological measurements

Height was measured in cm using a SECA 216 stadiometer, with participants standing barefoot, shoulders relaxed, heels and buttocks against the vertical bar, and head facing forward. Weight was measured in kg using a calibrated SECA 704 scale, with participants barefoot and wearing light clothing. These measurements were used to calculate BMI (kg/m^2). BMI percentiles were determined using the Center for Disease Control and Prevention (CDC) growth charts covering from the 50th percentile to the 190th percentile (13). Waist circumference was measured in cm by placing the anthropometric tape at the midpoint between the last floating rib and the upper edge of the iliac crest during a normal exhalation. Percent body fat and lean mass were assessed via bioelectrical impedance analysis (BIA) using the InBody 570 (InBody, South Korea) (14). Tests were performed in a

fasting state, with prior instructions to avoid intense exercise and maintain hydration the day before the test.

Grip strength was measured using a TAKEI Tkk-5001 hand grip dynamometer (TAKEI, Japan). After identifying the dominant hand, adjusting the handlebar grip size, and performing a short warm up with fist tightening and releasing movements; participants performed three trials holding the arm at 90-degree elbow angle, with 1-minute rest between attempts. The maximum value in kg from the dominant hand was used for analyses. Fasting glucose and insulin were obtained after 8-12 hours of fasting duration from external laboratories within 1-3 weeks prior to the first visit. Insulin values $\geq 12 \mu\text{U}/\text{mL}$ and a HOMA-IR ≥ 2.5 were used to identify IR.

Physical activity was assessed using a GT3X+BT accelerometer (Amerits, Pensacola, FL) worn on the hip for 24 hours/day over eight consecutive days, excluding day one to reduce reactivity bias. Devices were initialized to collect data at a rate of 90 Hz, and data was downloaded using ActiLife software (v.6.11.6, Amerits, Pensacola, FL). Moderate to vigorous physical activity (MVPA) was obtained using the Evenson et al. (15) algorithm.

Statistical analysis

Descriptive statistics (mean, proportions, standard deviation) were calculated for variables. Independent t-test assessed sex differences. Pearson correlations and linear regressions examined association between insulin, grip strength, and anthropometric measures. Statistical analyses were performed using STATA 15.1 software (StataCorp LLC), with significance set at alpha less than 0.05.

Results

All participants exhibited fasting insulin levels above 12 $\mu\text{U}/\text{mL}$, and a HOMA-IR values above 2.5, confirming insulin resistance. Table 1 summarizes anthropometric and body composition, blood glucose, insulin, HOMA-IR, grip strength, and MVPA by sex. Boys had significantly greater height, lean mass, and fasting glucose compared to girls. The mean BMI percentile indicated severe obesity, averaging 141.3% above the 95th percentile. MVPA was markedly low, averaging 11.7 min/day, far below the recommended 60 min/day (16).

Fasting glucose correlated positively with fasting insulin ($r = 0.34$, $R^2 = 0.11$, $P = 0.03$) and HOMA-IR ($r = 0.48$, $R^2 = 0.23$, $P = 0.001$). Fasting insulin and HOMA-IR were strongly correlated ($r = 0.98$, $R^2 = 0.95$, $P < 0.0001$).

Absolute grip strength showed no significant correlation with fasting insulin ($r = -0.08$, $P = 0.62$), HOMA-IR ($r = -0.07$, $P = 0.66$), or percent body fat ($r = 0.26$, $P = 0.11$). However, grip strength relative to body weight and lean mass demonstrated significant inverse correlations with percent body fat ($r = -0.64$, $R^2 = 0.41$, $P < 0.0001$; $r = -0.52$, $R^2 = 0.27$, $P = 0.0008$) and BMI percentile (Figures 1 and 2), indicating that higher adiposity and BMI percentile were associated with lower relative grip strength.

Waist circumference did not correlate with HOMA-IR ($r = 0.21$, $P = 0.19$) but was strongly associated with BMI percentile ($r = 0.75$, $R^2 = 0.56$, $P < 0.0001$) and absolute grip strength ($r = 0.41$, $R^2 = 0.16$, $P = 0.009$). When grip strength was adjusted for lean mass, the relationship became inverse ($r = -0.33$, $R^2 = 0.11$,

Table 1. Anthropometric, metabolic and grip strength characteristics (mean \pm SD).

Variables	All (n=41)	Girls (n=23)	Boys (n=18)	P
Age (years)	14.4 \pm 3.1	14.4 \pm 3.3	14.4 \pm 3.0	0.999
Weight (kg)	104.0 \pm 31.5	100.9 \pm 35.5	108.0 \pm 25.9	0.477
Height (cm)	163.1 \pm 12.7	159.5 \pm 12.9	167.8 \pm 11.2	0.035
BMI (kg/m ²)	38.4 \pm 8.6	38.6 \pm 9.8	38.2 \pm 7.1	0.869
BMI >95 percentile (%)	141.3 \pm 27.3	136.8 \pm 26.4	147.0 \pm 28.2	0.242
Waist circumference (cm)	110.4 \pm 19.8	105.7 \pm 20.9	116.4 \pm 16.9	0.084
Waist to hip ratio	0.67 \pm 0.10	0.67 \pm 0.07	0.67 \pm 0.12	0.846
Body fat (%)	46.0 \pm 6.6	47.3 \pm 5.6	44.3 \pm 7.5	0.157
Lean mass (kg)	60.0 \pm 15.9	52.5 \pm 14.1	69.6 \pm 12.8	<0.001
Glucose (mg/dL)	92.2 \pm 8.9	89.4 \pm 9.6	95.8 \pm 6.5	0.020
Insulin (μ U/mL)	38.3 \pm 31.6	37.5 \pm 29.6	39.3 \pm 34.8	0.856
HOMA-IR	8.9 \pm 8.1	8.8 \pm 8.9	9.1 \pm 7.4	0.896
Dominant grip strength (kg)	30.2 \pm 9.2	27.9 \pm 7.5	33.2 \pm 10.1	0.062
Non-dominant grip strength (kg)	29.3 \pm 10.3	27.8 \pm 9.8	33.2 \pm 10.9	0.299
Dominant grip strength relative to body weight	0.22 \pm 0.08	0.21 \pm 0.07	0.24 \pm 0.10	0.303
Non-dominant grip strength relative to body weight	0.29 \pm 0.09	0.28 \pm 0.08	0.30 \pm 0.10	0.636
Dominant grip strength relative to lean body mass	0.51 \pm 0.13	0.54 \pm 0.11	0.48 \pm 0.14	0.130
Non-dominant grip strength relative to lean body mass	0.49 \pm 0.14	0.53 \pm 0.13	0.45 \pm 0.14	0.076
Moderate to vigorous physical activity (min/week)	82.0 \pm 85.2	84.7 \pm 96.6	78.7 \pm 71.3	0.829

Note: BMI = Body mass index, HOMA-IR = homeostatic model assessment - insulin resistance.

P=0.03; Figure 3), suggesting that greater waist circumference is linked to lower grip strength relative to lean mass.

Discussion

This study aimed to examine the relationship between grip strength, insulin and HOMA-IR levels, and anthropometric measures in children and adolescents with obesity and IR. Participants exhibited severe obesity and low physical activity, with an average body fat of 46%, BMI 141% above the 95th percentile, and only 82 minutes per week of MVPA. Additionally, waist circumference values exceeded the 90th percentile (17), and the mean waist-to-height ratio of 0.67 was well above the recommended 0.45, confirming a high prevalence of abdominal obesity (18).

Grip strength, a recognized marker of overall muscle strength in pediatric populations (19), was comparable to values reported in other studies

of similar age groups (20, 21). Contrary to previous findings that boys typically exhibit higher grip strength than girls (18), no significant sex differences were observed in absolute grip strength or grip strength relative to body weight and lean mass. Notably, grip strength relative to body weight (0.22 kg for the dominant hand and 0.29 kg for the non-dominant hand) was substantially lower than the 0.46 kg observed in non-obese populations (22), highlighting the impact of excess weight on functional strength.

Consistent with prior research (23), grip strength was positively associated with lean mass ($r = 0.60$, $R^2 = 0.36$, $P < 0.0001$). Few studies have reported grip strength relative to lean mass, which in this study were 0.51 kg for the dominant hand and 0.49 kg for the non-dominant hand. Inverse correlations between grip strength relative to lean body mass and both BMI percentile and percent body fat suggest that higher relative strength is associated with lower adiposity. These findings align with evidence that fat mass negatively impacts grip strength, whereas lean mass exerts a positive effect (23). Given that skeletal muscle accounts for 75% to 95% of insulin-mediated glucose disposal (6), reductions in muscle mass and function might contribute to IR. However, no significant associations were found between absolute or relative grip strength and fasting insulin or HOMA-IR, possibly

Figure 1. Association between grip strength relative to lean body mass and percent body fat (95% CI: -42.7, -12.2).

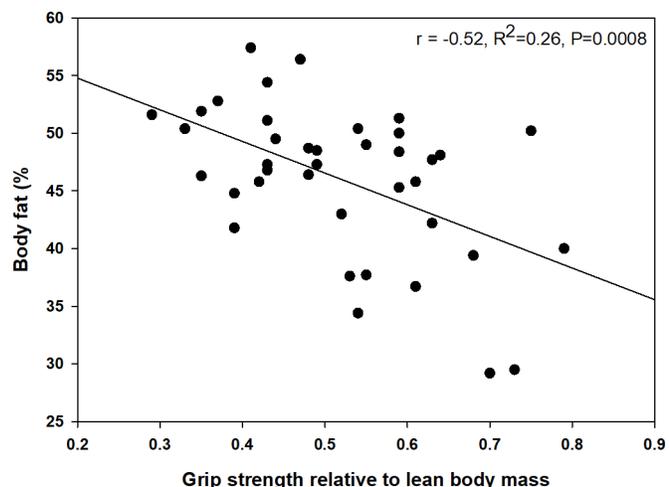


Figure 2. Association between grip strength relative to lean body mass and BMI percentile (95% CI: -159.6, -33.3).

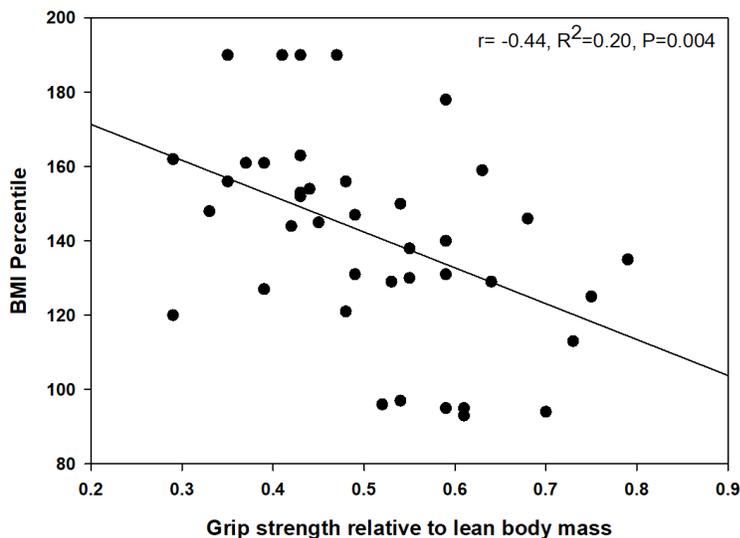
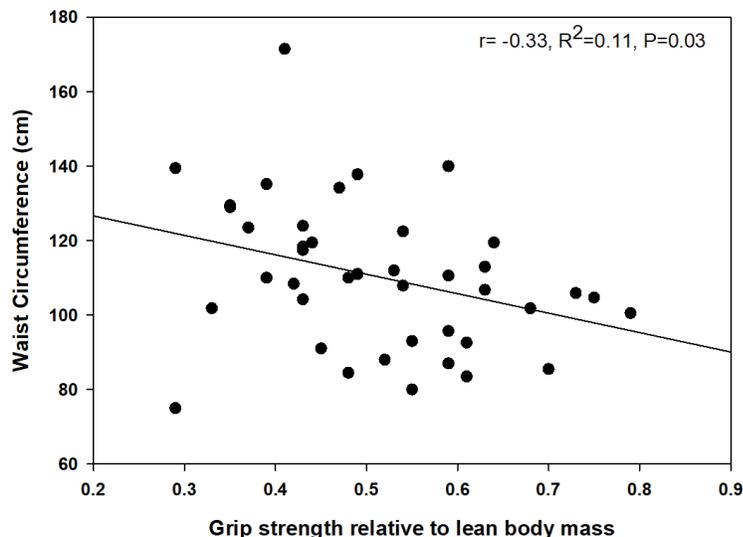


Figure 3. Association between grip strength relative to lean body mass and waist circumference (95% CI: -100.5, -4.1).



due to limited variability in insulin levels as all participants exhibited elevated fasting insulin and HOMA-IR indicative of IR.

Interestingly, absolute and relative to lean mass grip strength were significantly correlated with waist circumference. Central adiposity is metabolically detrimental, characterized by increased lipolysis, IR, and free fatty acid release (24). The positive association between absolute grip strength and waist circumference suggest that greater abdominal fat might be linked to greater absolute strength, likely reflecting higher overall body mass. Conversely,

the inverse relationship between grip strength relative to lean mass and waist circumference underscores the importance of muscle quality rather than absolute strength in mitigating the adverse effects of abdominal obesity (25, 26). These findings reinforce the clinical relevance of assessing central obesity, and highlight the potential benefits of interventions aimed at preserving or increasing lean mass to improve metabolic health.

A notable contribution of this study is the confirmation of the fasting insulin cutoff of 12 $\mu\text{U}/\text{mL}$ as a marker of IR in pediatric populations, consistent with a HOMA-IR threshold of 2.5 (9). Limitations include the absence of a comparison group without IR, lack of data on dietary intake, socioeconomic status, duration of obesity, and relatively small sample size, which may limit generalizability. Future studies should address these factors and explore longitudinal associations between muscle strength, body composition, and metabolic outcomes.

In summary, while grip strength was not associated with IR markers, it was significantly related to anthropometric measures, particularly waist circumference. Children with obesity demonstrated similar absolute grip strength to peers without obesity but exhibited lower strength relative to body weight, a finding of clinical importance given that low muscle strength in childhood predicts low strength in adulthood (27). These results underscore the need for strategies that enhance muscular fitness and preserve lean mass as part of a comprehensive obesity and metabolic disease management.

Resumen

Objetivo: Los objetivos de este estudio fueron: 1) describir y evaluar la asociación entre fuerza de agarre y características antropométricas en pacientes pediátricos con obesidad y resistencia a insulina (RI), y 2) comparar la RI utilizando el modelo HOMA-IR y la insulina en ayuno. **Métodos:** Análisis secundario de datos de 41 niños y adolescentes con obesidad y RI (18 niños y 23 niñas, edad promedio: 14.4 ± 3.1 años) en un programa clínico de manejo de peso. Se realizaron pruebas t-independiente para detectar diferencias por sexo y análisis de correlación para determinar asociación entre variables. **Resultados:** En promedio, el índice de masa corporal (IMC) estuvo sobre el percentil 99, la circunferencia de cintura en 109.6 ± 19.7 cm, $45.6 \pm 6.7\%$ de grasa, 59.9 ± 15.7 kg de masa magra, 91.8 ± 8.9 mg/dL de glucosa y 36.9 ± 31.5 $\mu\text{U}/\text{mL}$ de insulina, 8.6 ± 1.2 de HOMA-IR y 30.2 ± 9.0 kg de fuerza de agarre. Los

niños tuvieron mayor estatura, glucosa, masa magra y fuerza de agarre que las niñas. Se observó una correlación alta entre insulina en ayuno y HOMA-IR ($r=0.98$, $P<0.0001$). No hubo asociación entre fuerza de agarre, insulina y HOMA-IR. Sin embargo, la fuerza de agarre correlacionó inversamente con la circunferencia de cintura, porcentaje de grasa y percentil de IMC. Conclusión: El nivel de insulina y HOMA-IR no parecen influir la fuerza de agarre en los niños y adolescentes con obesidad y RI. Sin embargo, las características antropométricas influyen la fuerza de agarre. Una insulina en ayuno de $12 \mu\text{U/mL}$ es un corte apropiado para detectar RI en este grupo pediátrico.

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