Asociación entre la fuerza prensil relativa de la mano y la obesidad abdominal, la diabetes de tipo 2 y la hipertensión en una población Mexicana

Association between relative handgrip strength and abdominal obesity, type-2 diabetes and hypertension in a Mexican population

Association between relative handgrip strength and abdominal obesity, type-2 diabetes and hypertension in a Mexican population

Asociación entre la fuerza prensil relativa de la mano y la obesidad abdominal, la diabetes de tipo 2 y la hipertensión en una población Mexicana

Iris Paola Guzmán-Guzmán[1], Pedro Delgado-Floody[2], Ilse Adriana Gutiérrez-Pérez[3], Felipe Caamaño-Navarrete[4], Daniel Jerez-Mayorga[5], Óscar Zaragoza-García[3], and Isela Parra-Rojas[1]

[1]Facultad de Ciencias Químico-Biológicas. Universidad Autónoma de Guerrero. Chilpancingo, Guerrero. Mexico. [2]Department of Physical Education, Sport, and Recreation. Universidad de La Frontera. Temuco, Chile. [3]PhD Program in Biomedical Science. Facultad de Ciencias Químico-Biológicas. Universidad Autónoma de Guerrero. Chilpancingo, Guerrero. Mexico. [4]Facultad de Educación. Universidad Católica de Temuco. Temuco, Chile. [5]Facultad de Ciencias de la Rehabilitación. Universidad Andrés Bello. Santiago, Chile

Correspondence: Iris Paola Guzmán-Guzmán. Facultad de Ciencias Químico-Biológicas. Universidad Autónoma de Guerrero. Lázaro Cárdenas, El Centenario. 39086 Chilpancingo de los Bravo, Guerrero. Mexico
e-mail: pao_nkiller@yahoo.com.mx

ABSTRACT

Background: handgrip strength (HGS) is a health-status parameter associated with multicomorbidity in the adult population.

Objective: the aim of the present study was to determine the association between HGS (i.e., absolute and relative) and abdominal obesity (AO), type-2 diabetes (T2D), and hypertension (HT), as well as to determine the association between low relative HGS with the presence

of multicomorbidity (i.e., the co-occurrence of two or more comorbidities together) in a Mexican population.

Methodology: a cross-sectional study was carried out in 860 participants from the south of Mexico (661 women and 199 men). The age range evaluated was from 18 to 65 years. Assessments were made of sociodemographic data, clinical history, anthropometric parameters, and measurement of maximal HGS.

Results: the regression models adjusted by age show that the presence of comorbidities (i.e., AO, HT and T2D) was linked negatively to HGS (i.e., absolute and relative). Moreover, in men, a low relative HGS in both hands reported an association with the presence of three simultaneous comorbidities (right, RR: 17.2, p < 0.001; left, RR: 11.92, p = 0.020). In women the same association was found (right, RR: 10.42, p < 0.001; left, RR: 9.90, p < 0.001).

Conclusion: lower levels of relative HGS were linked to the presence of simultaneous comorbidities (i.e., the joint presence of AO, T2D and HT). Furthermore, HGS (i.e., absolute and relative) presented an inverse association with individual anthropometric and clinical parameters related to cardiovascular risk in the Mexican population.

Keywords: Handgrip strength. Abdominal obesity. Type-2 diabetes. Hypertension. Multicomorbidity.

RESUMEN

Introducción: la fuerza prensil de la mano (FPM) es un parámetro asociado con la multicomorbilidad en la población adulta.

Objetivo: el objetivo del presente estudio fue determinar la asociación entre la FPM (absoluta y relativa) y la obesidad abdominal (OA), la diabetes de tipo 2 (DT2) y la hipertensión (HT), así como su asociación

con la multicomorbilidad (co-occurrencia de dos o más comorbilidades conjuntas) en una población mexicana.

Metodología: se presenta un estudio transversal realizado en 860 participantes del sur de México (661 mujeres y 199 hombres). El rango de edad de los participantes fue de 18 a 65 años. Se evaluaron las características sociodemográficas de la población, los parámetros clínicos y antropométricos, y la medición de la FPM máxima.

Resultados: los resultados demostraron una asociación entre la disminución de la FPM (absoluta y relativa) y la presencia de comorbilidades (OA, DT2 e HT). En los hombres, la disminución de la FPM relativa reportada en ambas manos se asoció con la presencia simultánea de tres comorbilidades (derecha, RR: 17,2, $p < 0,001$; izquierda, RR: 11,92, $p = 0,020$). Se observó una asociación similar también en las mujeres (derecha, RR: 10,42, $p < 0,001$; izquierda, RR: 9,90, $p < 0,001$).

Conclusión: los bajos niveles de FPM relativa se asocian con la presencia simultánea de comorbilidades (presencia conjunta de OA, DT2 y HT). Además, la FPM (absoluta y relativa) se relaciona negativamente con los parámetros clínicos y antropométricos relacionados con el riesgo cardiovascular en la población mexicana.

Palabras clave: Fuerza prensil de la mano. Obesidad abdominal. Diabetes de tipo 2. Hipertensión. Multicomorbilidad.

INTRODUCTION

Skeletal muscle strength is a predictor of all causes of mortality; higher levels of upper- and lower-body muscular strength are associated with a lower risk of mortality (1) related to several medical conditions such as cardiovascular disease (CVD) and cancer, amongst others (2).

Particularly, handgrip strength (HGS) is a health status marker (3). This represents a simple parameter, convenient, and fast for the assessment of total muscle strength that, nevertheless, may vary depending on age and health status (4). The cutoff points of HGS for low muscle strength in men and women vary between populations. HGS has shown a correlation with anthropometric parameters such as weight and height, and has been used to form indexes with the maximal HGS (5). In recent studies, relative HGS, defined as absolute HGS divided by BMI (HGS/BMI), showed a stronger correlation with cardiovascular biomarkers, thus muscle strength adjusted for BMI has been recommended to minimize the confounding effect of body size (6,7). By itself, in older adults, low HGS is a biomarker for sarcopenia and functional limitations (8,9). In addition, HGS levels can be an effective screening tool for CVD and different comorbidities such as T2D in the younger (3) and older population (10). On the other hand, high levels of relative HGS in the adult population have been associated with a low risk for CVD, including hypertension (HT), T2D and dyslipidemia (11); meanwhile, low levels of HGS are associated with alcohol consumption, poor exercise, dietary pattern, education level, age, BMI and T2D (12). A study by Kim et al. (13) has shown that the lowest relative HGS tertile in both sexes can have an influence on chronic disease development or aggravation. Stenholm et al. (14) proved that the occurrence of obesity determines the presence of low levels of HGS. In the Mexican population, the prevalence of obesity is high and represents a main factor related to HT, T2D and dyslipidemia (15). Although low HGS has been related to mortality of all causes (16,17), the relation between levels of relative HGS and specific comorbidities have not been explored.

Accordingly, the objective of the present study was to determine the association between HGS (absolute and relative) and AO, T2D, and HT, as well as to determine the association between low relative HGS with

co-occurrence of comorbidities or multicomorbidity (i.e., presence of two or three comorbidities together) in the Mexican population.

METHODS

A cross-sectional study was carried out in 860 participants from the south of Mexico. The studied group consisted of 661 female and 199 male participants, while the evaluated age range went from 18 to 65 years. The participants were invited to partake in this study and those interested were evaluated in health care centers and educational centers. Pregnant women or volunteers who were unable to stand upright with or without assistance, along with those with a physical disability that prevented independent walking (such as lower limb amputations, hemiplegia and monoplegia, musculoskeletal sequel) were not considered in the study. The study was approved by the local Research Ethics Committee of the University of Guerrero. Informed written consent was obtained from all participants before enrollment in the study and all procedures were carried out according to the Declaration of Helsinki.

Measurements

Assessments were made regarding sociodemographic variables, clinical, and anthropometric parameters, as well as the measurement of maximal HGS.

Sociodemographic data

Sociodemographic data such as age, gender, educational level, socioeconomic level, job occupation, and marital status were obtained using a questionnaire. In addition, lifestyle habits including smoking, alcohol consumption, and physical activity (150 min/week) were also recorded. Presence of diagnosed diseases such as T2D and HT, or uses of medication for their treatment were self-reported.

Measurement of blood pressure and anthropometrics

The evaluation of the participants was performed in the morning hours between 7:00 and 10:00 AM. A physical examination of neck, folds and underarm allowed the identification of acanthosis nigricans (AN). Resting heart rate (RHR) and blood pressure were measured using an automated baumanometer (HEM-712C, OMRON, IL, USA); two measurements were made on the left arm, with the participant resting in a sitting position for at least 5 minutes before and between measurements. Body composition was evaluated according to the bioelectrical impedance technique with HBF-514C (OMRON, IL, USA) to assess weight, body mass index (BMI) (kg/m^2), free fat mass % (FFM), visceral fat % (VF), and body fat (BF) percent. Height was determined using a portable stadiometer (Seca 240, Hamburg, Germany). Waist circumference (WC) was measured at the level of the umbilicus, with the subject standing. Hip girth was measured at the maximal circumference of the buttocks; both were measured in duplicate, using a measuring tape with an accuracy of ± 0.1 cm (Seca 201, Hamburg, Germany). Anthropometric indices were defined according to the following formulas: body mass index (BMI) = weight (kg) / height (m)^2; waist to hip ratio (WHR) = WC (cm) / hip (cm); waist to height ratio (WHtR) = WC (cm) / height (m).

Handgrip strength

HGS was assessed using an electronic dynamometer (EH101; CAMRY, Guangdong, China). Participants were tested under the same conditions and the dynamometer was adjusted to the optimal fit for each participant according to the manufacturer's instructions. HGS was measured twice in each hand, in the standing position and with the arm extended to the front (horizontal angle 90 °). The maximal handgrip strength values (kg) were considered the maximal force from each hand and were used for the data analysis. Relative HGS (^{R}HGS) was calculated

as the absolute maximal handgrip strength (kg) (^{A}HGS) divided by BMI (reported as kg/BMI) (5). In this study most of the subjects were right-handed. Only twelve participants were left-handed.

Relative handgrip strength classification

The values of ^{R}HGS showed a better parametric distribution in comparison to ^{A}HGS, therefore ^{R}HGS was used in the principal analyses. Values below the median were considered to evaluate the presence of decreased strength and its association with the presence of comorbidities. The values that defined decreased strength in men were: ^{R}HGS < 1.26 kg/BMI for the left hand and < 1.38 kg/BMI for the right hand; for women, decreased strength was considered as ^{R}HGS < 0.75 kg/BMI for the left hand, and ^{R}HGS < 0.81 kg/BMI for the right hand. Concurrently, the ^{A}HGS values that defined decreased strength in men were: ^{A}HGS < 34.2 kg for the left hand and < 38.1 kg for the right hand. In women, decreased strength was considered as ^{A}HGS < 21.2 kg for the left hand, and ^{A}HGS < 22.9 kg for the right hand.

Comorbidities

Comorbidities were defined according to the following criteria: abdominal obesity (AO) was defined by a waist circumference for women ≥ 88 cm, and ≥ 102 cm for men according to the WHO criteria (18). Pre-hypertension (Pre-HT) was defined by the presence of diastolic and systolic blood pressure ≥ 80-189/120-139 mmHg, and hypertension (HT) was defined according to American Heart Association criteria, by self-reporting, use of antihypertensive treatment, and presence of diastolic and systolic blood pressure ≥ 90/140 mmHg (19). Acanthosis nigricans (AN) was defined by the presence of dark, velvety hyperpigmentation and thickened skin, symmetrically distributed over the neck, armpits, and other flexural regions of the body, and type-2 diabetes (T2D) was

defined by self-reports of previous physicians' diagnosis and use of antidiabetic medication.

In this study, joint presence refers to the co-occurrence of two or more conditions or metabolic characteristics, which may or may not directly interact with each other within the same individual. On the other hand, the number of comorbidities refers to the presence of one, two, and three conditions, regardless of which one.

Statistical analysis

Participants' baseline demographics, anthropometrics, and lifestyle characteristics were reported as median and percentile ranges (5 and 95) for continuous variables, and were reported as proportions for categorical variables. These were analyzed using the Mann-Whitney U-test and Chi-square test, respectively. The correlation between [R]HGS and anthropometric parameters was determined by Spearman's rank correlation. We calculated the β coefficient to determine the effect of the presence of comorbidities and their joint presence in regards to [R]HGS and [A]HGS in a model adjusted by age. Therefore, relative risk (RR) and 95 % confidence intervals (CI) were estimated using logistic regression models to determine the association between [R]HGS and number of comorbidities — model 1, adjusted by age, and model 2, adjusted by age and physical activity. A value of $p < 0.05$ was considered statistically significant using the STATA. V.13.0 software.

RESULTS

In this study, 860 participants were enrolled. The baseline demographics and lifestyle characteristics are shown in table I. The median age was 42 years. In terms of lifestyle, a low proportion of participants smoked and occasionally drank alcohol, while 57 % said they were physically active. The men reported higher [A]HGS ($p < 0.001$) and [R]HGS ($p < 0.001$) in both hands, when compared to women; however, the frequency of lowest

[R]HGS was similar in both sexes: around 25 % of the population showed [R]HGS below the first quartile. On the other hand, women had higher WC (p < 0.001), WtHR (p < 0.001) and resting HR than men (p < 0.007). Instead, men reported higher SBP (p < 0.001) and WHR (p < 0.001) (Table II).

The [R]HGS in both hands showed a better relationship with the co-occurrence of comorbidities as well as with the number of comorbidities in women (Fig. 1C and D) and men (Fig. 2C and D), in comparison to [A]HGS (Fig. 1 & 2, panels A and B).

In this study, the prevalence of cardiometabolic-based disease was elevated. AO was the most frequent condition (55.9 %), followed by Pre-HT (26.28 %), HT (21.05 %), AN (17.17 %) and T2D (13.6 %). However, 26.63 % of participants did not present any comorbidity. The co-occurrence of comorbidities is present in around 45 % of the total sample, being more frequent the combination of AO + Pre-HT. In relation to the number of comorbidities, one third of the population had two comorbidities, principally women, although the comorbidities related to elevated blood pressure were more frequent in men (Table III).

The regression models adjusted by age show that the presence of comorbidities was linked to [R]HGS (Table IV). T2D presented the highest decrease of [A]HGS in both hands (left, β: −5.47, −8.89 to −2.05, p = 0.002, and right, β: −6.24, −10.0 to −2.46, p = 0.001). AO presented an inverse association with HGS in both the left (relative, β: −0.24, −0.31 to −0.18, p < 0.001, and absolute, β: −1.76, −3.44 to −0.081, p = 0.040) and right hands (relative, β: −0.28, −0.35 to −0.21, p < 0.001, and absolute, β: −2.22, −4.08 to −0.37, p = 0.019) (Table IV).

Similarly, considering the median values for defining the cutoff points of HGS for low muscle strength, in an adjusted model the presence of low [R]HGS in men (right, RR: 17.2, 95 % CI: 1.91-154.2, p < 0.001, and left, RR: 11.92, 95 % CI: 1.33-106.4, p = 0.020) and women (right, RR: 10.42, 95 % CI: 5.31-20.47, p < 0.001, and left, RR: 9.90, 95 % CI: 5.11-19.19, p

< 0.001) presented an association with the joint presence of disease, associated with components of metabolic syndrome (MetS) (i.e., AO, HT and T2D). In general, the risk associated with low HGS is in accordance with an increase in the number of comorbidities (Fig. 3A and B).

DISCUSSION

The main findings of our study prove that low HGS (absolute and relative) were linked to the presence of cardiometabolic-based comorbidities, as well as to multicomorbidity (i.e., the joint presence of AO, T2D and HT). The evidence has shown that improved muscle function can affect whole-body glucose–lipid metabolism and peripheral insulin sensitivity, due to the direct or indirect regulation of whole-body energy homeostasis through myokines that are secreted from the muscle and their subsequent effects on the endocrine system (20).

In this study the prevalence of cardiometabolic disorders was elevated. AO was the most frequent condition (55.9 %), followed by Pre-HT (26.28 %), HT (21.05 %), AN (17.17 %) and T2D (13.6 %). In this context, our study evaluated the clinical components of the MetS. It has been reported that MetS consists of a cluster of metabolic abnormalities that increase the risk of developing CVD and Mexico has one of the highest prevalences of metabolic disease worldwide (21). In line with this finding, a study reported that the prevalence of MetS in Mexican adults was 36.8 % — AO was 42.7 %, HT was 42.6 %, and elevated fasting glucose was 21.0 % (22). Another recent study showed that the most frequent MetS component was low HDL-c levels (75.8 %), while central obesity was the second most frequent component in females (61 %), and elevated blood pressure was 42.7 % in Mexican adults from different ethnic groups (21). In the Korean population relative HGS has been inversely associated with the risk of MetS (5,23).

In the present study, participants with T2D presented a negative relationship with absolute and relative HGS in both hands. In agreement

with these findings, a longitudinal study reported a negative association between HGS and T2D risk in adults (24). Similarly, the evidence suggests that HGS was inversely associated with fasting glucose, fasting insulin levels and insulin resistance (HOMA-IR) score; in addition, this study indicated that HGS was significantly inversely associated with T2D and insulin resistance (25). In addition, [R]HGS was significantly associated with better cardiometabolic health in adult subjects, therefore muscle strength may play an important role in cardiovascular health (7). Likewise, a recent study concluded that HGS may be a risk indicator for T2D in the general population (26). Karvonen-Gutierrez et al. (27) reported that a rise in the normal grip strength value by 0.1 was associated with a 19 % lower incidence of T2D; therefore, the authors concluded that improving muscle strength may contribute to preventing diabetes among women. In agreement with these findings, a study conducted in older males and females indicated that muscle weakness was associated with an increased rate of T2D (28).

Particularly in this study the prevalence of obesity was high. We found that AO presented an inverse association with HGS (i.e., relative and absolute). Another study reported that subjects with low [R]HGS showed high levels of AO and fat mass (29). In addition, another study found a significant association between higher [R]HGS and more favorable features of WC and body weight in women (30). Also, evidence has shown that HGS is inversely associated with MetS and its components, such as AO in adult men and women (23). Similarly, it has been reported that the direct effect of AO on [R]HGS was statistically significant. In addition, this study suggests that high glucose levels could worsen the association between AO status and lower HGS (31).

In our study, [R]HGS presented consistent and better relations with the number of comorbidities (i.e., 1, 2 or 3 comorbidities) than [A]HGS in both hands in both sexes. The differences in results across absolute and relative HGS measures support the utility of [R]HGS to simultaneously

assess health risks of increased BMI (kg/m^2) and furthermore, low muscle strength may be a feasible measure to use in future muscle strength and body composition research, given that it is relatively simple, quick, reliable and inexpensive to use (6). In an adult population, values of ^{R}HGS < 2.52 in men and < 1.55 in women were associated with CVD in men and women (32). These cut-off values are significantly higher than those found in our study, and this can be determined by the high frequency of multicomorbidity in our population; therefore, the clinical value of this parameter must be determined between populations.

The ^{R}HGS in the Taiwanese population was linked to different cardiometabolic risk factors (7). Our results are in line with previous studies, showing that in Korean men between 20-64 years old ^{R}HGS presents a positive association with BMI and in women, moreover, ^{R}HGS is positively correlated with systolic blood pressure and LDL-c (3), and ^{R}HGS decreases are significantly associated with increasing weight status (6). On the other hand, ^{R}HGS is useful to identify subjects at high risk of pre-diabetes (33), in addition to presenting an association with T2D (34) and fasting blood glucose levels (6). In this context, women with lower BMI-related HGS have a higher prevalence of T2D and HT than those with higher levels of HGS (35). A recent study identifies a strong relationship between ^{R}HGS and the prevalence of MetS in adults, regardless of sex (36). On the other hand, in older adults, fasting glucose is inversely related to ^{R}HGS (31). Also, subjects with higher ^{R}HGS had a lower risk of HT, T2D and dyslipidemia than those with lower HGS (11). In addition, ^{R}HGS is inversely associated with dyslipidemia in both men and women (37). In a Korean population aged 40 to 79 years old, ^{R}HGS showed an inverse relationship with cardiovascular risk factors such as blood pressure, waist circumference, Framingham risk score, and high-sensitivity C-reactive protein levels (25). Similarly, it has been demonstrated that ^{R}HGS is inversely associated with CVD risk factors and all-cause mortality events, therefore HGS may be a useful

prognostic tool for fatal CVD events (38). As well, it could be a screening tool for a number of comorbidities and for intervention strategies design. It has been determined that an increase of 1 kg in HGS reduced the 10-year CVD risk by 1.76 times (39), with a 3 % decreased risk of mortality 5 years later (16). A meta-analysis showed that isolated progressive resistance training resulted in an increase in lower and upper body strength, and improved aerobic fitness to a similar degree as aerobic training in coronary heart disease cohorts (40). Therefore, improving muscle strength should be a prioritized public health strategy.

Limitations

Limitations include the lack of measurements of biochemical-metabolic parameters as well as the lack of detailed information on cardiorespiratory fitness and the lower sample size of men compared to women. Also, the cut-off for [R]HGS that defines risk associated with comorbidity presence in this study can vary between populations, i.e., according to lifestyle or presence of disease. Therefore, HGS averages must be estimated in multiple populations in order to determine general cutoff values.

CONCLUSION

Lower levels of HGS (i.e., absolute and relative) presented an association with the presence of T2D and AO in the Mexican population; moreover, lower levels of relative HGS were linked to the co-occurrence of comorbidities (i.e., joint AO, HT and T2D). Therefore, public health policies should incorporate strategies to improve HGS, due to its association with the presence of joint comorbidities.

REFERENCES

1. García-Hermoso A, Cavero-Redondo I, Ramírez-Vélez R, Ruiz JR, Ortega Fb, Lee DC, et al. Muscular strength as a predictor of all-cause mortality in an apparently healthy population: a systematic review and meta-analysis of data from approximately 2 million men and women. Arch Phys Med Rehabil 2018;99(10):2100-13.e5. DOI: 10.1016/j.apmr.2018.01.008

2. Volaklis KA, Halle M, Meisinger C. Muscular strength as a strong predictor of mortality: a narrative review. Eur J Intern Med 2015;26(5):303-10. DOI: 10.1016/j.ejim.2015.04.013

3. Chong H, Choi YE, Kong JY, Park JH, Yoo HJ, Byeon JH, et al. Association of Hand Grip Strength and Cardiometabolic Markers in Korean Adult Population: The Korea National Health and Nutrition Examination Survey 2015-2016. Korean J Fam Med 2020;41(5):291-8. DOI: 10.4082/kjfm.18.0129

4. Salaffi F, Farah S, Di Carlo M. Force-time curve features of handgrip strength in fibromyalgia syndrome. Sci Rep 2020;10(1):3372. DOI: 10.1038/s41598-020-60227-8

5. Yi D, Khang AR, Lee HW, Son SM, Kang YH. Relative handgrip strength as a marker of metabolic syndrome: the Korea National Health and Nutrition Examination Survey (KNHANES) VI (2014-2015). Diabetes Metab Syndr Obes 2018;11:227-40. DOI: 10.2147/DMSO.S166875

6. Lawman HG, Troiano RP, Perna FM, Wang CY, Fryar CD, Ogden CL. Associations of relative handgrip strength and cardiovascular disease biomarkers in US adults, 2011-2012. Am J Prev Med 2016;50(6):677-83. DOI: 10.1016/j.amepre.2015.10.022

7. Lee WJ, Peng LN, Chiou ST, Chen LK. Relative Handgrip Strength Is a Simple Indicator of Cardiometabolic Risk among Middle-Aged and

Older People: A Nationwide Population-Based Study in Taiwan. PLoS One 2016;11(8):e0160876. DOI: 10.1371/journal.pone.0160876

8. Bohannon RW. Grip Strength: An Indispensable Biomarker For Older Adults. Clin Interv Aging 2019;14:1681-91. DOI: 10.2147/CIA.S194543

9. Riviati N, Setiati S, Laksmi PW, Abdullah. Factors Related with Handgrip Strength in Elderly Patients. Acta Med Indones 2017;49(3):215-9.

10. Jeong YJ, Lee SK, Shin C. Normalized Hand Grip and Back Muscle Strength as Risk Factors for Incident Type 2 Diabetes Mellitus: 16 Years of Follow-Up in a Population-Based Cohort Study. Diabetes Metab Syndr Obes 2021;14:741-50. DOI: 10.2147/DMSO.S283853

11. Hao G, Chen H, Ying Y, Wu M, Yang G, Jing C. The relative handgrip strength and risk of cardiometabolic disorders: a prospective study. Front Physiol 2020;11:719. DOI:10.3389/fphys.2020.00719

12. Kim CR, Jeong YJ, Jeong T. Risk factors associated with low handgrip strength in the older Korean population. PLoS One 2019;14(3):e0214612. DOI: 10.1371/journal.pone.0214612

13. Kim YM, Kim S, Bae J, Kim SH, Won YJ. Association between relative hand-grip strength and chronic cardiometabolic and musculoskeletal diseases in Koreans: A cross-sectional study. Arch Gerontol Geriatr 2021;92:104181. DOI: 10.1016/j.archger.2020.104181

14. Stenholm S, Sallienen J, Koster A, Rantanen T, Sainio P, Heliövaara M, et al. Association between obesity history and hand grip strength in older adults-exploring the roles of inflammation and insulin sesistance as mediating factors. J Gerontl A Biol Sci Med Sci 2011;66(3):341-8. DOI: 10.1093/Gerona/glq226

15. Barquera S, Hernández-Barrera L, Trejo-Valdivia B, Shamah T, Campos-Nonato I, Rivera-Dommarco J. Obesity in Mexico, prevalence and trends in adults. Ensanut 2018-19. Salud Publica Mex 2020;62(6):682-92. DOI: 10.21149/11630

16. Al Snih S, Markides KS, Ray L, Ostir GV, Goodwin JS. Handgrip strength and mortality in older Mexican Americans. J Am Geriatr Soc 2002;50(7):1250-6. DOI: 10.1046/j.1532-5415.2002.50312.x

17. Castillo-Martínez L, Rodríguez-García WD, González-Islas DG, Orea-tejeda A, Lozada-Mellado M, Rodríguez-Silverio J, et al. Abnormal fluid distribution ans low handgrip strength index as predictor of mortality in Mexican patients with chronic heart failure. Nutrition 2020;72:110699. DOI: 10.1016/j.nut.2019.110699

18. Organization, World Health. Obesity: preventing and managing the global epidemic: World Health Organization; 2000.

19. James PA, Oparil S, Carter BL, Cushman WC, Dennison-Himmelfarb C, Handler J, et al. 2014 evidence-based guideline for the management of high blood pressure in adults: report from the panel members appointed to the Eighth Joint National Committee (JNC 8). JAMA 2014;311(5):507-20. DOI: 10.1001/jama.2013.284427

20. Oh KJ, Lee DS, Kim WK, Han BS, Lee SC, Bae KH. Metabolic adaptation in obesity and type II diabetes: myokines, adipokines and hepatokines. Int J Mol Sci 2017;18(1):8. DOI: 10.3390/ijms18010008

21. Mendoza-Caamal EC, Barajas-Olmos F, García-Ortiz H, Cicerón-Arellano I, Martínez-Hernández A, Córdoba EJ, et al. Metabolic syndrome in indigenous communities in Mexico: a descriptive and cross-sectional study. BMC Public Health 2020;20(1):339. DOI: 10.1186/s12889-020-8378-5

22. Rojas R, Aguilar-Salinas CA, Jiménez-Corona A, Shamah-Levy T, Rauda J, Avila-Burgos L, et al. Metabolic syndrome in Mexican adults: results from the National Health and Nutrition Survey 2006. Salud Publica Mex 2010;52(Suppl 1):S11-8. DOI: 10.1590/s0036-36342010000700004

23. Wu H, Liu M, Chi VTQ,Wang J, Zhang Q, Liu L, et al. Handgrip strength is inversely associated with metabolic syndrome and its

separate components in middle aged and older adults: a large-scale population-based study. Metabolism 2019;93:61-7. DOI: 10.1016/j.metabol.2019.01.011.16

24. Wander PL, Boyko EJ, Leonetti DL, McNeely MJ, Kahn SE, Fujimoto WY. Greater hand-grip strength predicts a lower risk of developing type 2 diabetes over 10 years in leaner Japanese Americans. Diabetes Res Clin Pract 2011;92(2):261-4. DOI: 10.1016/j.diabres.2011.01.007

25. Lee MR, Jung SM, Bang H, Kim HS, Kim YB. Association between muscle strength and type 2 diabetes mellitus in adults in Korea: Data from the Korea national health and nutrition examination survey (KNHANES) VI. Medicine (Baltimore) 2018;97(23):e10984. DOI: 10.1097/MD.0000000000010984

26. Kunutsor SK, Isiozor NM, Khan H, Laukkannen JA. Handgrip strength-A risk indicator for type 2 diabetes: Systematic review and meta-analysis of observational cohort studies. Diabetes Metab Res Rev 2020;37:e3365. DOI: 10.1002/dmrr.3365

27. Karvonen-Gutierrez CA, Peng Q, Peterson M, Duchowny K, Nan B, Harlow S. Low grip strength predicts incident diabetes among mid-life women: the Michigan Study of Women's Health Across the Nation. Age and Ageing 2018;47(5):685-91. DOI: 10.1093/ageing/afy067

28. McGrath R, Vincent BM, Al Snih S, Markides KS, Peterson MD. The Association Between Muscle Weakness and Incident Diabetes in Older Mexican Americans. J Am Med Dir Assoc 2017;18(5):452.e457-452.e412. DOI: 10.1016/j.jamda.2017.01.017

29. Ramírez-Vélez R, Meneses-Echavez JF, González-Ruíz K, Correa JE. Muscular fitness and cardiometabolic risk factors among Colombian young adults. Nutr Hosp 2014;30(4):769-75. DOI: 10.3305/nh.2014.30.4.7684

30. Hong S. Association of Relative Handgrip Strength and Metabolic Syndrome in Korean Older Adults: Korea National Health and Nutrition Examination Survey VII-1. J Obes Metab Syndr 2019;28(1):53-60. DOI: 10.7570/jomes.2019.28.1.53

31. Pérez-Sousa MÁ, Del Pozo-Cruz J, Cano-Gutiérrez CA, Ferrebuz AJ, Sandoval-Cuellar C, Izquierdo M, et al. Glucose Levels as a Mediator of the Detrimental Effect of Abdominal Obesity on Relative Handgrip Strength in Older Adults. J Clin Med 2020;9(8):2323. DOI: 10.3390/jcm9082323

32. Jang SK, Kim JH, Lee Y. Effect to relative handgrip strength on cardiovascular disease among Korean adults aged 45 years and older: Results from the Korean Longitudinal Study of Aging (2006-2016). Arch Gerontol Geriatr 2020;86:103937. DOI: 10.1016/j.archger.2019.103937

33. Manda CM, Hokimoto T, Okura T, Isoda H, Shimano H, Wagatsuma Y. Handgrip strength predicts new prediabetes cases among adults: A prospective cohort study. Prev Med Rep 2020;17:101056. DOI: 10.1016/j.pmedr.2020.101056.22

34. Momma H, Sawada SS, Kato K, Gando Y, Kawakami R, Miyachi M, et al. Physical fitness tests and type 2 diabetes among Japanese: a longitudinal study from the Niigata Wellness Study. J Epidemiol 2019;29(4):139-46. DOI: 10.2188/jea.JE20170280

35. Lombardo M, Padua E, Campoli F, Panzarino M, Mîndrescu V, Annino G, et al. Relative Handgrip Strength is Inversely Associated with the Presence of Type 2 Diabetes in Overweight Elderly Women with Varying Nutritional Status. Acta Diabetol 2021;58(1):25-32. DOI: 10.1007/s00592-020-01588-4

36. Ji C, Xia Y, Tong S, Wu Q, Zhao Y. Association of handgrip strength with the prevalence of metabolic syndrome in US adults: the national health and nutrition examination survey. Aging (Albany NY) 2020;12(9):7818-29. DOI: 10.18632/aging.103097

37. Kim BM, Yi YH, Kim YJ, Lee SY, Lee JG, Cho YH, et al. Association between Relative Handgrip Strength and Dyslipidemia in Korean Adults: Findings of the 2014-2015 Korea National Health and Nutrition Examination Survey. Korean J Fam Med 2020;41(6):404-11. DOI: 10.4082/kjfm.19.0073

38. Laukkanen JA, Voutilainen A, Kurl S, Araujo CG, Jae SY, Kunutsor SK. Handgrip strength is inversely associated with fatal cardiovascular and all-cause mortality events. Ann Med 2020;52(3-4):109-19. DOI: 10.1080/07853890.2020.1748220

39. Shim J, Yoo HJ. Effects of Handgrip Strength on 10-Year Cardiovascular Risk among the Korean Middle-Aged Population: The Korea National Health and Nutrition Examination Survey 2014. Healthcare (Basel) 2020;8(4):458. DOI: 10.3390/healthcare8040458

40. Hollings M, Mavros Y, Freeston J, Singh MF. The effect of progressive resistance training on aerobic fitness and strength in adults with coronary heart disease: A systematic review and meta-analysis of randomized controlled trials. Eur J Prev Cardiol 2017;24(12):1242-59. DOI: 10.1177/2047487317713329

Table I. General characteristics of the population

Variables	Total ($n = 860$)
Age, years[a]	42 (20-63)
Education levels, n (%)[b]	
Elementary	205 (23.8)
Secondary school	184 (21.4)
High school	170 (19.77)
University	301 (35.0)
Socioeconomic level, n (%)[b]	
Low	285 (33.5)
Medium	567 (66.5)
Belongs to ethnic group, n (%)[b]	
Yes	67 (7.8)
Smoking/Tobacco use, n (%)[b]	
Yes	59 (6.86)
Alcohol consumption, n (%)[b]	
Yes	186 (21.6)
Active physically, n (%)[b]	
Yes	491 (57.1)
Physical activity, min/week[a]	240 (60-630)

[a]Quantitative data shown as a 5th and 95th percentiles. [b]Qualitative data shown as n and proportions.

Table II. Comparison of variables according to sex

Variables	Total (n = 860)	Women (n = 661) (76.9 %)	Men (n = 199) (23.1 %)	p-value
Age (years)[a]	42 (20-63)	43 (20-62)	41 (18-65)	0.02
Clinical and anthropometric parameters				
BMI, (kg/m^2)[a]	27.6 (20.9-37.3)	27.6 (21.1-37.5)	27.7 (20.5-34.9)	0.18
BF, (%)[a]	40.6 (20.9-52.6)	42.8 (30.2-53.4)	28.2 (13.0-38.7)	< 0.001
FFM, (%)[a]	24.3 (20.2-38.6)	23.5 (19.8-28.0)	33.7 (27.3-43.7)	< 0.001
WC, (cm)[a]	92 (74-113)	96 (74-116.5)	90.5 (74-112)	< 0.001
VF, (%)[a]	8 (4-15)	8 (4-13)	11 (3-20)	< 0.001
WHR, (waist/hip)[a]	0.90 (0.80-1.01)	0.89 (0.80-0.99)	0.94 (0.82-1.05)	< 0.001
WtHR,(WC/height)[a]	0.59 (0.45-0.74)	0.59 (0.47-0.75)	0.57 (0.43-0.69)	< 0.001
Arm, (cm)[a]	29 (23.5-36)	29 (23.5-36)	30 (25-36)	< 0.001
SBP, (mmHg)[a]	114 (91-151)	113 (91-151)	118 (95-153)	< 0.001
DBP, (mmHg)[a]	74.5 (57-94)	74 (57-94)	75 (55-93)	0.78
RHR, (bpm)[a]	72 (56-94)	73 (59-94)	70 (52-96)	0.007
Absolute maximal handgrip strength (kg)				
Left-^{A}HGS[a]	23.1 (14.2-41.1)	21.2 (13.7-29.6)	34.2 (23.3-47.9)	< 0.001
Right-^{A}HGS[a]	24.5 (15.8-45.5)	22.9 (15.2-31.6)	38.1 (24.2-52.2)	< 0.001
Relative maximal handgrip strength (kg/BMI)				
Left-^{R}HGS[a]	0.90 (0.51-1.76)	0.75 (0.45-1.17)	1.26 (0.79-1.95)	< 0.001
Left-^{R}HGS (quartile), n (%)[b]				0.62
Q1	203 (23.6)	165 (24.96)	38 (19.1)	
Q2	215 (25.0)	154 (23.3)	61 (30.65)	
Q3	224 (26.0)	174 (26.32)	50 (25.13)	
Q4	218 (25.34)	168 (25.42)	50 (25.13)	
Right-^{R}HGS	0.83 (0.46-1.59)	0.81 (0.49-1.24)	1.38 (0.84-2.06)	< 0.001
Left-^{R}HGS (quartile), n (%)[b]				0.98
Q1	207 (24.06)	158 (23.9)	49 (24.62)	
Q2	225 (26.16)	174 (26.32)	51 (25.63)	
Q3	213 (24.76)	165 (24.96)	48 (24.12)	
Q4	215 (25.0)	164 (24.81)	51 (25.63)	

P < 0.05 was considered statistically significant. BF: body fat; BMI: body mass index; DBP: diastolic blood pressure; HGS: hand grip strength; FFM: mass free fat; Q:

quartile according to the range of relative HGS by group; [R]HGS: relative max strength obtained from strength max/MBI; RHR: resting heart rate, beats per minute (bpm); SBP: systolic blood pressure; WC: waist circumference; WHR: waist to hip ratio; WtHR: waist-to-height ratio. [a]Data shown as median (percentile 5 and 95), compared using the Mann-Whitney U-test. [b]Data shown as number and proportions, compared using the Chi-square test.

Table III. Co-occurrence of comorbidities according to frequency and sex

Comorbidities	Total %	Women	Men	p value
Type				< 0.001
None	26.6	160 (24.21)	69 (34.67)	
AO + Pre HT	17.7	128 (19.36)	24 (12.06)	
AO	16.3	126 (19.06)	14 (7.04)	
AO + T2D + HT	13.3	100 (15.13)	14 (7.04)	
Pre HT	8.6	33 (4.99)	41 (20.6)	
AO + AN	8.4	61 (9.23)	11 (5.53)	
HT	3.8	21 (3.18)	12 (6.03)	
T2D	3.7	19 (2.87)	4 (2.01)	
T2D + HT	2.7	13 (1.97)	10 (5.03)	
Number of comorbidities				< 0.001
0	26.6	160 (24.21)	69 (34.67)	
1	28.7	180 (27.23)	67 (33.67)	
2	31.4	221 (33.43)	49 (24.62)	
3	13.3	100 (15.13)	14 (7.04)	

p < 0.05 was considered statistically significant. AO: abdominal obesity; Pre HT: prehypertension; HT: hypertension; T2D: type-2 diabetes; AN: acanthosis nigricans. Data shown as number and proportions were compared using the Chi-square test.

Table IV. Effect of comorbidities on relative and absolute HGS in the total sample

Comorbidities	Left ^{R}HGS β Coefficient (95 % CI), p value	Left ^{A}HGS β Coefficient (95 % CI), p value	Right ^{R}HGS β Coefficient (95 % CI), p value	Right ^{A}HGS β Coefficient (95 % CI), p value
None	Ref	Ref	Ref	Ref
Pre HT	0.08 (0.001 to 0.16), 0.02	3.56 (1.49 to 5.64), 0.001	0.09 (0.005 to 0.17), 0.03	3.71 (1.42 to 6.01), 0.002
HT	−0.02 (−0.12 to 0.08),0.73	1.07 (−1.80 to 3.95), 0.46	−0.02 (−0.13 to 0.09), 0.72	1.19 (−1.98 to 4.37), 0.46
T2D + HT	−0.10 (−0.23 to 0.01), 0.09	−0.32 (−3.72 to 3.06), 0.84	−0.11 (−0.25 to 0.02), 0.10	−0.29 (−4.04 to 3.45), 0.87
AO + Pre HT	−0.24 (−0.30 to −0.17), <0.01	−0.94 (−2.67 to 0.79), 0.28	−0.27 (−0.34 to −0.20), < 0.001	−1.34 (−3..25 to 0.56), 0.16
AO	−0.24 (−0.31 to −0.18), <0.001	−1.76 (−3.44 to −0.081), 0.040	−0.28 (−0.35 to −0.21), < 0.001	−2.22 (−4.08 to −0.37), 0.019
T2D	−0.26 (−0.39 to −0.14), <0.001	−5.47 (-8.89 to −2.05), 0.002	−0.30 (−0.44 to −0.16), < 0.001	−6.24 (−10.0 to −2.46), 0.001
AO + AN	−0.34 (−0.42 to −0.26), <0.001	−1.91 (−3.97 to 0.14), 0.06	−0.38 (−0.47 to −0.30), < 0.001	−2.36 (−4.64 to −0.09), 0.041
AO + T2D + HT	−0.37 (−0.44 to −0.30), <0.001	−4.13 (−6.09 to −2.18), < 0.001	−0.39 (−0.47 to −0.31), < 0.001	−4.02 (−6.18 to −1.86), < 0.001
Number of comorbidities				
1	−0.12 (−0.18 to −0.06), < 0.001	0.18 (−1.29 to 1.67), 0.80	−0.14 (−0.20 to −0.08), < 0.001	-0.01 (−1.65 to 1.61), 0.98
2	−0.27 (−0.32 to −0.21), < 0.001	−1.56 (−3.06 to −0.065), 0.04	−0.30 (−0.36 to −0.24), < 0.001	−1.98 (−3.63 to −0.32), 0.019
3	−0.39 (−0.46 to −0.31), < 0.001	−4.18 (−6.16 to −2.21), < 0.001	−0.41 (−0.49 to −0.32), < 0.001	−4.08 (−6.26 to −1.90), < 0.001

$p < 0.05$ was considered statistically significant. AHGS: absolute handgrip strength; Ref: reference category; RHGS: relative handgrip strength. β coefficient (95 % confidence interval). Model adjusted by age.

A)

B)

C)

D)

Fig. 1. Absolute and relative handgrip strength (HGS) according to the co-occurrence and number of comorbidities in women. A) Absolute HGS according to co-occurrence of comorbidities in women. B) Absolute HGS according to number of comorbidities in women. C) Relative HGS according to co-occurrence of comorbidities in women. D) Relative HGS according to number of comorbidities in women.

A)

B)

C)

D)
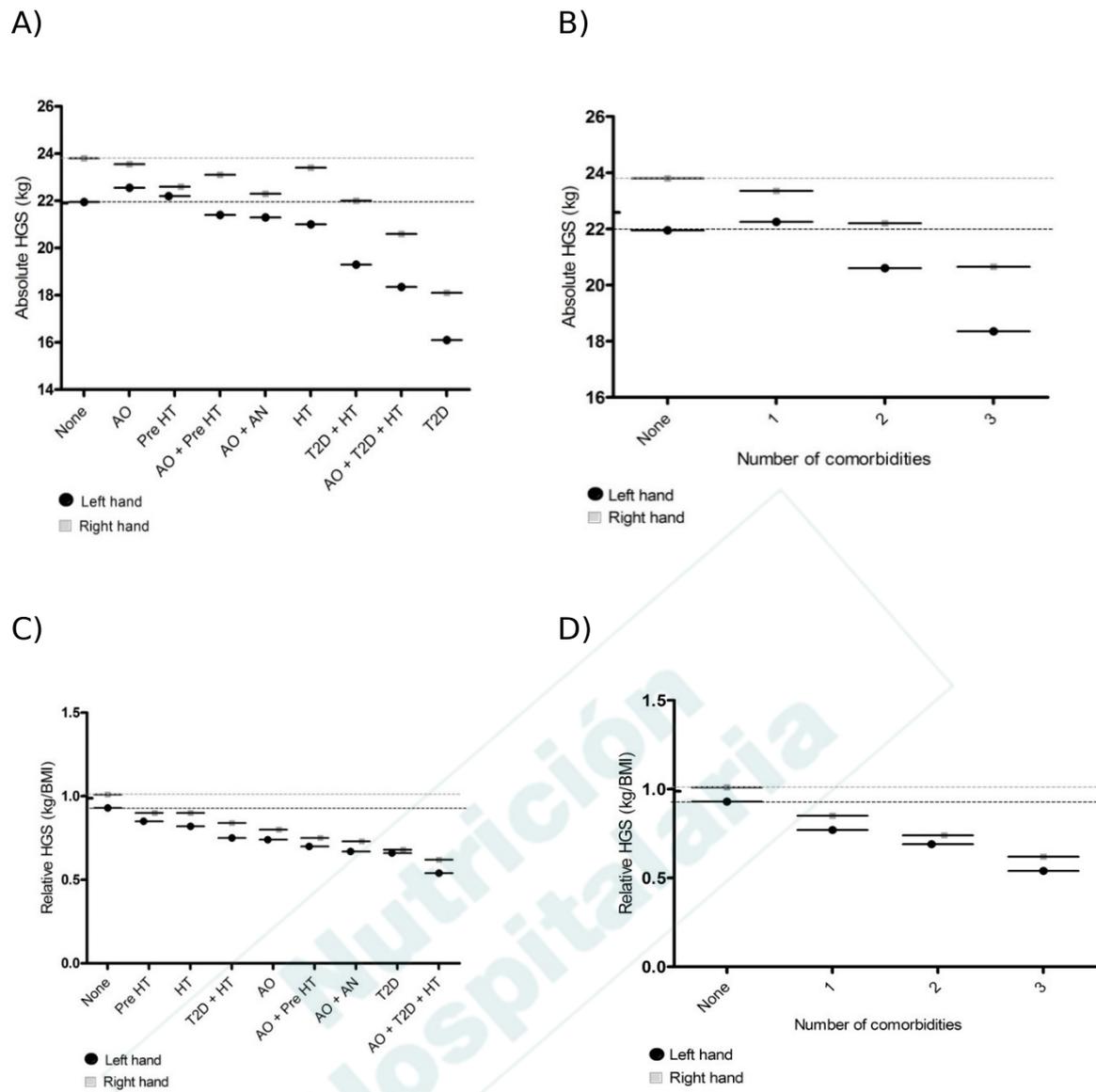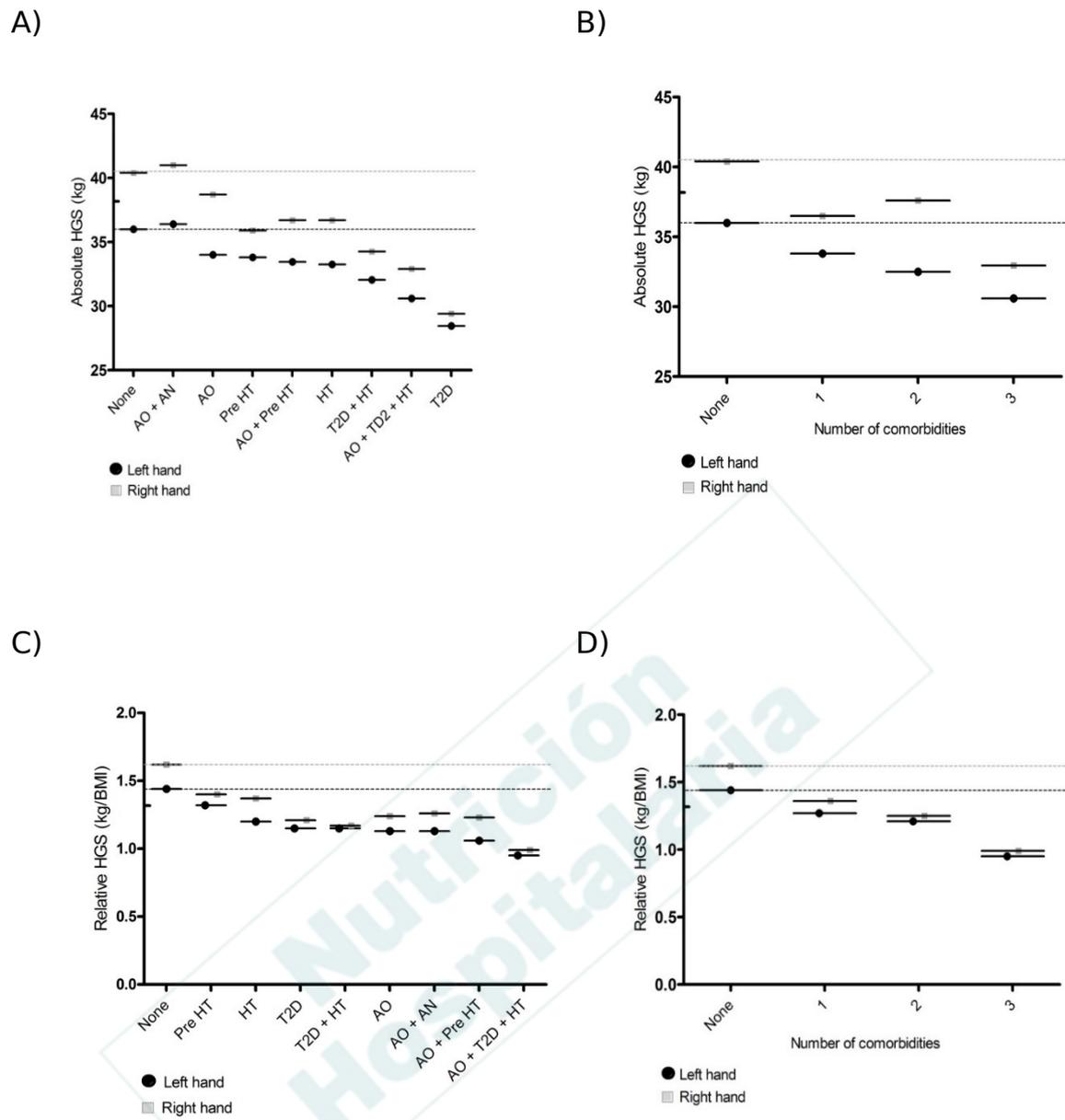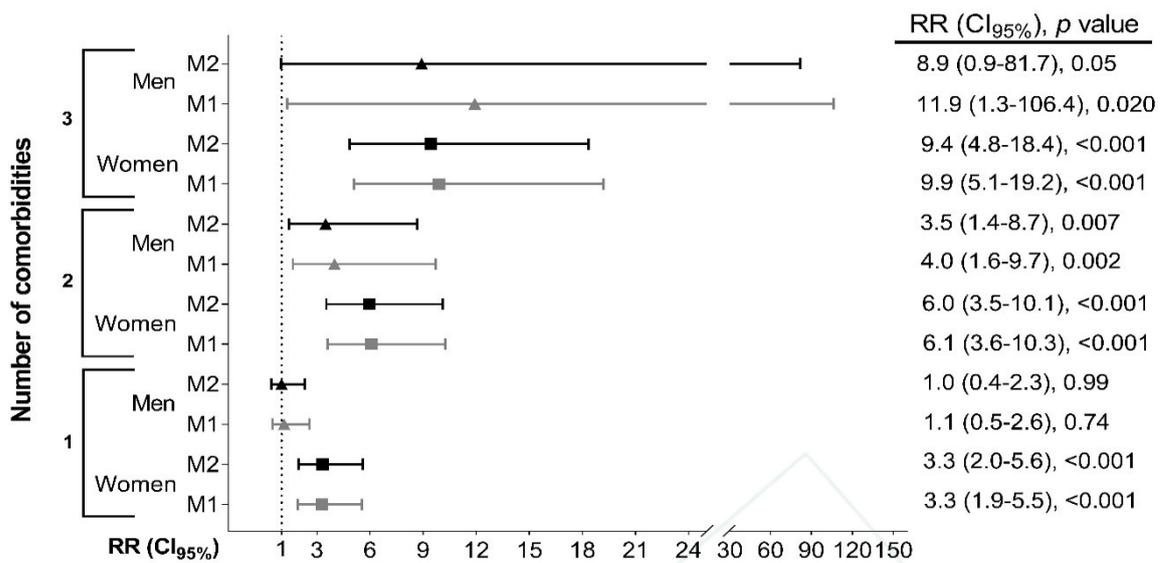

Fig. 2. Absolute and relative handgrip strength (HGS) according to the co-occurrence and number of comorbidities in men. A) Absolute HGS according to co-occurrence of comorbidities in men. B) Absolute HGS according to number of comorbidities in men. C) Relative HGS according to co-occurrence of comorbidities in men. D) Relative HGS according to number of comorbidities in men.

A)

		RR (CI_{95%}), *p* value
3 Men	M2	8.9 (0.9-81.7), 0.05
	M1	11.9 (1.3-106.4), 0.020
Women	M2	9.4 (4.8-18.4), <0.001
	M1	9.9 (5.1-19.2), <0.001
2 Men	M2	3.5 (1.4-8.7), 0.007
	M1	4.0 (1.6-9.7), 0.002
Women	M2	6.0 (3.5-10.1), <0.001
	M1	6.1 (3.6-10.3), <0.001
1 Men	M2	1.0 (0.4-2.3), 0.99
	M1	1.1 (0.5-2.6), 0.74
Women	M2	3.3 (2.0-5.6), <0.001
	M1	3.3 (1.9-5.5), <0.001

RR (CI_{95%}) 1 3 6 9 12 15 18 21 24 30 60 90 120 150

B)

		RR (CI_{95%}), *p* value
3 Men	M2	10.9 (1.2-99.9), 0.035
	M1	17.2 (1.9-154.2), 0.01
Women	M2	9.7 (4.9-19.1), <0.001
	M1	10.4 (5.3-20.5), <0.001
2 Men	M2	4.6 (1.8-11.8), 0.001
	M1	5.7 (2.3-14.2), <0.001
Women	M2	5.7 (3.3-9.8), <0.001
	M1	6.0 (3.5-10.3), <0.001
1 Men	M2	1.6 (0.7-3.8), 0.27
	M1	2.0 (0.9-4.6), 0.09
Women	M2	3.4 (2.0-5.8), <0.001
	M1	3.3 (1.9-5.6), <0.001

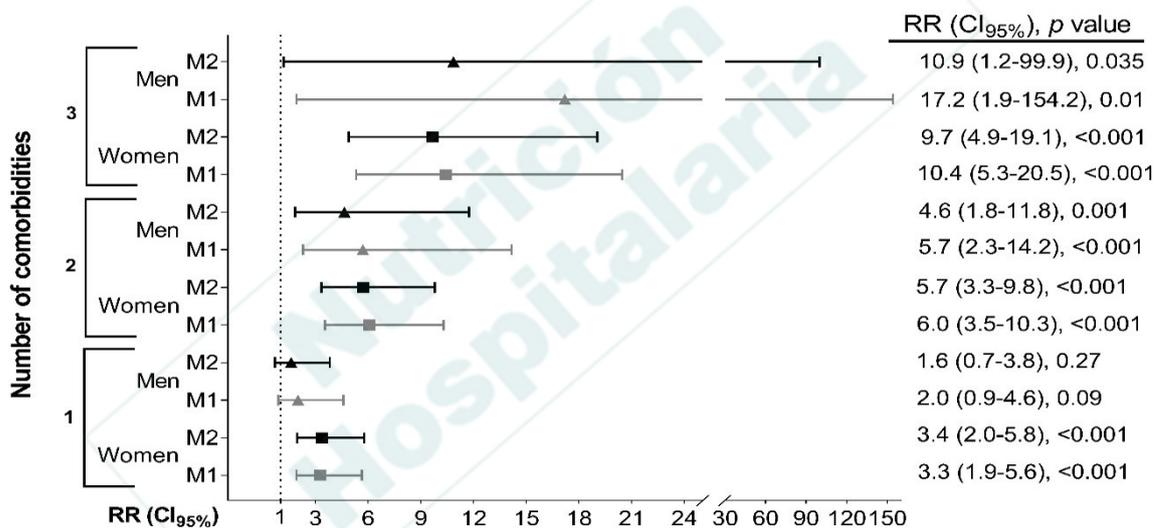RR (CI_{95%}) 1 3 6 9 12 15 18 21 24 30 60 90 120 150

Fig. 3. Low Relative handgrip strength (RHGS) is associated with comorbidities and the co-occurrence of cardiometabolic-based disease in the Mexican population. A) Relative handgrip strength – left-hand. B) Relative handgrip strength – right-hand. Low RHGS according to median values was considered < 1.26 kg/BMI for the left hand and < 1.38 kg/BMI for the right hand; and RHGS < 0.75 kg/BMI for the left hand and RHGS < 0.81 kg/BMI for the right hand for women. RR: relative risk (95 %

confidence interval), p value. M1: model 1 adjusted by age; M2: model 2 adjusted by age and physical activity.