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DYNAPENIA AND METABOLIC HEALTH IN OBESE AND NON-OBESE OLDER ADULTS AGED 70 YEARS AND OLDER: THE LIFE STUDY

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Abstract

Objective—The purpose of this study was to examine the relationship between dynapenia and metabolic risk factors in obese and non-obese older adults.

Methods—A total of 1453 men and women (age ≥ 70 years) from the Lifestyle Interventions and Independence for Elders (LIFE) Study were categorized as (1) non-dynapenic/non-obese (NDYN-NO), (2) dynapenic/non-obese (DYN-NO), (3) non-dynapenic/obese (NDYN-O), or (4) dynapenic/obese (DYN-O), based on muscle strength (FNIH criteria) and body mass index. Dependent

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variables were blood lipids, fasting glucose, blood pressure, presence of at least three metabolic syndrome (MetS) criteria and other chronic conditions.

Results—A significantly higher likelihood of having abdominal obesity criteria in NDYN-NO compared to DYN-NO groups (55.6 *vs* 45.1%, $p \leq 0.01$) was observed. Waist circumference was also significantly higher in obese groups (DYN-O=114.0±12.9 and NDYN-O=111.2±13.1) than in non-obese (NDYN-NO=93.1±10.7 and DYN-NO=92.2±11.2, $p \leq 0.01$); and higher in NDYN-O compared to DYN-O ($p = 0.008$). Additionally, NDYN-O demonstrated higher diastolic blood pressure compared to DYN-O (70.9±10.1 *vs* 67.7±9.7, $p \leq 0.001$). No significant differences were found across dynapenia and obesity status for all other metabolic components ($p>0.05$). The odds of having metabolic syndrome or its individual components were similar in obese and non-obese, combined or not with dynapenia (non-significant OR [95%CI]).

Conclusion—Non-obese dynapenic older adults had fewer metabolic disease risk factors than non-obese and non-dynapenic older adults. Moreover, among obese older adults, dynapenia was associated with lower risk of meeting metabolic syndrome criteria for waist circumference and diastolic blood pressure. Additionally, the presence of dynapenia did not increase cardiometabolic disease risk in either obese or non-obese older adults.

Keywords

Muscle strength; Obesity; metabolic syndrome; Aging

INTRODUCTION

The prevalence of overweight and obesity have dramatically increased across all segments of society in over the past two decades, including older adults. Thirty-three percent of American adults age 60 and older are now considered obese [1]. This is of concern as obesity, particularly abdominal obesity, has been widely recognized as a predisposing factor to cardiovascular disease (CVD) and the metabolic syndrome [2]. Moreover, the prevalence of the metabolic syndrome shows a clear linear trend with age [3]. Currently, 53% of adults over age 65 years old have metabolic syndrome, compared with 18% of adults below age 40 [3].

Abdominal obesity is associated with an upregulation of pro-inflammatory cytokines, such as interleukin-6 and tumor necrosis factor-alpha [4, 5], which may contribute to apoptosis in myocytes and lead to declines in muscle mass and strength. In addition, aging is independently associated with decreased muscle mass (sarcopenia) [6]. Some estimates indicate that 25 to 50% of adults aged 65 and older are sarcopenic [7]. This high prevalence of sarcopenia in older adults is concerning as low muscle mass is associated with the development of physical disabilities [8], as well as increased risk of hospitalization [9] and mortality. Sarcopenia may also contribute to metabolic complications and CVD in older adults [10, 11]. One potential explanation for these findings is that skeletal muscle atrophy is intricately linked to the metabolic alterations associated with physical inactivity and reduction of energy expenditure, which lead to insulin resistance [12]. In addition, sarcopenia is closely related to impairments in glucose homeostasis, underscoring the

potential negative additive effects of low muscle mass, when combined with obesity, on glucose regulation and insulin resistance [13].

The impact of sarcopenia-obesity on the metabolic profile is poorly studied, which is surprising given the large percentage (8–25%) of sarcopenic-obese individuals [14]. To our knowledge, the limited research that has been conducted on the combined effects of sarcopenia and obesity on metabolic risk factors and CVD in older adults has produced mixed findings [15–21]. Two studies [16, 17] indicate that sarcopenia-obesity has no particular deleterious impact on metabolic risk factors and CVD in Caucasian postmenopausal women. Conversely, in their review Prado et al. [18] showed that having low muscle mass and high fat mass increased CVD risk in Asian older adults. Yet another study by Castaneda et al [19] suggested that there may be health benefits associated with sarcopenia-obesity, as obese, sarcopenic older adults had reduced risk of diabetes compared to obese, non-sarcopenic older adults. Goulet et al. [22] also observed a better insulinemic profile in sarcopenic-obese postmenopausal women. Baumgartner [20] also reported that obese, sarcopenic elderly have less metabolic syndrome but higher rates of type II diabetes than either non-obese, sarcopenic or obese, non-sarcopenic older adults. Finally, Stephen et al. showed that sarcopenia, when combined with obesity, induced a modest increase in risk of CVD in community dwelling older men and women aged 65 years and older; this relationship was mediated mostly by muscle strength [23].

In addition to loss of muscle mass, a loss of muscle strength is also observed with aging [24]. Age-associated loss of muscle strength, called dynapenia [25], occurred in 60 % of adults aged 60 and older [26]. Dynapenia has been shown to be associated with poor cardio-respiratory function [27], a decline in mobility [8, 28], incident disability [29] and mortality [30, 31]. There is some evidence of a direct association between metabolic syndrome and insulin resistance with low muscular strength [32, 33]; intramuscular adipose tissue (IMAT) [34] and high blood pressure [35].

Based on these previous observations, the combined effect of dynapenia and obesity would be predicted to contribute to a worse metabolic profile compared to either condition alone. Dynapenic-obese individuals represent 7.6 to 11.1% of older adults [23, 36]. As for sarcopenia, only a few studies have been conducted on the effect of sarcopenic-obesity on metabolic risk factors and CVD in elderly people. Sénéchal et al. recently showed that the combination of abdominal obesity and dynapenia is associated with more metabolic alterations in adults 50 years of age and older (mean age: 65 ±10) than dynapenia or obesity alone [37]. In addition, both abdominal obesity and low muscular strength are characterized by high circulating levels of pro-inflammatory cytokines which are recognized as risk factors for CVD [4]. Atlantis et al. [11] and Karelis et al [38] observed that low muscle strength was associated with insulin resistance in elderly obese people. However, Barbat-Artigas et al. [39, 40] reported that dynapenia status appeared to be associated with a better insulinemic profile in obese postmenopausal women.

To our knowledge, no study has examined the metabolic effects of dynapenia in obese and non-obese older adults (age ≥ 70 years). Therefore, the purpose of this secondary analysis was to examine the relationship between dynapenia and metabolic risk factors in obese and

non-obese adults aged 70 years and older who participated in the Lifestyle Interventions and Independence for Elders (LIFE) Study. We hypothesized that dynapenic older adults would have higher metabolic disease risk factors compared to non-dynapenic obese and non-obese older adults.

METHODS

Participants

The LIFE Study eligibility criteria [41] targeted older persons, aged 70–89 years, who were: sedentary; at risk for mobility disability (SPPB score ≤10); able to walk 400 meters (m) in less than 15 minutes without sitting, using a walker, or needing the help of another person; and able to safely participate in the intervention. A total of 1,635 participants were recruited through eight field centers. Individuals with a Short Physical Performance Battery (SPPB) score below 7 were preferentially enrolled (45% of the sample) to enrich the sample with individuals at high risk for major mobility disability. For the present study, 147 of the 1635 participants were excluded because either handgrip or BMI measurements were not available. Thus, the total sample size for the present study was 1453 participants.

Anthropometrics measurements

Body weight, height, and waist circumference (WC) were measured during the baseline visit. Waist circumference was obtained horizontally at the midpoint between the highest point of the iliac crest and the lowest part of the costal margin in the mid-axillary line.

Sociodemographic measurements

Sociodemographic factors including age, race, education, income, and smoking were assessed by questionnaire at the screening interview.

Physical activity (PA) measurements

The Community Healthy Activities Model Program for Seniors (CHAMPS) was used to assess self-reported PA [42]. The Actigraph triaxial accelerometer (Model GT3X; Actigraph Inc., Pensacola, FL) was used to objectively measure total PA time and total steps. The accelerometer was worn on the right hip during at least 3 consecutive days in free-living conditions. Activity was recorded using 1-second epochs, which were added up to minute-to-minute epochs. Non-wear time was defined as a 60-minute window of zero counts in all three axes, allowing for up to two minutes of nonzero counts <100 in the vertical axis. Data files with fewer than 10 hours per day of wear time were excluded [43].

Self-reported chronic conditions

The following conditions were considered based on a self-reported questionnaire: arthritis, lung diseases (emphysema, asthma, or chronic bronchitis), and cardiovascular diseases (heart attack, or stroke). A score of 1 was given to each of the conditions when individuals answered positively. Global cognitive function was based on the Mini-Mental State Examination (3MS) [44]. Depressive symptoms were based on the Center for Epidemiological Studies–Depression Scale (Radloff LS).

Groups Classification

Body mass index (BMI)—Body weight was measured to the nearest 0.1 kg using a calibrated scale with the participants wearing light clothes and no shoes. Body height was measured to the nearest millimeter using a wall-mounted stadiometer. BMI was calculated as body weight (kg) divided by height (m) squared (kg/m^2). In our analyses, we used the clinical standard obesity BMI cut-point provided by the world health organization WHO (BMI > 30 kg/m^2).

Grip strength/Dynapenia—Right and left handgrip strengths were measured in kilograms using a handheld dynamometer (Jamar Handheld Dynamometer; J.A. Preston Corporation, Clifton, NJ). If the participant reported current flare-up of pain in the wrist or hand or had undergone fusion, arthroplasty, tendon repair, synovectomy, or other related surgery of the hand or wrist in the past 3 months, the affected side was not tested. Prior to data collection, a practice session was conducted to acquaint participants with the instrument and adjust it appropriately. Each measurement was made with the participant seated, elbow slightly flexed, wrist in a neutral position, and the interphalangeal joint of the index finger at a 90° angle. The participant was instructed to squeeze the handle with maximal effort for 3–5 seconds. The measurement was repeated after a 10-second pause for recovery. The average of the two trials from the stronger hand was used in the analyses.

The dynapenia criteria was determined using the FNIH cut-points [45]: (1) non-dynapenic group (W: ≥20; M: ≥32); (2) dynapenic group (19.9≤W; 31.9 ≤M).

Laboratory Assays

Blood samples were collected in early morning, after a 12-hour fast. Blood sampling was postponed in the event of an acute infection. All blood was collected, processed, divided into aliquots, and stored locally at −80°C until shipment to the Wake Forest University, where samples were stored for long term at −80°C until analysis. Serum glucose and lipoprotein lipids were measured by the Esoterix Clinical Trial Services, a Division of LabCorp (Cranford, NJ), using enzymatic method.

Definition of Metabolic Syndrome (MetS)

The diagnosis of the MetS was based on the criteria of the National Cholesterol Education Program (Adult Treatment Panel III, NCEP ATP III) [46].

The MetS was diagnosed when three or more of the following were present: *1) waist circumference (WC)* greater than or equal to 102 cm in men and greater than or equal to 88 cm in women, *2) triglycerides* greater than or equal to 150 mg/dL or drug treatment for elevated triglycerides, *3) high-density lipoprotein cholesterol (HDL-C)* less than 40 mg/dL in men and less than 50 mg/dL in women or drug treatment for low HDL, *4) fasting glucose* greater than or equal to100 mg/dL or drug treatment for elevated glucose, and *5) systolic blood pressure (BP)* greater than or equal to 130 mmHg or diastolic BP greater than or equal to 85 mmHg or on antihypertensive drug treatment with a history of hypertension.

Statistical Analyses

Continuous data are presented as unadjusted means and *SD*, whereas categorical variables are presented as counts and percentages. T-tests were used to identify differences in psycho-social characteristics (age, income, education level, race, gender, smoking status, comorbidities), grip strength, BMI, metabolic factors (WC, lipoprotein blood levels, blood pressure, glycemic blood level), metabolic criteria (NCEP ATP III), and level of physical activity (CHAMPS score, accelerometry) between dynapenic and non-dynapenic groups separately by obesity status. Partial correlation analyses for metabolic profiles were conducted adjusting for: age, BMI, gender, race, smoking status, education; physical activity levels and comorbidities (heart attack, lung disease, diabetes, and arthritis). *Logistic regression* was used to identify odd ratios for dichotomized dependent variables of the metabolic criteria. All regressions were adjusted for age, BMI, gender, race, smoking status, education; physical activity levels and comorbidities. Data management and statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

Baseline characteristics of participants (Table 1)

The mean (± SD) age of included participants was 78.8 (± 5.3) years, 34% were men, and 21% were racial/ethnic minorities (non-white). Participants were divided into two groups based on obesity criteria. Thereafter, obese and non-obese participants were divided according to FNIH dynapenia criteria (dynapenic: n = 637 vs non-dynapenic: n = 816). Table 1 displays characteristics of participants according to dynapenia and obesity classification.

By definition, dynapenic-obese (DYN-O; n = 256) and non-dynapenic obese (NDYN-O; n = 414) groups had a higher BMI compared with dynapenic non-obese (DYN-NO; n = 381) and non-dynapenic non-obese (NDYN-NO; n=402) individuals ($p \leq 0.01$). In addition, DYN-O and DYN-NO groups had a lower handgrip strength (kg or kg/BW) compared with NDYN-O and NDYN-NO individuals ($p \leq 0.01$). DYN-O and DYN-NO groups had a lower level of physical activity (counts) compared with NDYN-O and NDYN-NO individuals ($p \leq 0.01$). No difference regarding gender (% of males), level of education, cognitive function (3MS) and some comorbidities (arthritis, diabetes etc.) were observed between the groups (see Table 1).

Increased likelihood of MetS and its components according to dynapenia and obesity status (Table 2)

We observed a significantly higher likelihood of having abdominal obesity criteria in NDYN-NO compared to DYN-NO groups ($p \leq 0.01$). Waist circumference was also significantly higher in obese groups (DYN-O/NDYN) than in non-obese (NDYN-NO/DYN-NO) ($p \leq 0.01$), and perhaps more interesting, waist circumference was also significantly higher in NDYN-O compared to DYN-O ($p = 0.008$). Additionally, NDYN-O had significantly higher diastolic blood pressure compared to DYN-O ($p \leq 0.001$). Regarding the metabolic components, no significant differences were found across dynapenia and obesity status for MetS, glucose, HDL, triglycerides, or systolic blood pressure. Finally, fasting

glucose, triglycerides, HDL, LDL, total cholesterol, blood pressure (diastolic and systolic) did not differ between obese and non-obese participants.

Correlation between grip strength and MetS components (Table 3)

Except for BMI ($p \leq 0.05$; $r^2=0.05$) in the obese group, and for waist circumference in all individuals together ($p \leq 0.05$; $r^2=0.03$), we observed no correlation between grip strength and continuously measured MetS components (glucose, blood pressure, TG, HDL, LDL) in all, obese and non-obese participants even after controlling for age, sex, and race/ethnicity.

The odds ratio of meeting MetS and its components

Table 4 shows that odds of MetS was not significantly different between obese and non-obese groups, even when combined with dynapenia.

DISCUSSION

The aim of this study was to verify whether dynapenia affect metabolic risk factors in obese and non-obese older adults. Contrary to our hypothesis, our results demonstrated that non-dynapenic non-obese individuals, compared to dynapenic obese ones, have significantly higher risk of abdominal obesity. In addition, a lower prevalence of cardiovascular and metabolic disease risk factors (i.e. blood pressure and waist circumference) was observed in non-dynapenic compared to dynapenic obese people (Table 2&3).

Moreover, the presence of dynapenia and obesity did not increase the odds of presenting metabolic disease risk factors (Table 2) which suggests that a lower level of muscle strength is associated with a favorable metabolic profile than higher levels of muscle strength in men and women aged 70 years and over. These findings are in agreement with those of Barbat-Artigas et al [40] which demonstrated that dynapenic-obese postmenopausal women (mean age 60±5 y) had a better metabolic profile than non-dynapenic obese women, suggesting that dynapenia has a protective effect on metabolic risk in older adults. Similar conclusions were drawn regarding sarcopenia by Aubertin-Leheudre et al. [16]. This cross-sectional study showed that sarcopenic-obese women had fewer metabolic risk factors predisposing to CVD than obese women (i.e. higher HDL levels, lower visceral and abdominal fat mass content, lower triglyceride levels and a better cholesterol/HDL-cholesterol ratio). In addition, sarcopenic women tended to have lower HOMA and fasting glucose levels. Finally, an epidemiological cross-sectional study including middle-aged individuals (40–75 years old) conducted by Castaneda et al. [19] also showed that sarcopenic obese Caucasian individuals had lower odds of having hyperinsulinemia (OR: 3.68 vs 19.6) and poor glycemic control (OR: 4.27 vs 7.98), concluding that sarcopenia was not a positive predictor of poor glycaemic control and thus, of diabetes.

In this regard, Lebon et al. recently concluded that in sedentary postmenopausal women lower muscle mass is not detrimental to insulin sensitivity even after adjusting for visceral fat mass [47]. Also, You et al. [48] reported that overweight and obese postmenopausal women with a higher skeletal muscle mass displayed a higher number of metabolic alterations—including impaired glucose homeostasis—compared to those with a normal metabolic profile.

In an attempt to interpret our findings, it can be argued that adipose tissue infiltration may have a major role if we consider that it is reduced in dynapenic individuals compared to non-dynapenic individuals. Recently, Barbat-Artigas et al. [39] and Goodpaster et al. [49] demonstrated that muscle quality (muscle strength/skeletal muscle mass) increased as skeletal muscle mass decreased, and the reduction in muscle mass was associated with lower muscle fat infiltration in obese individuals. This characteristic would predispose dynapenic people to present a better metabolic profile. Another potential explanation is that dynapenia occurs initially and mostly in peripheral upper and lower limbs (locomotor) which favor an accumulation of fat mass, more specifically intramuscular fat (IMAT), in peripheral members rather than in the abdominal area. Two studies observed an association between higher IMAT and reduced insulin resistance and an inverse association between HDL or blood pressure and IMAT in sedentary adults [50, 51].

In this sense, it was previously observed that skeletal muscle of trained endurance athletes is markedly insulin sensitive despite having an elevated intramyocelular lipid content [34] when compared to sedentary people [52]. It seems that skeletal muscle oxidative capacity (SMOC) play a role in this relationship because the SMOC is predictive of insulin action in sedentary and physically active individuals [53]. Moreover, type I muscle fibers are more sensitive to insulin compared with type II muscle fibers. Several previous studies reported that a higher proportion of type II instead of type I muscle fibers are associated with insulin resistance [54–56]. This observation is confirmed by Nyholm et al. who showed that first-degree relatives of type 2 diabetes patients who were insulin resistant had an increased number of type IIb muscle fibers [54]. Furthermore, Lillioja et al. observed significant correlations between insulin-stimulated glucose uptake and type I (positive) and type IIb (negative) muscle fibers in men [57]. Indeed, type II fibers are known to be positively associated with muscle strength [58]. It has also been reported that loss of leg muscle mass or strength in older adults is associated with a more prominent type II muscle fiber decline [59–61]. Therefore, it is possible that dynapenic people have a lower proportion of type II muscle fibers than non-dynapenic women, which explain the beneficial association between low muscle strength and insulin sensitivity.

This study is not without limitations. First, we used a cross-sectional approach, which does not allow us to draw conclusions regarding causal associations between dynapenia and metabolic syndrome. Second, we measured handgrip strength thus, these results may not be extrapolated to whole-body muscle strength. Third, we did not obtain any specific body composition data or muscle biopsies, so we could not confirm our hypothesis. Fourth, we did not measure the effects of dynapenia on physical function in the present study. However, we considered that many previous studies reported lower levels of muscle strength being associated with functional incapacities [26, 62]. Finally, the results of the present study should be considered preliminary, but they may hopefully stimulate interest in the characterization of dynapenic obese individuals using clinical criteria.

The major strength of this study is that a huge community-based sample of older adults was investigated and, especially persons susceptible to an increased risk of mobility disability. It is noteworthy that important confounding factors were taken into account, avoiding the influence of factors other than those of interest.

CONCLUSION

In conclusion, our results indicate that non-obese dynapenic older adults have fewer metabolic disease risk factors than non-obese non-dynapenic elderly people. Among obese, older adults, dynapenia was associated with lower risk of meeting metabolic syndrome criteria for waist circumference and diastolic blood pressure. Thus, in obese older adults dynapenia may have protective effects on metabolic disease risk. Our findings have clinical implications and suggest that metabolic disease risk is not increased by the presence of dynapenia in obese individuals. Further research is needed to explore the potential mechanisms underlying these observed associations.

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Table 1

Characteristics of participants according to obesity & dynapenia classification (N=1453)

Description	Non-Obese group (n = 783)			Obese group (n= 670)		
	Non-Dynapenic N=402	Dynapenic N=381	P-value	Non-Dynapenic N=414	Dynapenic N=256	P-value
Age (yrs)	79.2 ± 5.1	81.5 ± 5.0	**<.0001**	76.3 ± 4.7	78.0 ± 4.6	**<.0001**
BMI (kg/m2)	26.2 ± 2.7	25.5 ± 2.8	**0.002**	35.6 ± 4.8	34.9 ± 4.3	**0.042**
Handgrip (kg)	28.9 ± 9.1	18.7 ± 6.5	**<.0001**	29.7 ± 9.0	18.4 ± 5.8	**<.0001**
Handgrip/BW (kg/kg)	0.40 ± 0.11	0.27 ± 0.08	**<.0001**	0.30 ± 0.08	0.20 ± 0.06	**<.0001**
Male (%)	138 (34.3)	145 (38.1)	0.28	136 (32.9)	77 (30.1)	0.45
White (%)	324 (80.6)	331 (87.1)	**0.014**	291 (70.6)	200 (78.4)	**0.026**
Max educ: College or more	279 (69.4)	250 (66.0)	0.30	242 (58.6)	159 (62.1)	0.37
3MS (X/100)	91.8 ± 5.3	91.1 ± 5.4	0.07	91.9 ± 5.3	92.4 ± 5.0	0.26
Heart Attack: (n: (%))	34 (8.5)	29 (7.7)	0.25	20 (4.9)	25 (9.8)	**0.03**
Lung Disease: (n: (%))	58 (14.5)	57 (15.1)	0.78	54 (13.1)	55 (21.5)	**0.014**
Arthitis or Rhem: (n: (%))	58 (14.4)	68 (18.1)	0.17	85 (20.6)	56 (22.0)	0.68
Diabetes: (n: (%))	87 (21.8)	72 (19.0)	0.50	133 (32.3)	81 (31.6)	0.96
Total PA per day (counts)	95617 ± 49660	84046 ± 51892	**0.005**	94160 ± 49862	84995 ± 43571	**0.029**
Avg steps/day (n)	2938 ± 1573	2703 ± 1703	0.07	2622 ± 1327	2406 ± 1199	**0.056**
Avg Min >500 counts/day	55.8 ± 36.6	46.0 ± 35.2	**.0008**	57.3 ± 38.3	49.8 ± 34.4	**0.021**
Total CHAMPS score	21.6 ± 37.1	16.3 ± 31.2	**0.03**	16.7 ± 33.1	16.3 ± 33.2	0.89

Table only includes LIFE study participants with sufficient grip strength and metabolic syndrome data.

Continuous measures reported as mean ± SD, while categorical measures are reported as N (%).

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Table 2

Metabolic syndrome characteristics of participants according to obesity & dynapenia classification. N=1453

Description	Non-Obese group (n = 783)			Obese group (n = 670)		
	Non-Dynapenic N=402	Dynapenic N=381	P-value	Non-Dynapenic N=414	Dynapenic N=256	P-value
Waist Circ (cm)	93.1 ± 10.7	92.2 ± 11.2	0.22	114.0 ± 12.9	**111.2 ± 13.1**	**0.008**
Systolic (mmHg)	127.7 ± 18.1	125.9 ± 19.6	0.17	128.3 ± 16.3	127.4 ± 17.8	0.46
Diastolic (mmHg)	67.0 ± 10.0	67.1 ± 10.4	0.91	70.9 ± 10.1	**67.7 ± 9.7**	**<.0001**
LDL (mg/dL)	93.5 ± 33.3	92.5 ± 32.6	0.67	94.9 ± 32.6	92.1 ± 31.8	0.29
HDL (mg/dL)	63.2 ± 18.8	64.0 ± 19.3	0.59	57.6 ± 14.8	58.2 ± 15.5	0.58
Triglycerides (mg/dL)	112.9 ± 53.3	116.1 ± 59.9	0.44	131.4 ± 59.3	131.4 ± 56.9	1.00
Total Cholesterol (mg/dL)	179.2 ± 41.9	179.7 ± 41.1	0.88	178.8 ± 37.2	176.6 ± 38.2	0.48
Glucose (mg/dL)	101.2 ± 20.6	100.7 ± 23.2	0.76	108.7 ± 27.4	106.3 ± 22.4	0.23
MetS Abdominal Obesity (n (%))	**222 (55.6)**	170 (45.1)	**0.003**	409 (99.3)	251 (98.0)	0.16
MetS Glucose (n (%))	173 (43.4)	153 (40.2)	0.33	256 (61.8)	155 (60.5)	0.74
MetS HDL (n (%))	74 (18.5)	69 (18.2)	0.84	113 (27.6)	69 (27.6)	0.98
MetS triglycerides (n (%))	97 (24.3)	91 (24.1)	0.87	152 (37.2)	87 (34.7)	0.52
MetS Blood Pressure (n (%))	301 (74.9)	281 (73.8)	0.44	358 (86.5)	208 (81.3)	0.09
Metabolic Syndrome (n (%))	154 (38.3)	122 (32.0)	0.056	284 (68.6)	168 (65.6)	0.42

Table only includes LIFE study participants with sufficient grip strength and metabolic syndrome data.

Continuous measures reported as mean ± SD, while categorical measures are reported as N (%).

Table 3

Partial correlation coefficients between grip strength and components of the metabolic syndrome.

Variable	Subgroup	BMI		Waist circumference		Glucose		Systolic BP		Diastolic BP		TG		HDL		LDL	
		Part r	P-value	Part r	P-value	Part r	P-value	Part r	P-value	Part r	P-value	Part r	P-value	Part r	P-value	Part r	P-value
Grip Strength	All	0.04	0.15	0.06	**0.04**	0.00	0.95	0.04	0.21	0.03	0.39	−0.01	0.75	−0.04	0.24	−0.00	0.90
	Obese	0.09	**0.03**	0.07	0.11	−0.02	0.65	0.05	0.26	−0.01	0.81	−0.06	0.14	−0.02	0.58	−0.04	0.39
	Non-obese	0.00	0.96	0.04	0.33	0.02	0.70	0.01	0.79	0.06	0.17	0.02	0.69	−0.03	0.44	0.03	0.51

Adjusted for age, sex, race/ethnicity, education, smoking, physical activity, comorbidities, and BMI (BMI model not adjusted for BMI)

Table 4

Odds of meeting metabolic syndrome and its components

Outcome	Non-Obese Group OR (95% CI)	Obese Group OR (95% CI)
Metabolic Syndrome	0.84 (0.56,1.25)	0.81 (0.53,1.23)
MetS Abdominal Obesity	0.89 (0.59,1.35)	0.32 (0.04,2.54)
MetS Glucose	0.87 (0.58,1.31)	0.83 (0.54,1.29)
MetS HDL	1.12 (0.71,1.77)	0.86 (0.56,1.31)
MetS Blood Pressure	0.93 (0.62,1.39)	0.82 (0.49,1.36)
MetS Triglycerides	1.08 (0.71,1.62)	0.80 (0.54,1.19)

*All models adjusted for age, sex, race/ethnicity, education, smoking, physical activity, comorbidities, and BMI