

Sarcopenia is associated with hypertension in older adults: a systematic review and meta-analysis

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Abstract

Background: Sarcopenia and handgrip strength have been observed and correlated in association with hypertension among the old-age people. However, the results reported in different studies were inconsistent. In the current study, we conducted a systematic review and meta-analysis to reveal the significant association between sarcopenia, handgrip strength, and hypertension in older adults. **Methods:** PubMed, MEDLINE, Cochrane Library, and EMBASE databases were searched from inception to 15 November, 2019 to retrieve the original research studies that addressed the association between sarcopenia, handgrip strength, and hypertension. All the relevant data were retrieved, analyzed, and summarized. **Results:** 19 studies met the inclusion criteria and a total of 21301 participants were included in the meta-analysis. Eight eligible studies have reported the odd ratios (ORs) of hypertension and the ORs ranged from 0.41 to 4.38. When pooled the ORs together, the summarized ORs was 1.29 [95% confidence interval (CI) =1.00-1.67]. The summarized ORs for the Asian group 1.50 (95% CI=1.35-1.67) was significantly higher than that of Caucasian group 1.08 (95% CI=0.39-2.97). Eleven studies have provided the data on association between handgrip strength and hypertension. The overall ORs and 95% CI was 0.99 (95% CI=0.80-1.23), showing no significant association. **Conclusion:** Sarcopenia was associated with hypertension, but no correlation was found between handgrip strength and hypertension in older adults.

Background

The number of elderly people among the world population is expected to reach about 30% by the year 2050 [1]. However, the aging process is accompanied with alterations in some physiological systems collaborating to the development of geriatric syndromes and chronic diseases. It was previously reported that hypertension is affecting more than 70% of the older people [2] and predisposing them to an increased risk of stroke (i.e., hemorrhagic and ischemic) and myocardial infarction [2,3]. In the past few years, a large number of studies have indicated that hypertension is predominantly associated with elevated cardiovascular risk [4-6].

Recently, data from population studies have demonstrated that sarcopenia, a neuromuscular disease characterized by a progressive muscular atrophy accompanied by diminished muscle strength and/or lower muscle limb function, could be a risk factor of hypertension [7-9]. This definition of sarcopenia consensuses by European geriatric and gerontological societies proposed a mandatory measurement of the muscle mass with an option to measure either the muscle strength by hand grip or physical performance by gait speed [10]. Meanwhile, sarcopenia has been demonstrated to have substantial associations with the aging process and can lead to significant morbidity and disability, including the loss of independence, poor quality of life, and mortality [11-14]. Sarcopenia had been reported with several contributing factors, such as primarily advanced age, immobility, inadequate nutrition, neurodegenerative disease, malignancy, chronic multiple endocrine disorders, and cardiometabolic disease. Moreover, the rate of sarcopenia in the elderly is expected to increase in the future [15] and is becoming a major public health problem [16]. Reduced muscle mass has been characterized in association with other cardiovascular risk factors to induce arterial stiffness [17], and is suggested as the main additive effects of low muscle mass on blood pressure.

The handgrip strength examination is often applied as a diagnostic approach for sarcopenia in clinical setting, and such a measure is considered inexpensive, simple, easy, and can be implemented with portable

measuring tool. Up to now, a significant association between sarcopenia and grip strength, and hypertension in older adults were controversial [7-9,18,19] and has not been systemically summarized. Therefore, a comprehensive investigation on this topic might allow an early detection of the key risk factors of hypertension in elderly patients suffering with sarcopenia and may help to effectively organize prevention or treatment strategies associated with specific vulnerability factors.

Methods

Literature Search

A literature search was conducted using the individual and joint keywords, “handgrip strength”, “grip strength”, “sarcopenia”, and “hypertension” following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [20]. To enhance the retrieval of potential literatures, we kept the search terms as broadly as possible to identify the relevant publications. A systematic electronic data search of PubMed, MEDLINE, Cochrane Library, and EMBASE databases were performed up to 15 November, 2019. Moreover, the bibliographies of all relevant studies and reviews, and Google Scholar for literatures citing relevant studies were also checked and identified.

Eligibility Criteria

The inclusion criteria were as follows: (1) The observational studies addressing the association between sarcopenia and hypertension, or handgrip strength and hypertension; (2) studies providing clear diagnostic criteria of sarcopenia and hypertension; (3) necessary data extracted from original studies; (4) studies published in English; and (5) only the study providing more detailed information was included if the population was reported in duplicate.

Reviews, case reports, abstracts or posters for conferences, studies focused on animal experiments or experiments *in vitro*, and studies published in languages other than English were excluded.

Data extraction

Two investigators (TTB and FF) have independently extracted the necessary information of included studies using a customized and standardized form, and the consensus were reached on all items by these two authors. For each included study, the following information were extracted: the author and year of publication, country, study design, sample size, patient demographic characteristics (e.g., age, sex, and nation), diagnostic criteria of sarcopenia and hypertension, sample size and characteristics for each group, follow-up period, and outcomes of each group.

Quality scoring of studies

Two reviewers (FKL and JMC) have assessed the methodological strength of included studies independently in order to interpret the validity of any findings observed through the Newcastle-Ottawa Scale (NOS), a procedure performed to independently assess the methodological quality of meta-analysis of observational studies [21]. Newcastle-Ottawa Scale included three categories of factors: (1) patient selection (three items); (2) comparability of the two study arms (two items); and (3) assessment of the outcomes (two items). The

detailed criteria for the three assessments are: whether the cases were defined adequately, the representativeness of the cases, the process of selection and definition of controls, comparability of cases and controls based on the design or analysis, ascertainment of exposure, the same method of ascertainment for cases and controls, and nonresponse rate.

Studies were awarded one star for each numbered item within the selection and exposure categories, and one or two stars for comparability. Studies were graded on an ordinal scoring scale. The scores ranged from 2 to 9 stars. Therefore, a scale of 0 to 4 stars was considered as poor quality, 5 to 6 stars as moderate quality, and 7 to 9 stars as high quality.

Statistical analysis

The inverse variance method with random effects was conducted to summarize the dichotomous outcomes, odd ratios (ORs), and 95% confidence intervals (CIs). Stratified analyses were also performed with respect to the characteristics of the study population and outcome. Heterogeneity between included studies was assessed using the I^2 and Q tests. Heterogeneity was defined as low, moderate, and high to I^2 values of 25%, 50%, and 75%, respectively [22]. The Begg rank correlation [23] and Egger weighted regression methods [24] were used to assess the publication bias ($P < 0.05$ was considered indicative of a statistically significant publication bias). Review Manager (Version 5.3, The Cochrane Collaboration, Oxford, UK) was used for generation of forest plot and statistical analyses. The Begg and Egger tests were assessed by STATA 15.0 (Stata Corporation, College Station, TX, USA). A P value of $< .05$ was considered significant for all analysis.

Results

Study selection

In total, 1221 studies were retrieved as potentially relevant literature reports through the initial searches in different databases and after removing the duplicates, 1013 were left. Majority of potentially irrelevant literatures were excluded after reviewing the browsing title or abstract. After retrieving 30 full-length manuscripts, finally, 12 articles [7-9,18,19,25-31] of 19 studies were eligible for data extraction and meta-analysis. The flow chart of the studies enrolled in the current study can be found in **Figure 1**.

Study characteristics

19 studies (12 articles) met the inclusion criteria and a total of 21301 participants were included in the study. Four articles [8, 16, 24, 29] were divided into two or four studies as the participants were categorized into several groups according their characteristics. Eight studies [7-9,19,28-30] addressed the association between sarcopenia and hypertension, and 11 studies [18,25-27,31] focused on the association between handgrip strength and hypertension. The sarcopenia was defined by three methods, the European Working Group on Sarcopenia in Older People (EWGSOP) criteria [32], the Asian Working Group for Sarcopenia (AWGS) criteria, and ASM/weight (kg) less than one standard deviation (SD). The hypertension was defined as systolic blood pressure (SBP) >140 mmHg or diastolic blood pressure (DBP) >90 mmHg. Handgrip strength was diagnosed by dynamometers according to the protocol from the Institute of Medicine [33]. The included studies were published between 2013 and 2019 and the sample size ranged from 72 to 4771. The participants'

demographic characteristics in the included studies can be found in **Supplementary Table 1** and **Supplementary Table 2**.

Six studies were conducted in China [18,19,28,31], two each in Republic of Korea [8] and Japan [26], and United States [9,25,34,35], one each in Turkey [30], Switzerland [27], Italy [7], and Spain [29]. Most of the studies were cross-sectional studies except two cohort studies [7,9]. The characteristics of the included studies and patients were summarized in **Table 1** and **Table 2**.

Quality assessment of studies

Newcastle-Ottawa Scales for the eligible studies were presented in **Supplementary Table 3** and all included studies were found to exhibit an acceptable quality. Four studies were evaluated as 6 stars, 6 studies were 7 stars, and 2 studies were 8 stars.

The association between sarcopenia and hypertension

All the eight eligible studies have reported the ORs of hypertension, and the ORs ranged from 0.41 to 4.38. When pooled the ORs together, the summarized ORs was 1.29 (95% CI=1.00-1.67, $P=0.04$) with a moderate heterogeneity ($I^2 = 74\%$). The detailed information could be found in **Figure 2** and **Supplementary Figure 1**.

To explore the sources of heterogeneity, the subgroup analysis was performed by categorizing the studies according to the ethnicity of the participants and the Newcastle-Ottawa Scales than were equal to or more than 7 stars. The Asian group included 4 studies from China and Korea, the Caucasian group included four studies conducted in United States, Italy, Spain, and Turkey. The summarized ORs for the Asian group 1.50 (95% CI = 1.35-1.67, $P = 0.00$) was significantly higher than that of Caucasian group 1.08 (95% CI=0.39-2.97, $P=0.88$). The heterogeneities for the two subgroups were significantly decreased to $I^2 = 34\%$ and $I^2 = 40\%$. When the studies with low quality were removed (Newcastle-Ottawa Scales<6), the overall OR were 1.53 (95%CI = 1.37-1.71, $P = 0.00$) with lower heterogeneity ($I^2 = 2.62\%$). More data is presented in **Figure 3** and **Figure 4**.

The association between handgrip strength and hypertension

Eleven studies have provided the data on association between handgrip strength and hypertension, and among them ten studies have reported the odds ratios and 95% CI. The overall odds ratios and 95% CI was 0.99 (95% CI=0.80-1.23, $P=0.93$) with a higher heterogeneity ($I^2 = 76\%$) and significant publication bias ($P < 0.01$). The detailed data can be found in **Figure 5**.

As shown in **Figure 6** and **Figure 7**, in order to explore the sources of heterogeneity and publication bias, the included studies were categorized into two groups by the gender of the participants. For the males, the pooled OR was 1.14 (95%CI=0.91-1.43, $P=0.27$) with an acceptable heterogeneity ($I^2 = 31\%$) and without publication bias ($P > 0.05$). The female group was not showing any statistically significant difference with an OR as 0.81 (95%CI=0.52-1.26, $P=0.34$, $I^2 = 45\%$) without publication bias ($P > 0.05$).

Seven studies have reported the β value and standard error of the linear regression on hypertension and the pooled β value was -1.57 with an SE equal to 1.03, and the heterogeneity was 99%. As two studies have provided the data on different body mass indexes, two more subgroup analysis were done, such as underweight or normal body mass index group (OR=1.04, 95%CI=0.81-1.33, $P=0.77$), and overweight or obese body mass index group (OR=1.18, 95%CI=0.94-1.41, $P=0.16$). The data was presented in **Supplementary Figure 3** and **Supplementary Figure 4**.

Publication bias

Most of the analysis except one has shown potential publication bias among the included trials according to Begg rank correlation analysis and Egger weighted regression analysis (P value of the analysis was more than 0.05). The detailed potential publication bias of each analysis can be found in **Supplementary Table 4**

Discussion

To the best of our knowledge, the current meta-analysis is the first systematic review and meta-analysis study summarizing the association between sarcopenia and hypertension, and the association of handgrip strength and hypertension. 19 studies with 21301 participants were included, among which eight studies have addressed the association between sarcopenia and hypertension and indicated that sarcopenia was a risk factor for the hypertension. 11 studies have focused on the association between handgrip strength and hypertension and was found by the pooled results.

As a standard definition for sarcopenia is lacking, the current study proved that sarcopenia was a risk factor for hypertension. Several prospective and cross-sectional studies have found the correlation between sarcopenia and hypertension [8,19]. The prevalence of sarcopenia can vary dramatically depending on the definition of sarcopenic obesity. In the current study, Asian Working Group for Sarcopenia (AWGS) criteria and the European Working Group on Sarcopenia in Older People (EWGSOP) criteria were used, which showed significantly different odds ratio. This might partly explain that Asian groups had a stronger association with hypertension than that of Caucasian group. Many potential mechanisms for sarcopenia have been researched, such as chronic inflammation [36], and its relevant catabolic cytokines remain the most widely accepted mechanism of sarcopenia [36]. It was also reported that the chronic inflammation and its relevant catabolic cytokines production is the major risk factor for age-related chronic diseases, such as hypertension [8]. Sarcopenia now needs to be recognized in routine clinical settings. Frailty is the most problematic expression of population ageing. It is a state of vulnerability to poor resolution of homeostasis and is a consequence of cumulative decline in many physiological systems during a lifetime. The adverse outcomes of infirmity might be mediated by sarcopenia, which may be considered the biological substrate for the development of frailty and the related negative health outcomes [37]. Most importantly, it is becoming exceedingly important for us to verify whether preventive strategies focusing on the early detection and treatment of sarcopenia could get better survival in the older people.

In the current study, handgrip strength was significantly associated with hypertension in both men and women, and these result was controversial in various other studies [26,27]. The specific biological mechanism linking grip strength and sarcopenia with hypertension is largely unknown. However, the regular exercise,

which has been shown consistently in plenty of studies to improve the blood pressure, may eventually improve the mitochondrial functions, reduce inflammation, enhance metabolic functions and alleviate sarcopenia symptoms [38].

It is necessary to consider the limitations of the present meta-analysis while interpreting the results. First, the definition of sarcopenia was inconsistent in different studies and the variations in assessment of sarcopenia across studies could have caused methodological limitations and compromised the results. Second, the number of the included studies was limited and majority of them were from Asian countries. As the sarcopenia might be affected by the economic level, medical stage, and genetic factors, the associations between sarcopenia, handgrip strength, and hypertension in different countries could be different. Therefore, the result in the current study can only partly annotate the associations. Third, almost all of the studies addressing the sarcopenia did not provide the specific sarcopenia symptoms by gender and age. Due to the limited sample size and information in each studies, we could not perform more subgroups or sensitivity analyses, especially on the sensitivity analyses based on the age and sex. Moreover, due to the large disparity in the numbers of participants among the included studies, the conclusions related to the association of sarcopenia with hypertension might be overstated. Four, potential language bias might have existed because our literature searches only considered articles published in English.

Conclusions

In conclusion, our meta-analysis provided pooled results based on 19 studies from eight different regions or countries and summarized a large data set of 21301 participants. The current study highlighted that sarcopenia was significantly associated with hypertension. In the future, by stratifying patients, efforts must be made to prevent and treat sarcopenia in the older population, which would also decrease the risk and the comorbidities of hypertension. At the same time, performing larger sample size studies from different countries in future may substantially corroborate the conclusive remarks derived from this study.

List Of Abbreviations

ORs: Odd ratios;

CI: Confidence interval;

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses;

NOS: Newcastle-Ottawa Scale;

AWGS: Asian Working Group for Sarcopenia;

EWGSOP: European Working Group on Sarcopenia in Older People.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Study concept: JMC and TTB. Study design: JMC, TTB and FF. Data acquisition: TTB, FF and FKL. Quality control of data and algorithms: JMC and FKL. Data analysis and interpretation: TTB, YR and JAH. Manuscript preparation: TTB and FF. Manuscript editing: TTB and FKL. Manuscript review: JMC and JAH. All authors (TTB, FF, FKL, YR, JAH, JMC) have read and approved the final version of the manuscript.

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References

1. Nations U. *World Population Prospects*. New York: United Nations Publications; 2017.
2. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, et al. Heart Disease and Stroke Statistics-2016 Update: A Report From the American Heart Association. *Circulation*. 2016;133(4):e38-360. doi: 10.1161/cir.0000000000000350.
3. Organization WH. *Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks*. Geneva, Switzerland World Health Organization; 2009.
4. McLaughlin VV, Vachieri JL, Oudiz RJ, Rosenkranz S, Galie N, Barbera JA, et al. Patients with pulmonary arterial hypertension with and without cardiovascular risk factors: Results from the AMBITION trial. *The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation*. 2019;38(12):1286-95. doi: 10.1016/j.healun.2019.09.010.
5. Cingolani OH. Cardiovascular Risks and Organ Damage in Secondary Hypertension. *Endocrinology and metabolism clinics of North America*. 2019;48(4):657-66. doi: 10.1016/j.ecl.2019.08.015.

6. Nieman LK. Hypertension and Cardiovascular Mortality in Patients with Cushing Syndrome. *Endocrinology and metabolism clinics of North America*. 2019;48(4):717-25. doi: 10.1016/j.ecl.2019.08.005.
7. Landi F, Cruz-Jentoft AJ, Liperoti R, Russo A, Giovannini S, Tosato M, et al. Sarcopenia and mortality risk in frail older persons aged 80 years and older: results from the iSIRENTE study. *Age and ageing*. 2013;42(2):203-9. doi: 10.1093/ageing/afs194.
8. Han K, Park YM, Kwon HS, Ko SH, Lee SH, Yim HW, et al. Sarcopenia as a determinant of blood pressure in older Koreans: findings from the Korea National Health and Nutrition Examination Surveys (KNHANES) 2008-2010. *PLoS one*. 2014;9(1):e86902. doi: 10.1371/journal.pone.0086902.
9. Koo BK, Kim D, Joo SK, Kim JH, Chang MS, Kim BG, et al. Sarcopenia is an independent risk factor for non-alcoholic steatohepatitis and significant fibrosis. *Journal of hepatology*. 2017;66(1):123-31. doi: 10.1016/j.jhep.2016.08.019.
10. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age and ageing*. 2010;39(4):412-23. doi: 10.1093/ageing/afq034.
11. Woodrow G. Body composition analysis techniques in the aged adult: indications and limitations. *Current opinion in clinical nutrition and metabolic care*. 2009;12(1):8-14. doi: 10.1097/MCO.0b013e32831b9c5b.
12. Narici MV, Maffulli N. Sarcopenia: characteristics, mechanisms and functional significance. *British medical bulletin*. 2010;95:139-59. doi: 10.1093/bmb/ldq008.
13. Dip RM, Cabrera MA, Prato SF. Association between body composition and stair negotiation ability among individuals >55 years of age: a cross-sectional study. *Clinical interventions in aging*. 2017;12:1289-96. doi: 10.2147/cia.s126779.
14. Cawthon PM, Marshall LM, Michael Y, Dam TT, Ensrud KE, Barrett-Connor E, et al. Frailty in older men: prevalence, progression, and relationship with mortality. *Journal of the American Geriatrics Society*. 2007;55(8):1216-23. doi: 10.1111/j.1532-5415.2007.01259.x.
15. Landi F, Calvani R, Lorenzi M, Martone AM, Tosato M, Drey M, et al. Serum levels of C-terminal agrin fragment (CAF) are associated with sarcopenia in older multimorbid community-dwellers: Results from the iSIRENTE study. *Experimental gerontology*. 2016;79:31-6. doi: 10.1016/j.exger.2016.03.012.
16. Curcio F, Ferro G, Basile C, Liguori I, Parrella P, Pirozzi F, et al. Biomarkers in sarcopenia: A multifactorial approach. *Experimental gerontology*. 2016;85:1-8. doi: 10.1016/j.exger.2016.09.007.
17. Snijder MB, Henry RM, Visser M, Dekker JM, Seidell JC, Ferreira I, et al. Regional body composition as a determinant of arterial stiffness in the elderly: The Hoorn Study. *Journal of hypertension*. 2004;22(12):2339-47. doi: 10.1097/00004872-200412000-00016.
18. Ji C, Zheng L, Zhang R, Wu Q, Zhao Y. Handgrip strength is positively related to blood pressure and hypertension risk: results from the National Health and nutrition examination survey. *Lipids in health and disease*. 2018;17(1):86. doi: 10.1186/s12944-018-0734-4.
19. Xu HQ, Shi JP, Shen C, Liu Y, Liu JM, Zheng XY. Sarcopenia-related features and factors associated with low muscle mass, weak muscle strength, and reduced function in Chinese rural residents: a cross-sectional study. *Archives of osteoporosis*. 2018;14(1):2. doi: 10.1007/s11657-018-0545-2.

20. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ (Clinical research ed.)*. 2009;339:b2700. doi: 10.1136/bmj.b2700.
21. G W. The Newcastle Ottawa Scale (NOS) for assessing the quality of non-randomised studies in meta-analysis. Paper presented at: Proceedings of the Third Symposium on Systematic Reviews2000; England.
22. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ (Clinical research ed.)*. 2003;327(7414):557-60. doi: 10.1136/bmj.327.7414.557.
23. Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. *Biometrics*. 1994;50(4):1088-101.
24. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ (Clinical research ed.)*. 1997;315(7109):629-34. doi: 10.1136/bmj.315.7109.629.
25. Mainous AG, 3rd, Tanner RJ, Anton SD, Jo A. Grip Strength as a Marker of Hypertension and Diabetes in Healthy Weight Adults. *American journal of preventive medicine*. 2015;49(6):850-8. doi: 10.1016/j.amepre.2015.05.025.
26. Kawamoto R, Ninomiya D, Kasai Y, Kusunoki T, Ohtsuka N, Kumagi T, et al. Handgrip strength is associated with metabolic syndrome among middle-aged and elderly community-dwelling persons. *Clinical and experimental hypertension (New York, N.Y. : 1993)*. 2016;38(2):245-51. doi: 10.3109/10641963.2015.1081232.
27. Gubelmann C, Vollenweider P, Marques-Vidal P. Association of grip strength with cardiovascular risk markers. *European journal of preventive cardiology*. 2017;24(5):514-21. doi: 10.1177/2047487316680695.
28. Han P, Yu H, Ma Y, Kang L, Fu L, Jia L, et al. The increased risk of sarcopenia in patients with cardiovascular risk factors in Suburb-Dwelling older Chinese using the AWGS definition. *Scientific reports*. 2017;7(1):9592. doi: 10.1038/s41598-017-08488-8.
29. Coto Montes A, Boga JA, Bermejo Millo C, Rubio Gonzalez A, Potes Ochoa Y, Vega Naredo I, et al. Potential early biomarkers of sarcopenia among independent older adults. *Maturitas*. 2017;104:117-22. doi: 10.1016/j.maturitas.2017.08.009.
30. Can B, Kara O, Kizilarlanoglu MC, Arik G, Aycicek GS, Sumer F, et al. Serum markers of inflammation and oxidative stress in sarcopenia. *Aging clinical and experimental research*. 2017;29(4):745-52. doi: 10.1007/s40520-016-0626-2.
31. Zhang X, Huang L, Peng X, Xie Y, Bao X, Huang J, et al. Association of handgrip strength with hypertension among middle-aged and elderly people in Southern China: A cross-sectional study. *Clinical and experimental hypertension (New York, N.Y. : 1993)*. 2019:1-7. doi: 10.1080/10641963.2019.1601206.
32. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age and ageing*. 2019;48(4):601. doi: 10.1093/ageing/afz046.
33. Pate RR, Daniels S. Institute of Medicine report on fitness measures and health outcomes in youth. *JAMA pediatrics*. 2013;167(3):221-2. doi: 10.1001/jamapediatrics.2013.1464.
34. Pinero F, Mendizabal M, Quiros R, Fauda M, Arufe D, Gonzalez Campana A, et al. Neurological events after liver transplantation: a single-center experience. *Transplant international : official journal of the European*

- Society for Organ Transplantation. 2014;27(12):1244-52. doi: 10.1111/tri.12404.
35. Kork F, Rimek A, Andert A, Becker NJ, Heidenhain C, Neumann UP, et al. Visual quality assessment of the liver graft by the transplanting surgeon predicts postreperfusion syndrome after liver transplantation: a retrospective cohort study. *BMC anesthesiology*. 2018;18(1):29. doi: 10.1186/s12871-018-0493-9.
 36. Schragger MA, Metter EJ, Simonsick E, Ble A, Bandinelli S, Lauretani F, et al. Sarcopenic obesity and inflammation in the InCHIANTI study. *Journal of applied physiology* (Bethesda, Md. : 1985). 2007;102(3):919-25. doi: 10.1152/jappphysiol.00627.2006.
 37. Liguori I, Russo G, Aran L, Bulli G, Curcio F, Della-Morte D, et al. Sarcopenia: assessment of disease burden and strategies to improve outcomes. *Clinical interventions in aging*. 2018;13:913-27. doi: 10.2147/cia.s149232.
 38. Lackland DT, Voeks JH. Metabolic syndrome and hypertension: regular exercise as part of lifestyle management. *Current hypertension reports*. 2014;16(11):492. doi: 10.1007/s11906-014-0492-2.

Tables

Table 1. Demographic and clinical characteristics of the subjects included in studies that focused on sarcopenia

Study included	No. of sarcopenia patients HTN (-)/HTN (+)	No. of non-sarcopenia patients HTN (-)/HTN (+)	Means±SD (mmHg, non-sarcopenia/sarcopenia)		% of participants taking antihypertensive drugs	Odd ratios (95% CI) ^c
			SBP	DBP		
Han, et.al., 2014 ^a	2326/1156	894/544	126.40±0.50/ 129.30±0.90	74.30±0.30/ 75.10±0.50	33.00±1.30/ 45.30±1.90	1.50 (1.23-1.84)
Han, et.al., 2014 ^b	594/393	1032/771	129.90±0.80/ 131.20±0.70	76.90±0.50/ 77.60±.40	52.00±2.40/ 62.30±1.90	NA
Koo, et.al., 2016	239/98	70/41	98.10 ± 14.8/ 127.9 ± 17.4	77.8 ± 11.0/ 77.2 ± 11.5	NA	NA
Can, et.al., 2016	36/4	36/12	NA	NA	NA	NA
Han, et.al., 2017	634/267	77/36	NA	NA	NA	NA
Montes, et.al., 2017	148/116	52/33	NA	NA	NA	NA
Xu, et.al., 2019	4459/NA	312/NA	NA	NA	NA	1.44 (1.16-1.78)

Abbreviations: HTN, Hypertension; SD, standard deviation; SBP, systolic blood pressure; DBP, diastolic blood pressure; CI, confidence interval; NA, not available.

^a participants whose BMI was less than 25.00 kg/m².

^b participants whose BMI was equal or more than 25.00 kg/m².

^c Odd ratios stands for hypertension with sarcopenia compared to without sarcopenia.

Table 2. Demographic characteristics of the subjects included in studies that focused on handgrip strength

Study included	Sample size	Handgrip strength (means±SD, per kg)	Odd ratios (95% CI) for High blood pressure ^g	β of linear regression (standard error)
Mainous, et.al., 2015	1469	60.8±1.61 ^a /71.5±0.84 ^b	NA	-4.93 (0.03)
Kawamoto, et.al., 2016 ^a	742	33.40±7.50	0.78 (0.66, 0.94)	NA
Kawamoto, et.al., 2016 ^b	937	21.30±4.10	0.72 (0.62, 0.83)	NA
Gubelmann, et.al., 2017 ^a	1891	NA	1.23 (1.04-1.46)	NA
Gubelmann, et.al., 2017 ^b	1577	NA	1.01 (0.80-1.27)	NA
Ji, et.al., 2018 ^a	2184	41.50 ± 8.80	1.23 (1.04, 1.46)	0.21 (0.09)
Ji, et.al., 2018 ^b	2413	26.70 ± 5.70	1.01 (0.80, 1.27)	0.01 (0.12)
Ji, et.al., 2018 ^c	563	NA	1.14 (0.83, 1.55)	0.13 (0.16)
Ji, et.al., 2018 ^d	1292	NA	1.29 (1.04, 1.59)	0.030 (0.17)
Ji, et.al., 2018 ^d ^e	636	NA	0.88 (0.58, 1.33)	-0.13 (0.21)
Ji, et.al., 2018 ^d ^f	1323	NA	1.02 (0.76, 1.38)	0.02 (0.15)
Zhang, et.al., 2019 ^a	515	35.94±19.72	0.55 (0.28, 1.08)	NA
Zhang, et.al., 2019 ^b	637	14.45±10.41	0.19 (0.07, 0.55)	NA

Abbreviations: CI, confidence interval; SD, Standard deviation; NA, not available.

^a, males.

^b, females.

^c, Underweight or normal body mass index of males.

^d, Underweight or normal body mass index of females.

^e, Overweight body mass index of males.

^f, Overweight or obese body mass index of females.

^g, Odd ratios stands for hypertension with sarcopenia compared to without sarcopenia.

Additional Files

Additional file 1(.doc)

Supplementary Figure 1. Funnel plot for the overall odds ratio of hypertension among sarcopenia and non-sarcopenia patients.

Supplementary Figure 2. Funnel plot for the odds ratio of handgrip strength among hypertension and non-hypertension patients.

Supplementary Figure 3. Summarized overall odds ratio of underweight or normal body mass index (BMI) in patients.

Supplementary Figure 4. Summarized overall odds ratio of overweight or obese body mass index in patients.

Additional file 2(.doc)

Supplementary Table 1. Demographic and clinical characteristics of the subjects included in studies that focused on sarcopenia.

Supplementary Table 2. Demographic and clinical characteristics of the subjects included in studies that focused on handgrip strength.

Supplementary Table 3. Quality assessment of included studies by Newcastle-Ottawa Scale

Supplementary Table 4. Publication bias of summarized outcome.

Figures

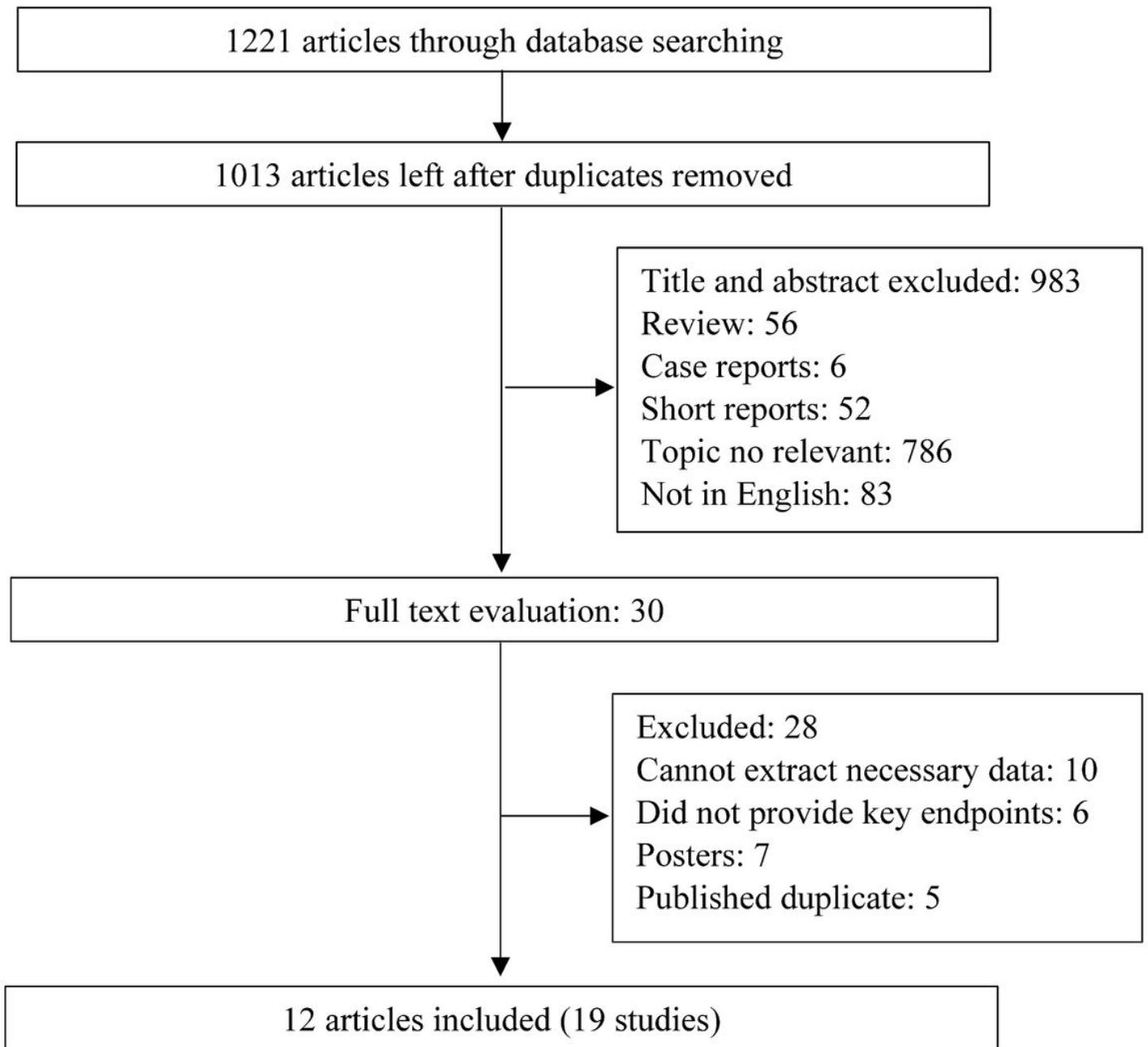


Figure 1

Flow chart of the study selection.

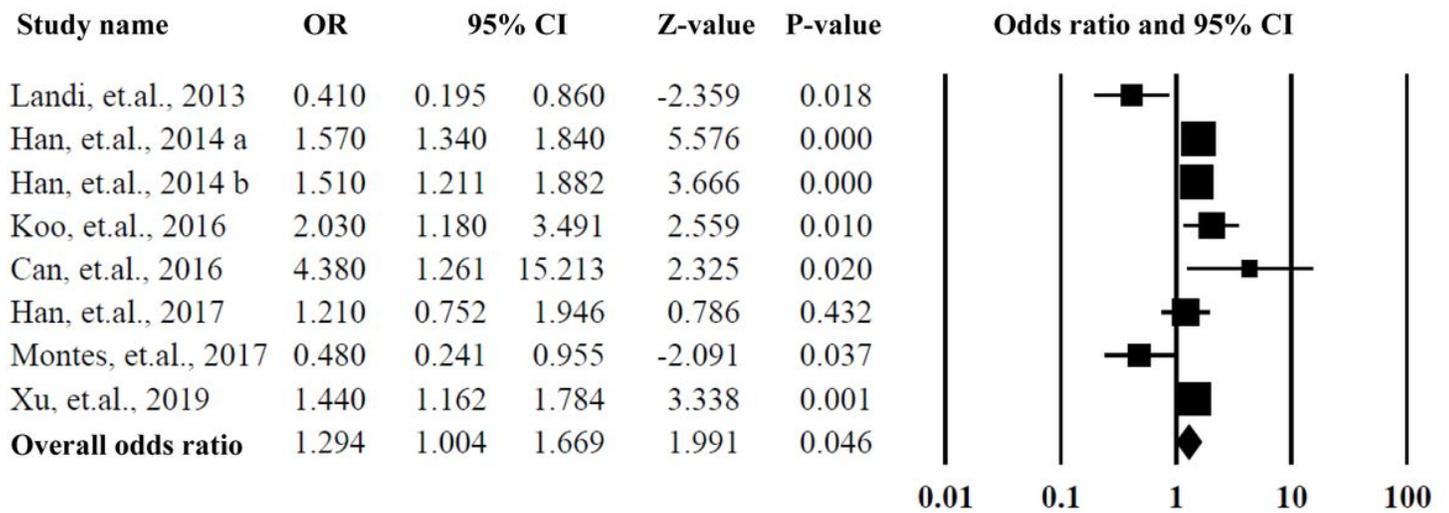
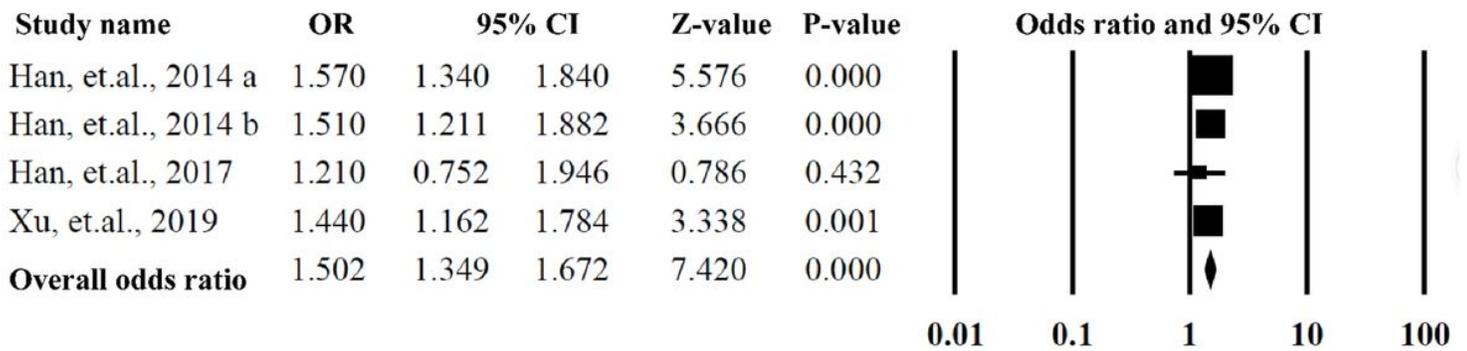
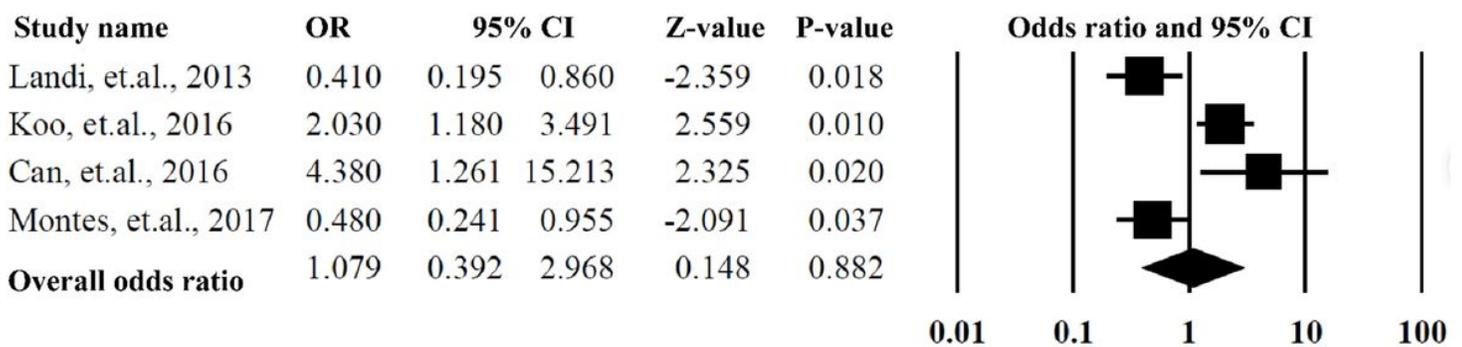


Figure 2

Summarized overall odds ratio of hypertension



a. Summarized overall odds ratio of hypertension of the studies from Asia



b. Summarized overall odds ratio of hypertension of the studies from Europe

Figure 3

Summarized overall odds ratio of hypertension of the studies grouped by ethnicity of the participants

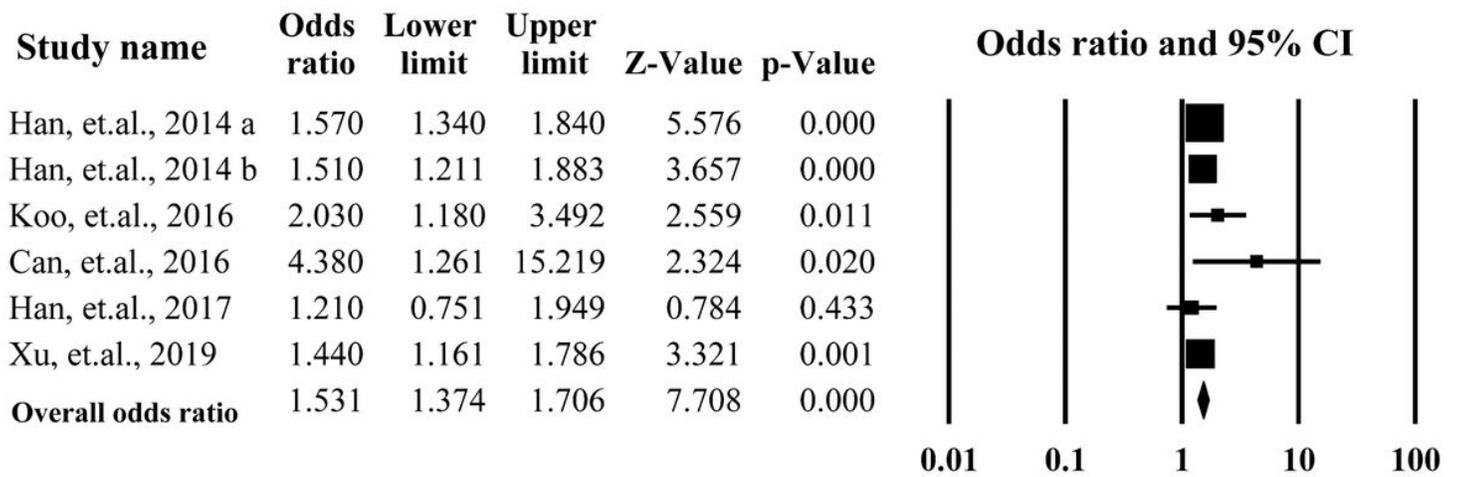


Figure 4

Summarized overall odds ratio of hypertension of the studies that with equal to or more than 7 stars of the Newcastle-Ottawa Scales

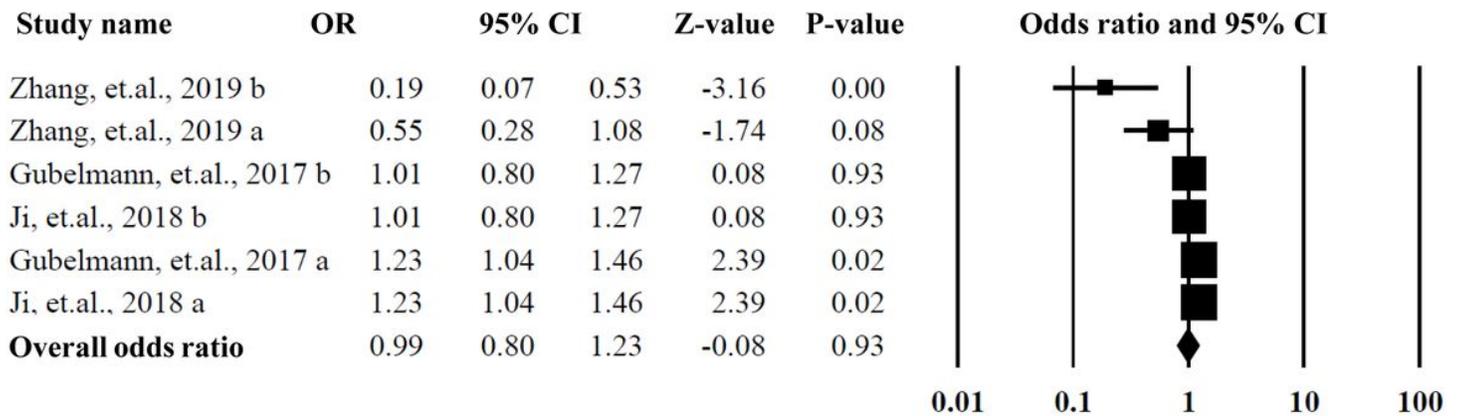


Figure 5

Summarized overall odds ratio of handgrip strength

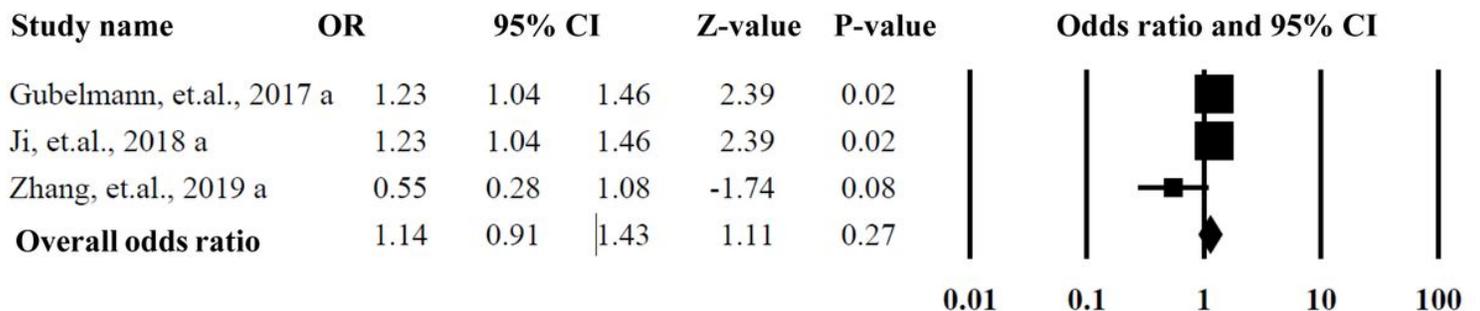


Figure 6

Summarized overall odds ratio of handgrip strength based on male participants

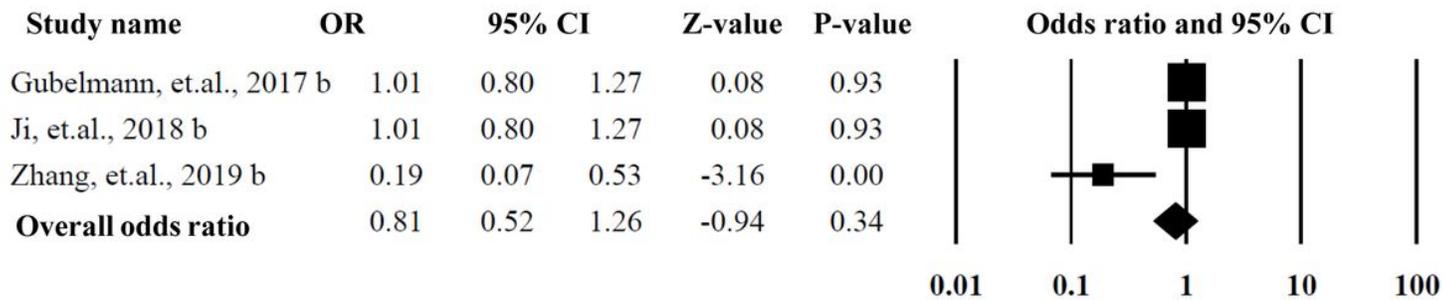


Figure 7

Summarized overall odds ratio of handgrip strength based on female participants

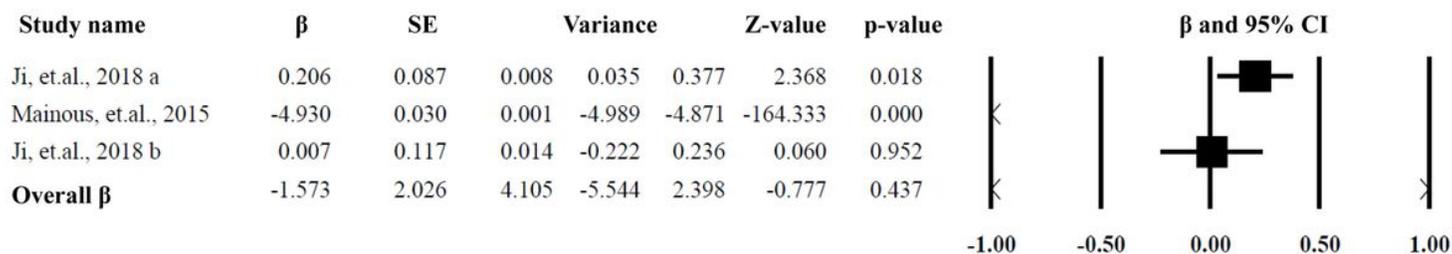


Figure 8

Summarized overall β for the linear regression and stand error

Supplementary Files

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