



Assessment of Tongue Strength in Sarcopenia and Sarcopenic Dysphagia: A Systematic Review and Meta-Analysis

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Sarcopenic dysphagia is defined as difficulty in swallowing due to sarcopenia, which may be related to weakness of the tongue muscles. This meta-analysis aimed to explore the association between tongue strength and sarcopenia and to determine whether tongue strength measurement could be a specific indicator of sarcopenic dysphagia. We conducted a systematic search of electronic databases from their inception to February 2021 for clinical studies that investigated tongue strength in participants with and without sarcopenia. The primary outcome was the weighted mean difference (WMD) and standardized mean difference (SMD) of tongue pressure between the different groups. The secondary outcome was the correlation of tongue pressure with the subcomponents that defined sarcopenia. Ten studies that involved 1,513 participants were included in the meta-analysis. Compared with those without sarcopenia, patients with sarcopenia had significantly less tongue pressure, with a WMD of -4.353 kPa (95% CI, -7.257 to -1.450) and an SMD of -0.581 (95% CI, -0.715 to -0.446). There was no significant difference in tongue pressure between patients with sarcopenic dysphagia and those with non-sarcopenic dysphagia, with a WMD of -1.262 kPa (95% CI, -8.442 to 5.918) and an SMD of -0.187 (95% CI, -1.059 to 0.686). Significant positive associations were identified between tongue pressure and grip strength and between tongue pressure and gait speed, with correlation coefficients of 0.396 (95% CI, 0.191 to 0.567) and 0.269 (95% CI, 0.015 to 0.490), respectively. Reduced tongue strength is associated with sarcopenia but is not an exclusive marker for sarcopenic dysphagia. Tongue strength correlates with the values of subcomponents that define sarcopenia. In patients with

low performance of sarcopenia subcomponent, tongue pressure must be examined to diagnose subclinical dysphagia.

Protocol registration: This meta-analysis was registered on INPLASY (registration number INPLASY202120060).

Keywords: sarcopenia, dysphagia, tongue strength, frailty, tongue pressure

INTRODUCTION

Sarcopenia was first used by Rosenberg to describe an age-related decrease in muscle mass (1). According to the European Working Group on Sarcopenia in Older People (EWGSOP) (2) and the Asian Working Group for Sarcopenia (AWGS) (3) diagnostic criteria, sarcopenia is defined as low muscle mass, strength, and/or physical performance. The prevalence of sarcopenia has been reported to be between 1 and 29% in the community-dwelling population and between 14 and 33% in residents living in long-term care facilities (4). The association between sarcopenia and adverse health outcomes, such as mortality, incidence of falls, and longer hospitalization, has been reported in previous studies (5, 6). In addition, studies have shown that sarcopenia not only reduces the strength of limbs but also that of the oropharyngeal muscles, leading to swallowing impairment (7, 8).

Dysphagia is a term derived from Greek words, meaning worsening in eating (9) and is related to organic or neurological diseases, such as nasopharyngeal cancer, stroke, Parkinson's disease, and dementia (10). Sarcopenic dysphagia is characterized by sarcopenia of the entire body and swallowing-related muscles (11). The swallowing process can be divided into four phases: oral preparatory, oral, pharyngeal, and esophageal phases. The tongue plays a key role in bolus transport from the oral cavity to the pharynx. Tongue movements stimulate oropharyngeal receptors and trigger subsequent swallowing events (12). Abnormal tongue function is associated with oral and pharyngeal dysphagia (13). It has been reported that tongue strength is positively correlated with swallowing function (14). Aging-related fatty infiltration, amyloid deposition, and loss of tongue muscle fibers can lead to a decrease in tongue pressure (15). In addition, decreased tongue pressure during swallowing has been observed in patients with post-stroke dysphagia (16).

The diagnosis of sarcopenic dysphagia is important because sarcopenic dysphagia increases the risk of complications such as dehydration, malnutrition, and aspiration pneumonia (17). The prevalence of dysphagia in the sarcopenic population was reported to be 32% (18). Tongue strength measurement has been proposed as a diagnostic tool for sarcopenic dysphagia (19). The modified water swallowing test (MWST) has been widely used by medical practitioners to screen for dysphagia (20). However, it puts the examinees at risk of choking. The measurement of tongue strength is theoretically safer and more

reliable than MWST. Since the measurement of tongue pressure is an objective method for assessing tongue strength, whether or not tongue pressure differs in the sarcopenic population is a clinically important issue. Therefore, the purpose of the meta-analysis was two-fold: (1) to explore the association between tongue strength and sarcopenia and (2) to determine whether tongue strength measurement could be a specific indicator for sarcopenic dysphagia.

METHODS

Protocol Registration

The study was performed in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) program (21). The meta-analysis was prospectively registered on Inplasy.com (INPLASY202120060).

Studies Search and Selection

PubMed (US National Library of Medicine) and Embase (Wolters Kluwer Ovid) were searched for cross-sectional, case-control, and cohort studies that investigated tongue strength in the sarcopenia population from their inception to February 2021. Key search terms included: "sarcopenia," "frailty," "dysphagia," "swallowing disorder," "tongue pressure," "tongue strength" (**Appendix 1**). There was no restriction on language during the literature search. Furthermore, relevant narratives and systemic reviews were manually retrieved for potentially eligible articles.

Inclusion and Exclusion Criteria

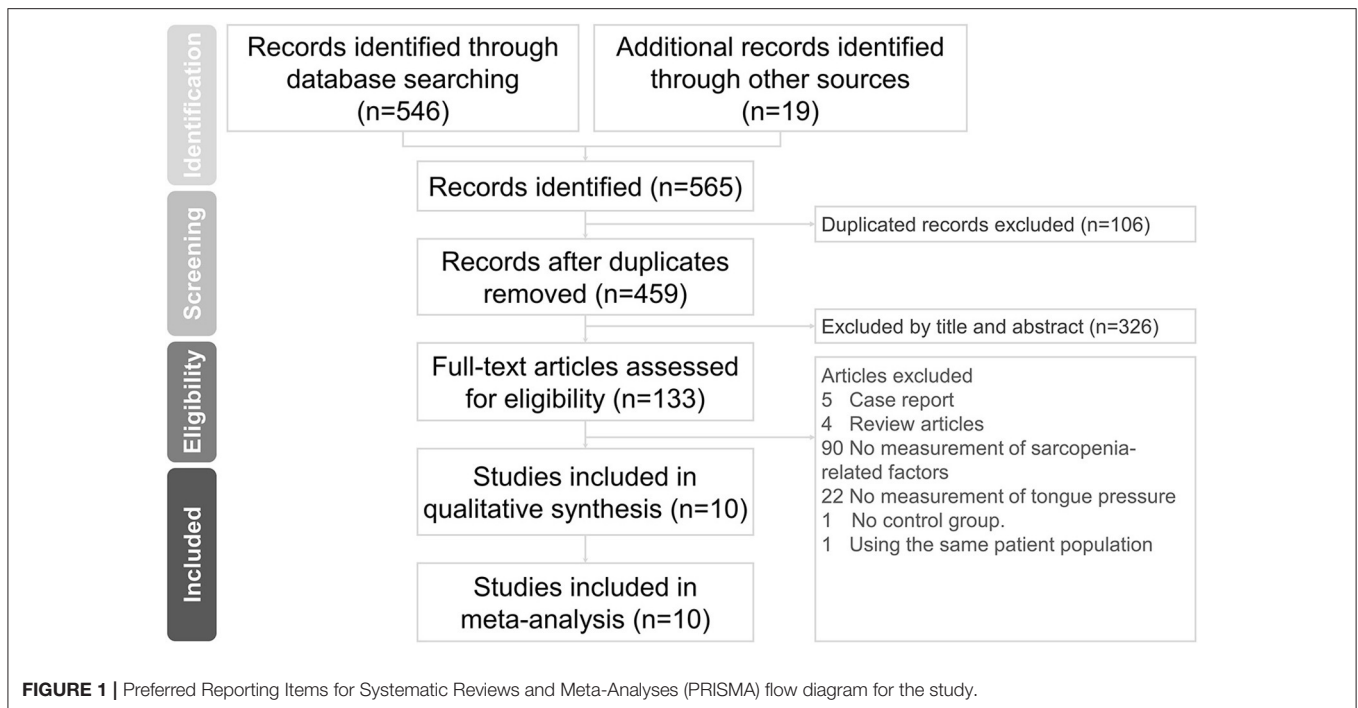
Studies were included if they: (1) investigated human subjects over the age of 18 years; (2) provided measurements for tongue pressure; (3) provided how sarcopenia was evaluated and (4) evaluated swallowing performance. The study types were divided into cross-sectional studies, cohort studies, case-control studies, and clinical trials.

The following studies were excluded: (1) case reports, case series, and research protocols; (2) studies that did not measure tongue pressure and sarcopenia components; (3) studies that validated technologies or devices for tongue strength assessment; and (4) studies that lacked a control group with normal muscle volume and function.

Quality Assessment

The Newcastle–Ottawa Scale (NOS) was used to assess the quality of each study (22). It evaluates eight aspects of each retrieved study: representativeness of sarcopenic patients, selection of control, ascertain of tongue pressure measurement, outcome of interest not present at start, comparability of

Abbreviations: WMD, Weighted mean difference; SMD, standardized mean difference; MWST, modified water swallowing test; EWGSOP, the European Working Group on Sarcopenia in Older People; AWGS, Asian Working Group for Sarcopenia.



cohorts, assessment of outcome, enough follow-up period, and adequacy of follow-up. The quality assessment was conducted by both reviewers individually, while the outcomes of the evaluation were decided based on a consensus or by the corresponding author.

Data Extraction

Two authors (K.C.C and K.V.C) independently screened the titles and abstracts to determine whether the articles met the scope of the present meta-analysis. The full texts of the pertinent articles were retrieved for further data extraction. The author, publication year, study design, diagnostic criteria for sarcopenia, number of included patients, population characteristics, sex ratio, and data collection period were extracted from all included studies. If some data were missing in the published articles, the corresponding authors of the original studies were contacted for the required information. Questions arising from data abstraction were resolved through discussions or by the corresponding author.

Statistical Analysis

The primary outcome included the weighted mean difference (WMD) and standardized mean difference (SMD) between the groups. The SMD was calculated as the difference in the mean tongue pressure divided by the pooled standard deviation (23). The WMD provided the absolute between-group difference in tongue pressure in kPa, whereas the SMD facilitated the awareness of the magnitude of the effect regarding tongue strength discrepancy for the two target populations. An SMD of 0.2, 0.5, and 0.8, is considered a small, moderate, and large effect size, respectively (24). The secondary outcome was

the correlation of tongue pressure with the subcomponents of sarcopenia. The correlation coefficients were analyzed using the Hedges-Olkin method based on the Fisher Z transformation of the variables (25). We also analyzed the association between sarcopenia and low tongue pressure using the risk ratio (26).

The random effect model was used for pooling the data, considering the variations in the study designs and enrolled participants. The between-group heterogeneity was evaluated using the Cochran's Q and I^2 statistics. An $I^2 > 50\%$ was considered to indicate significant heterogeneity (27). Publication bias was determined by visual inspection of the funnel plots and the p-value of the Egger's test (28). All statistical analyses were conducted using Comprehensive Meta-analysis Software v 3 (Biostat, Englewood, NJ), and a $p < 0.05$ was considered to indicate statistical significance.

RESULTS

Literature Search

The initial literature search identified 565 articles. After excluding 106 duplicate articles and 326 non-relevant articles by screening their titles and abstracts, 133 studies were eligible for subsequent evaluation. Five case reports, four review articles, 90 studies that did not measure sarcopenia-related factors, 22 studies that did not assess tongue pressure, one study without a control group, and one study (29) involving the same patient cohort as another study were excluded (Figure 1). Finally, a total of ten articles were included in the meta-analysis (8, 18, 30–37). These articles

TABLE 1 | Characteristics of the included study.

References	Study design	Patient characteristic	Outcome measurement	N Sarcopenia	N non-sarcopenic	Age	Sex ratio M/F	Data collection period	Swallowing evaluation tool	Country
Shimizu et al. (37)	Cross-sectional	Admissions for orthopedic conditions, aged ≥ 65 years, no history of cerebrovascular or neuromuscular disease, without an implanted pacemaker	TP, MNA-SF, BMI, FIM	105	92	81.3 \pm 7.6	39/158	November 2018 to September 2019.	FOIS MASA	Japan
Chen et al. (35)	Cross-sectional	Elderly sarcopenic patients without dysphagia, age ≥ 65 years, living independently, fully cooperative, eat orally	TP, Submental ultrasonography, 100-mL WST	47	47	75.1 \pm 5.8	26/68	NA	EAT-10	Taiwan
Kobuchi et al. (36)	Cross-sectional	Patients living in nursing homes or university hospitals	TP, BMI, oral examination, BI, MNA-SF, cross-sectional area of the geniohyoid muscle, oral diadochokinesis	18	36	78.8 \pm 7.1	16/38	NA	EAT-10	Japan
Sakai et al. (34)	Cross-sectional	age > 65 years, post-acute phase of illness hospitalized for rehabilitation, MMSE ≥ 21 , presence of all upper and lower central incisors	TP, 100-mL WST, swallowing time, swallowing speed, lip force, MMSE, CCI, MNA-SF	86	159	84.0 (79–88)*	79/166	April 2015 to October 2016	FOIS	Japan
Wakabayashi et al. (18)	Prospective cohort	age > 65 years, dysphagia, referred for speech therapy	TP, BI, GNRI, BMI, total energy intake, C-reactive protein	35	73	76 \pm 7	72/36	August 2016 to March 2018	FILS	Japan
Kaji et al. (33)	Cross-sectional	Type 2 diabetes, age ≥ 60 years, tolerate standing position	TP, smoking, exercise, hemoglobin A1c	17	127	71.4 \pm 6.7	82/62	April 2017 to October 2017	Nil	Japan
Suzuki et al. (32)	Cross-sectional	Community-dwelling older women, age ≥ 65 years, walk independently, absence of dysphagia	TP, oral diadochokinesis, BMI	29	216	81.0 (75.0–85.0)*	NA	NA	EAT-10	Japan
Ogawa et al. (8)	Cross-sectional	Acute care hospitals or convalescent rehabilitation hospitals or long-term care hospitals or nursing homes, age > 65 years, able to answer a questionnaire	TP, thickness and area of the tongue and geniohyoid muscles, MNA-SF, BMI	36	19	82.1 \pm 7.4	31/24	October 2016 to April 2017	FILS	Japan
Machida et al. (30)	Cross-sectional	Community-dwelling older adults, living independently	TP, MNA-SF, jaw-opening force, BI	68	129	78.5 \pm 6.7(M) 77.8 \pm 6.2(F)	97/100	NA	EAT-10	Japan
Sakai et al. (31)	Cross-sectional	age ≥ 65 years, post-acute phase of illness, living independently, no history of dysphagia, MMSE ≥ 21 , presence of upper and lower central incisors	TP, BI, MNA-SF, BMI, serum albumin levels, CONUT, modified WST	134	40	84 (80–89)*	64/110	October 2014 to December 2015	FOIS EAT-10	Japan

WST, water swallowing test; EAT, Eating assessment tool; TP, tongue pressure; BI, Barthel Index; MNA-SF, Mini Nutritional Assessment-Short Form; MMSE, Mini Mental State Examination; CCI, Charlson Comorbidity Index; FILS, Food Intake Level Scales; GNRI, Geriatric Nutritional Risk Index; BMI, body mass index; FOIS, functional oral intake scale; EAT-10, 10-item Eating Assessment Tool; CONUT, controlling nutritional status; FIM, Functional Independence Measure; MASA, Mann Assessment of Swallowing Ability; NA, not available; *Interquartile range (IQR).

TABLE 2 | Diagnostic tools and criteria of sarcopenia in the included studies.

References	Muscle strength	Muscle volume	Muscle function	Diagnostic algorithm
Shimizu et al. (37)	Jamar digital handgrip gauge (MG-4800; CHARDER Electronic, Taichung, Taiwan) <28 kg for male, <18 kg for female	BIA ②	NA NA	AWGS: low HGS + low SMI
Chen et al. (35)	Handheld dynamometer ①	DEXA/BIA ③/②	5-m walk test ④	AWGS: low HGS + low SMI ± low gait speed
Kobuchi et al. (36)	Handgrip dynamometer (Takei Scientific Instruments Co., Ltd.) ①	BIA ③	5-m walk test in a 9 m path ④	AWGS: low SMI + low HGS or low gait speed
Sakai et al. (34)	Digital grip strength dynamometer ①	CC <34 cm for male; <33 cm for female	NA NA	AWGS: low HGS + low CC
Wakabayashi et al. (18)	NA ①	CC <30 cm for male; <29 cm for female	NA ④	AWGS: low HGS + low CC ± low gait speed
Kaji et al. (33)	Handgrip dynamometer (Smedley; Takei Scientific Instruments, Niigata, Japan) ①	BIA ②	NA NA	AWGS: low HGS + low SMI
Suzuki et al. (32)	Handgrip dynamometer (TTM, Tokyo, Japan) ①	BIA ②	5-m walk test ④	AWGS: low HGS + low SMI ± low gait speed
Ogawa et al. (8)	Grip strength ①	CC <34 cm for male; <33 cm for female	NA ④	AWGS: low HGS + low CC ± low gait speed
Machida et al. (30)	Handgrip dynamometer (TTM, Tokyo, Japan) Not clear mentioned	BIA Not clear mentioned	4-m walk test in 8 m path Not clear mentioned	AWGS:(low SMI + low HGS) or (low SMI + low gait speed)
Sakai et al. (31)	Digital grip strength dynamometer <30 kg for male, <20 kg for female	CC <34 cm for male; <33 cm for female	NA NA	EWGSOP: low HGS + low CC

DEXA, dual-energy X-ray absorptiometry; BIA, bioelectrical impedance analysis; CC, calf circumference; AWGS, Asian Working Group for Sarcopenia; EWGSOP, European Working Group on Sarcopenia in Older People; HGS, hand grip strength, SMI, skeletal muscle mass index.

Cuff off points:

①, Hand grip strength: male: <26 kg, female: <18 kg.

②, Skeletal muscle mass index: male: <7.0 kg/m², female: <5.7 kg/m².

③, Skeletal muscle mass index: male: <7.0 kg/m², female: <5.4 kg/m².

④, Gait speed <0.8 m/s.

comprised of nine cross-sectional studies (8, 30–37) and one cohort study (18). Data on the number of sarcopenic and non-sarcopenic groups were missing in one study and were retrieved by contacting the corresponding author of the article (36). The details of the included studies are presented in **Table 1**.

Study Characteristics

The ten studies involved 1,513 participants, with the mean (or median) ages ranging from 71.4 to 84.0 years. Three studies recruited community-dwelling older adults (30, 32, 35), three recruited hospitalized older people (18, 31, 34), one

recruited elderly patients with type 2 diabetes (33), one recruited older patients admitted for orthopedic conditions (37) and two recruited older adults who required rehabilitation (8, 33). Regarding the diagnostic algorithm for sarcopenia, one study employed the EWGSOP guidelines (31) and nine employed the AWGS criteria (8, 18, 30, 32–37). The diagnostic tools and criteria for sarcopenia in the included studies are shown in **Table 2**. The tools used for the evaluation of swallowing function are summarized in **Table 1**. They include the 10-item Eating Assessment Tool, Functional Oral Intake Scale, Food Intake Level Scale, and MWST and Mann Assessment of Swallowing Ability.

TABLE 3 | Quality assessment for the included studies by using the newcastle-ottawa scale.

	Representative of sarcopenia patients	Selection of control	Ascertain of sarcopenia measurement	Outcome of interest not present at start	Comparability of cohorts	Assessment of outcome	Enough follow-up period	Adequacy of follow up	Total point
Shimizu et al. (37)	★	★	★	★	★★	★			7
Chen et al. (35)	★	★	★	★	★★	★	-	-	7
Kobuchi et al. (36)	★	★	★	★	★★	★	-	-	7
Sakai et al. (34)	★	★	★	★	★★	★	-	-	7
Wakabayashi et al. (18)	★	★	★	★	★★	★	★	★	9
Kaji et al. (33)	★	★	★	★	★★	★	-	-	7
Suzuki et al. (32)	★	-	★	★	★★	★	-	-	6
Ogawa et al. (8)	★	★	★	★	★★	★	-	-	7
Machida et al. (30)	★	★	★	★	★★	★	-	-	7
Sakai et al. (31)	★	★	★	★	★★	★	-	-	7

★, numbers of points earned in each cell.

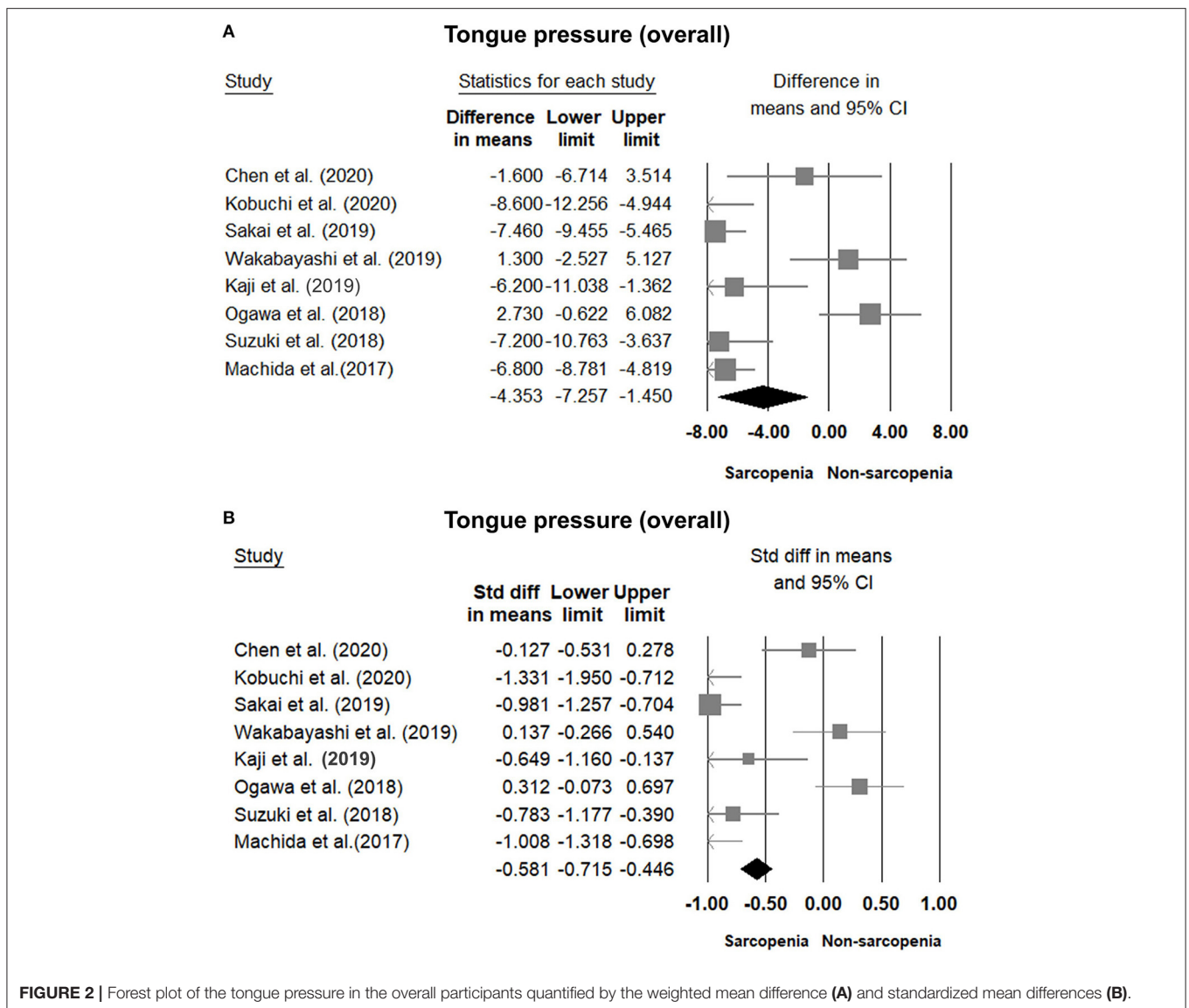


FIGURE 2 | Forest plot of the tongue pressure in the overall participants quantified by the weighted mean difference (A) and standardized mean differences (B).

Quality Assessment of the Included Studies

The results of the quality assessment are presented in **Table 3**. The domains for which most studies failed were “enough follow-up

period” and “adequacy of follow-up.” This is because the cross-sectional design was employed in the majority of the enrolled articles and the studies did not involve a longitudinal follow-up. The results of the quality assessment are shown in **Table 3**.

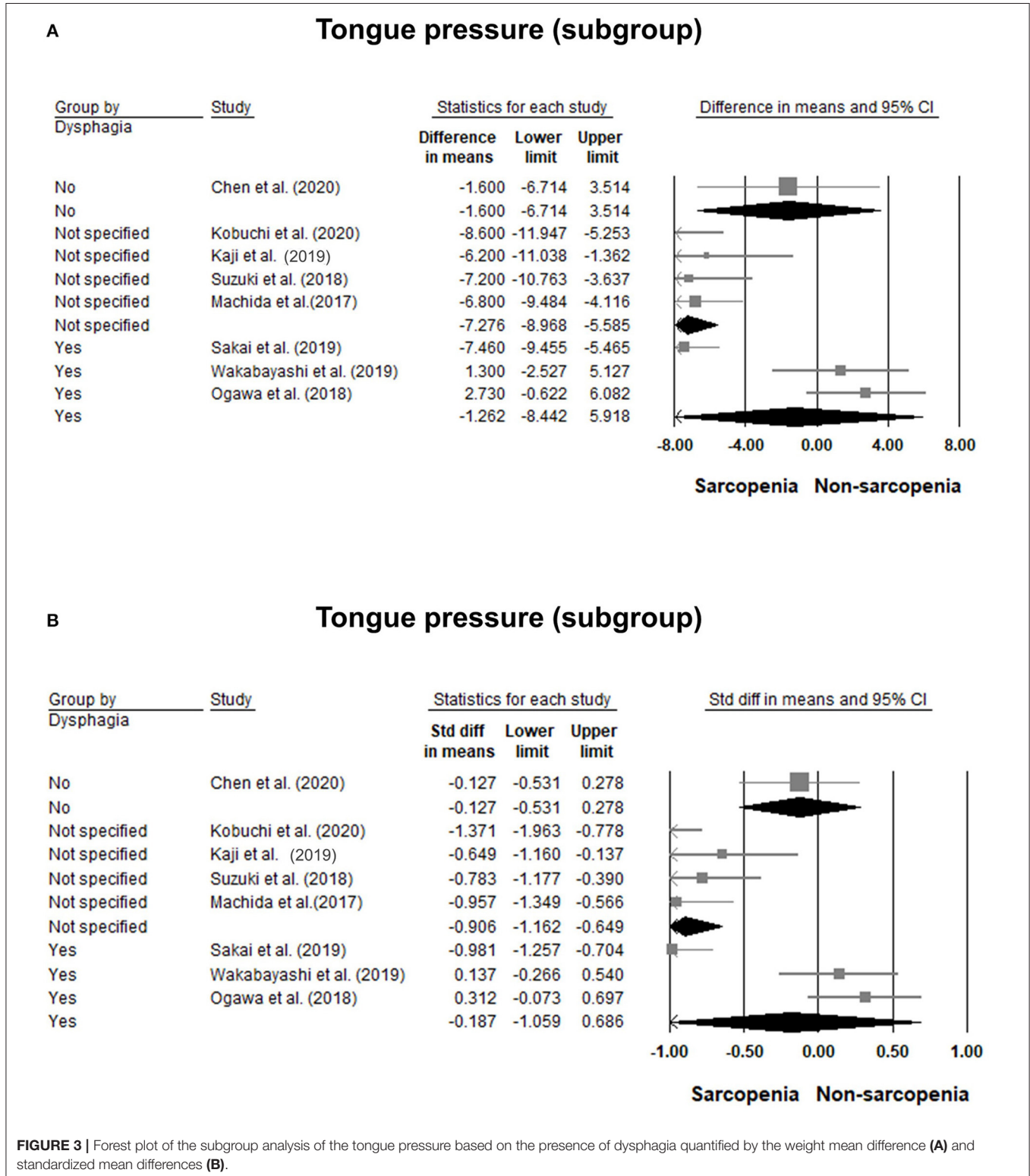
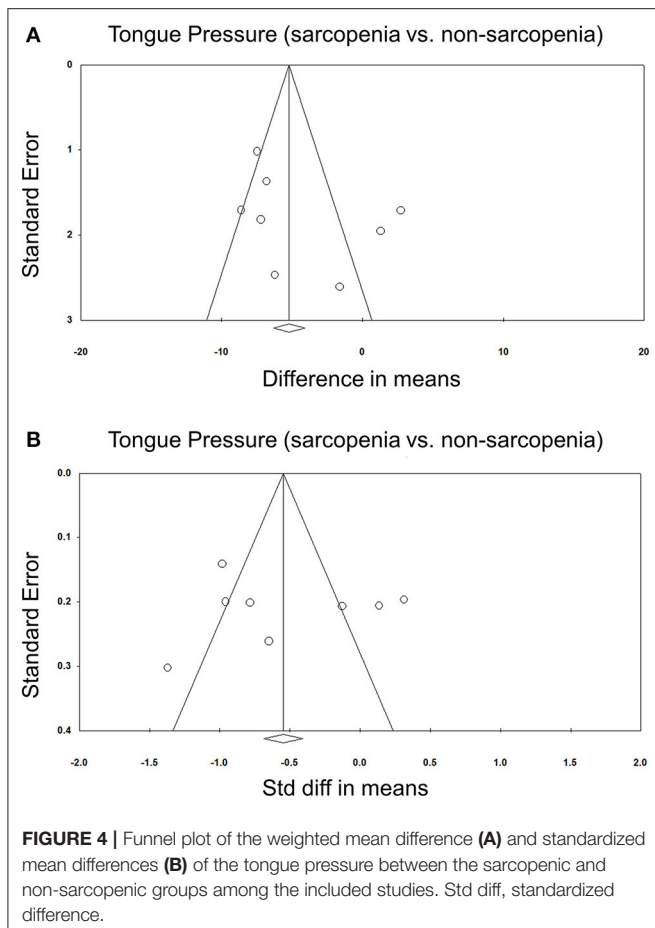
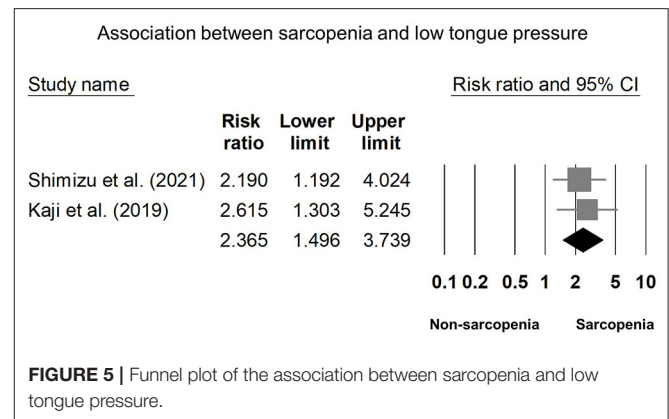


FIGURE 3 | Forest plot of the subgroup analysis of the tongue pressure based on the presence of dysphagia quantified by the weight mean difference (A) and standardized mean differences (B).



Comparisons of Tongue Pressure Between the Sarcopenic and Non-sarcopenic Group

Eight of our included studies (8, 18, 30, 32–36) compared tongue pressure. Compared with the non-sarcopenic group, patients with sarcopenia had significantly lower tongue pressure, with a WMD of -4.353 kPa (95% CI, -7.257 to -1.450 ; $I^2 = 84.9\%$) and an SMD of -0.581 (95% CI, -0.715 to -0.446 ; $I^2 = 88.2\%$) (Figure 2). Subgroup analysis was performed based on the presence of dysphagia. In studies that recruited patients with dysphagia (8, 18, 34), there was no significant difference in the tongue pressure between the non-sarcopenic and sarcopenic groups, with a WMD of -1.262 kPa (95% CI, -8.442 to 5.918 ; $I^2 = 94.1\%$) and an SMD of -0.187 (95% CI, -1.059 to 0.686 ; $I^2 = 94.5\%$). In studies that enrolled patients without specifying whether or not they had dysphagia (30, 32, 33, 36), the sarcopenic group still had significantly lower tongue pressure than the non-sarcopenic group, with a WMD of -7.112 kPa (95% CI, -8.601 to -5.623 ; $I^2 < 0.01\%$) and an SMD of -0.921 (95% CI, -1.152 to -0.690 ; $I^2 = 15.3\%$). Only one study included participants without clinical dysphagia (35). The patients in the aforementioned study had a WMD of -1.600 kPa (95% CI, -6.714 to 3.514) and an SMD of -0.127 (95% CI,



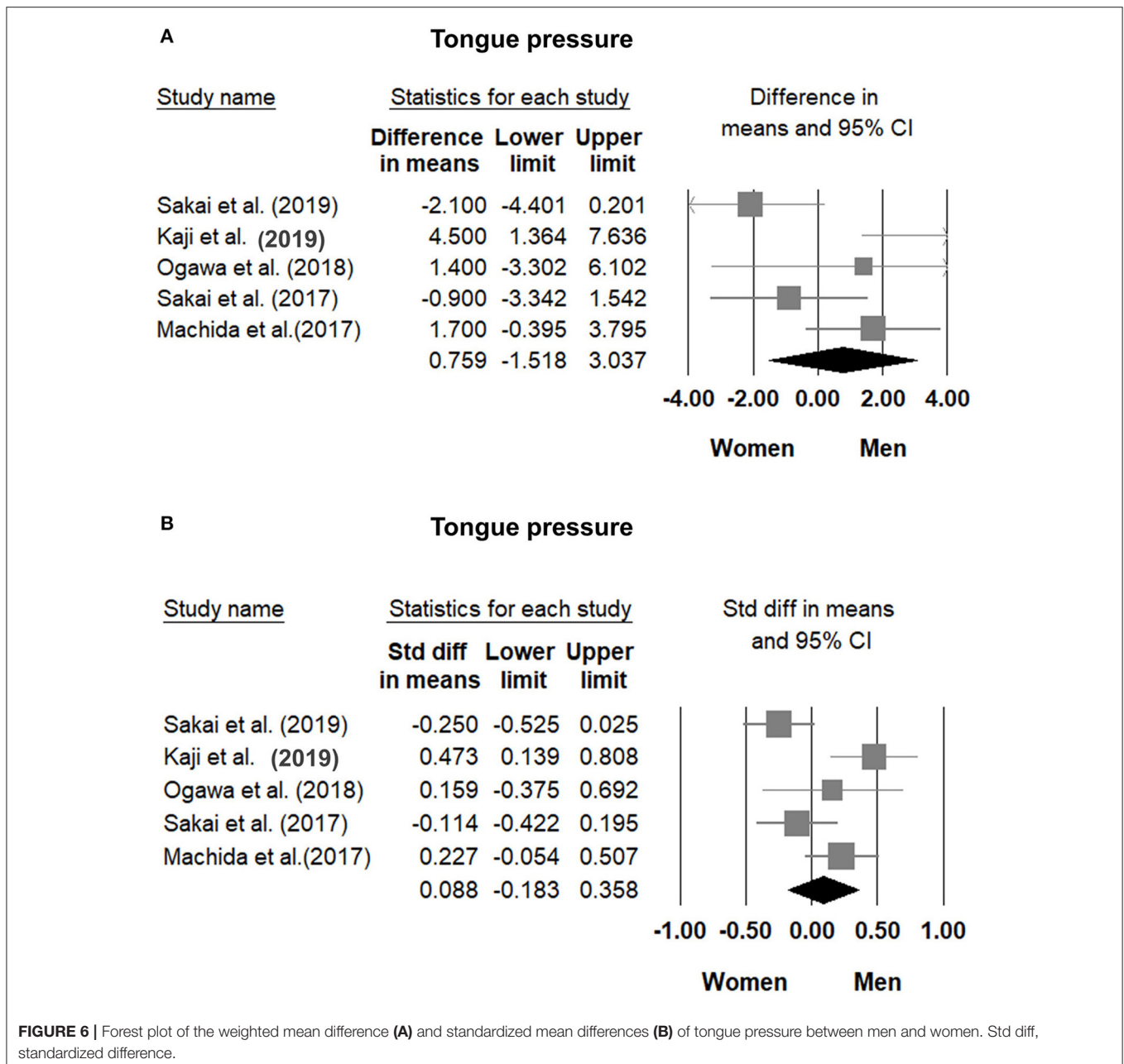
-0.531 to 0.278) (Figure 3). Visual inspection of the funnel plots and p -values following the Egger's test revealed no significant publication bias (Figure 4). The association between sarcopenia and low tongue pressure was available in two (33, 37) of our included studies. The threshold for defining low tongue pressure was 20 kPa in the one conducted by Shimizu et al. (37) and 21.6 kPa in the one conducted by Kaji et al. (33). The pooled analysis indicated that sarcopenia was associated with low tongue pressure, with a risk ratio of 2.365 (95% CI, 1.496 to 3.739; $I^2 < 0.001$) (Figure 5).

Comparisons of Tongue Pressure Between Men and Women

Comparisons of tongue pressure between male and female participants were available in five studies (8, 30, 31, 33, 34). No significant gender differences (men vs. women) were identified. The WMD was 0.759 kPa (95% CI, -1.518 to 3.037 ; $I^2 = 70.0\%$) and the SMD was 0.088 (95% CI, -0.183 to 0.358 ; $I^2 = 70.2\%$) (Figure 6). No significant publication bias was detected based on visual inspection of the funnel plots and p -values following Egger's test (Figure 7).

Correlation of Tongue Pressure With Subcomponents of Sarcopenia

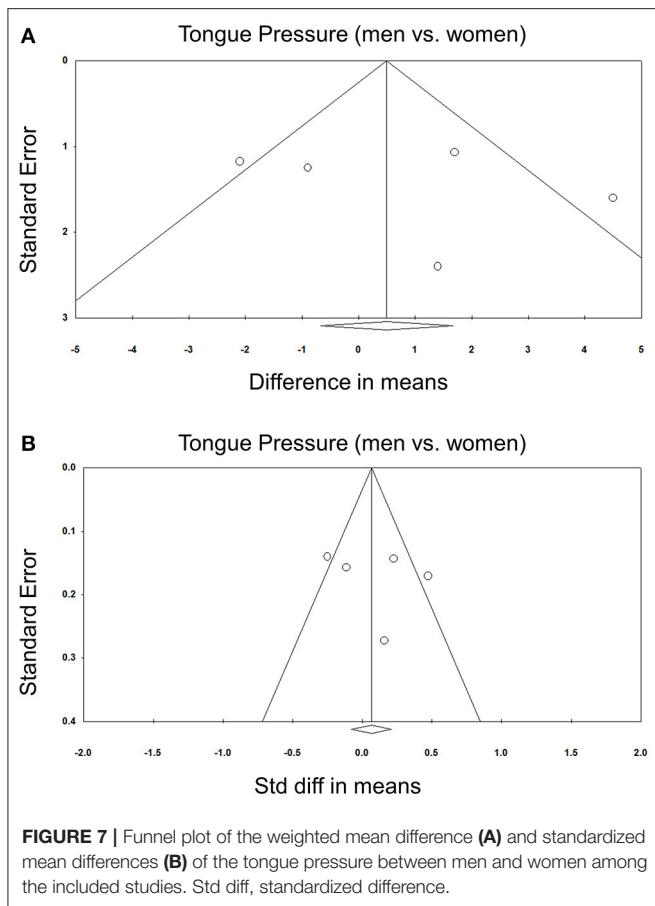
The correlation coefficient between tongue pressure and grip strength was available in three studies (29, 31, 36), with a pooled value of 0.396 (95% CI, 0.191 to 0.567). The results of the correlation analysis between tongue pressure and grip strength in the study conducted by Machida et al. (30) was derived from that reported by another study (29), since both studies involved the same population of patients. Two of the included studies (29, 36) reported a correlation coefficient between tongue pressure and gait speed, with a pooled value of 0.269 (95% CI, 0.015 to 0.490) (Figure 8). Likewise, the correlation analysis of tongue pressure and gait speed in the study conducted by Machida et al. (30) was available from another study (29), since both studies involved the same population of patients. The aforementioned analyses indicated a significant positive correlation between tongue pressure, grip strength, and gait speed.



DISCUSSION

The main finding of this study was that elderly patients with sarcopenia had significantly lower tongue pressure than those without sarcopenia. The subgroup analysis further revealed that there was no significant difference in tongue pressure between patients with sarcopenic dysphagia and those with non-sarcopenic dysphagia. No significant gender differences in tongue pressure were identified in our target population. In addition, a positive association existed between tongue pressure and subcomponents of sarcopenia, including grip strength and gait speed.

In our analysis, patients with sarcopenia had significantly lower tongue pressure, with an SMD of -0.581 , indicating a moderate between-group difference. Although the mechanism is not clearly understood, a possible reason is that the generalized decline of muscle mass and strength in the sarcopenic population also affects swallowing-related muscles, such as the tongue, infra-hyoid, supra-hyoid, and pharyngeal muscles. Type II muscle fibers are affected by malnutrition, a potential cause of sarcopenia, more easily than type I muscle fibers (38). Therefore, the swallowing muscles are vulnerable to the effects of insufficient nutrition due to its higher type II fiber content (39). These factors may lead to decreased tongue strength,



reduced range of tongue motion, weak contractility of pharyngeal muscle, impaired endurance of swallowing-related muscles, and an increased risk of dysphagia in patients with sarcopenia (13). In addition, a previous study found that tongue-pressure resistance training could improve tongue and supra-hyoid muscle function simultaneously and might be helpful for the prevention of sarcopenic dysphagia (40). Hence, our findings are consistent with existing evidence showing reduced tongue strength in the sarcopenic population.

However, there was no significant difference in tongue pressure between patients with and without sarcopenic dysphagia. We speculated that patients with dysphagia had decreased oral intake, which potentiated disuse atrophy of the tongue muscles regardless of pre-existing sarcopenia. Furthermore, neurological diseases such as stroke (41) and Parkinsonism (42) lead to uncoordinated posterior tongue movement and prolonged tongue elevation (43), which interfere with tongue pressure measurement and subsequent underestimation of tongue strength. Therefore, our findings showed that reduced tongue pressure was not an exclusive indicator of sarcopenic dysphagia.

No gender differences in tongue pressure were identified in our study population. A previous study also revealed no significant gender differences in isometric and peak

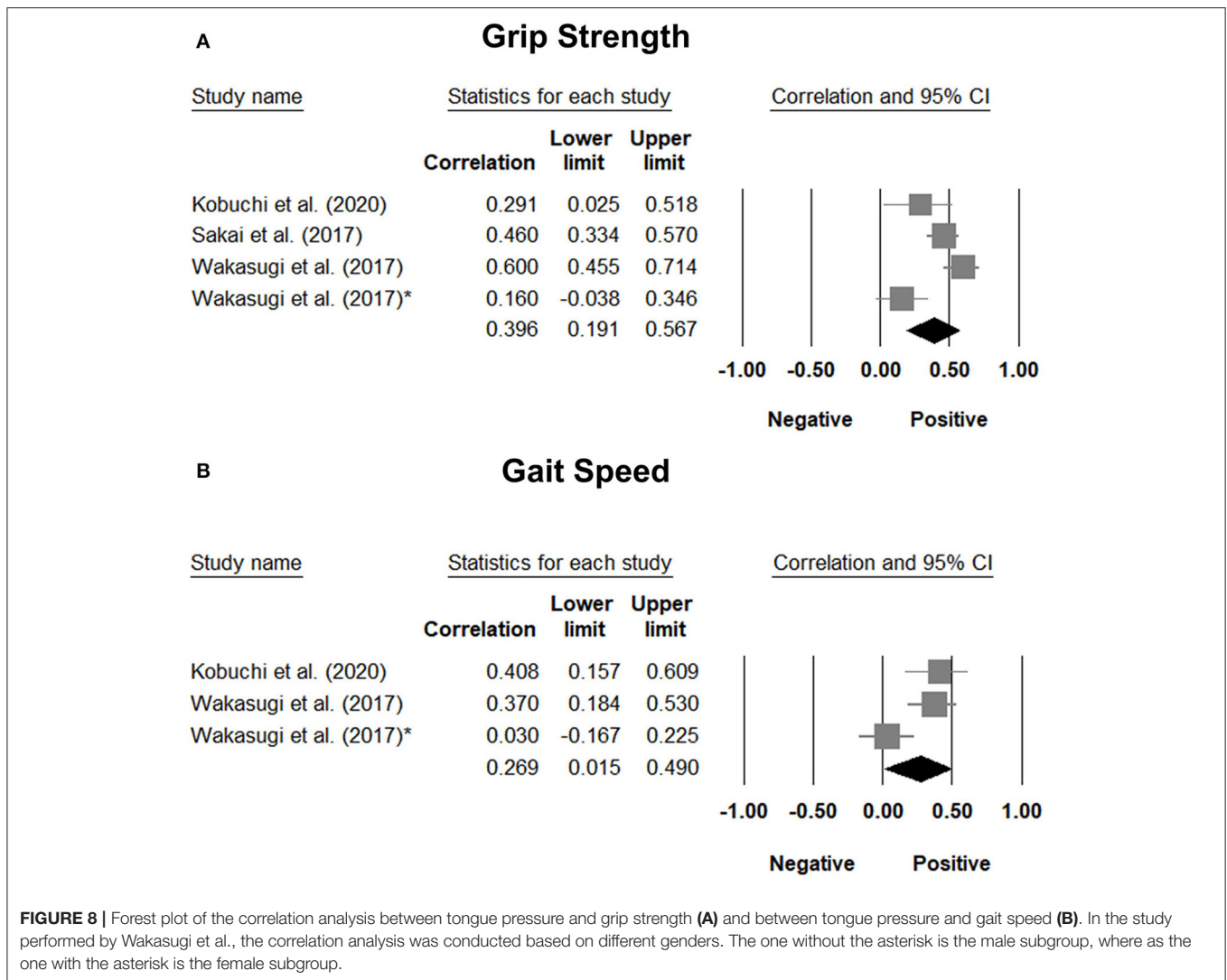
swallowing pressure measured by intraoral pressure sensors in 20 healthy participants (44). In contrast, some studies have revealed that men have greater maximum tongue pressures than women (45, 46). There were two factors that led to the absence of gender differences in our meta-analysis. First, our study population consisted mainly of older adults, whose tongue strength had already decreased with age. Second, the analysis involved patients with sarcopenia whose tongue strength had also been reduced, based on our analysis. Therefore, since tongue strength declined in our study participants, the gender difference in tongue strength was trivial.

The included studies revealed a positive correlation between tongue pressure, physical performance, and grip strength. Grip strength and physical performance are considered objective measurements of muscle function, a subcomponent of sarcopenia (2, 3). Our findings indicate that sarcopenia is a systemic disease that affects skeletal muscles in the whole body. The decline in tongue strength was shown to be proportional to the impact on the skeletal muscles of the limbs. A previous study reported that nutritional support and rehabilitation exercises to restore physical function could improve sarcopenic dysphagia (47). Therefore, in patients with low sarcopenia subcomponent values or performance, tongue pressure must be examined to detect subclinical dysphagia.

There are several limitations that must be acknowledged. First, the present meta-analysis included a relatively low number of studies. An updated meta-analysis may be needed in the future to include more prospective trials to confirm the association of tongue strength with sarcopenia and sarcopenic dysphagia. Second, all enrolled studies evaluated Asian populations. The generalizability of our findings to other ethnicities requires further validation. Third, nine studies used the AWGS criteria to diagnose sarcopenia (8, 18, 30, 32–37), and one study used the EWGSOP criteria (31). The difference in the diagnostic criteria for sarcopenia led to between-study heterogeneity. Fourth, video-fluoroscopic evaluation of swallowing was not performed in the studies that recruited patients with dysphagia. Therefore, it was difficult to investigate which phase of swallowing was impaired in these patients and how it was related to tongue pressure. Fifth, the majority of the included studies employed a cross-sectional design. Therefore, the causal relationship between sarcopenia and reduced tongue strength was not elucidated in our meta-analysis.

CONCLUSION

Based on our meta-analysis, reduced tongue strength is associated with sarcopenia; however, it is not an exclusive marker for sarcopenia. In addition, tongue strength is correlated with the subcomponents of sarcopenia, implying that sarcopenia is a systemic disease that affects the skeletal muscles of the whole body. Therefore, in patients with low sarcopenia subcomponent values or performance, tongue pressure must be examined to detect subclinical dysphagia.



DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

K-VC, K-CC, and T-ML conceived and designed the study, recruited the study subjects, and planned and performed the statistical analysis. W-TW, T-GW, D-SH, K-VC, and K-CC contributed to study supervision and critical revision of the manuscript. All authors have read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fnut.2021.684840/full#supplementary-material>

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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