Singing experience influences swallowing function

Naomi Yagi
Himeji Dokkyo University
Yoshitada Sakai (yossie@med.kobe-u.ac.jp)
Kobe University
Naoko Kawamura
Himeji Dokkyo University
Hitoshi Maezawa
Osaka University
Yutaka Hata
University of Hyogo
Masayuki Hirata
Osaka University
Hideki Kashioka
National Institute of Information and Communications Technology
Toshio Yanagida
Center for Information and Neural Networks

Research Article

Keywords: population, Singing, mastication, respiratory function, age-related disease

Posted Date: December 10th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-116319/v1

TITLE

Singing experience influences swallowing function

AUTHORS

Naomi Yagi, PhD[1], Yoshitada Sakai, MD, PhD[2*], Naoko Kawamura[1], Hitoshi Maezawa, PhD[3], Yutaka Hata, PhD[4], Masayuki Hirata, MD, PhD[3], Hideki Kashioka, PhD[5], Toshio Yanagida, PhD[6]

[1] Faculty of Health Care Science, Himeji Dokkyo University, Himeji, Japan

[2] Faculty of Medical Sciences, Graduate School of Medicine, Kobe University, Kobe, Japan

[3] Department of Neurological Diagnosis and Restoration, Graduate School of Medicine, Osaka University, Suita, Japan

[4] Graduate School of Simulation Studies, University of Hyogo, Kobe, Japan

[5] National Institute of Information and Communications Technology, Koganei, Japan

[6] Center for Information and Neural Networks, Suita, Japan

[*]Corresponding author: Yoshitada Sakai, E-mail: yossie@med.kobe-u.ac.jp

ABSTRACT

It has recently been shown that the aging population is refractory to the maintenance of swallowing function, which can seriously affect quality of life. Singing and vocal training contribute to mastication, swallowing and respiratory function. Previous studies have shown that singers have better vocal cord health. No consensus has been reached as to how vocal training affects swallowing function. Our study was designed to establish evidence that singers are statistically superior at swallowing function. In an effort to test our hypothesis we undertook a clinical trial on 55 singers and 141 non-singers (mean age: 60.1 ± 11.7 years). This cross-sectional study with propensity score matching resulted in significant differences in the repetitive saliva swallowing test among singers: 7.1 ± 2.4, $n = 53$ vs non-singers: 5.9 ± 1.9, $n = 53$, $p < 0.05$. We therefore conclude that singing can serve an important role in stabilizing the impact of age-related disease on speech.

INTRODUCTION

Pneumonia, including aspiration pneumonia, is a common cause of death in the elderly population[1-2]. The World Health Organization has noted that dysphagia due to difficulty swallowing leads to an increased risk of mortality. The likelihood of dysphagia increases with age, and substantially affects the morbidity of older adults. The best option for end-of-life care for patients with dysphagia, such as Percutaneous Endoscopic Gastrostomy (PEG), remains controversial. Risk-factors associated with dysphagia are major clinical therapeutic targets. Video fluoroscopy and endoscopy are considered the gold standard for evaluating dysphagia. As these invasive diagnostic techniques are not frequently used, non-invasive methods have been developed[3-5]. During swallowing the larynx elevates due to the contraction of several muscles to protect the airway against aspiration. The larynx serves many functions, including swallowing, respiration and vocalization, and its functional impairment leads to an increased incidence of dysphagia or dysphonia and a poor quality of life[6].

Several studies have previously addressed the efficacy of oral care and exercise in the elderly population. Various treatments have been suggested including rehabilitation programs, but few have been shown to be effective. Further, studies that investigate the mechanism of action of such agents are rare. No evidence is available regarding the effects of singing on airway protection. Several studies on breath-swallow discoordination[7-8] and tongue motor functions[9-10] have been performed. Although a previous study investigated the efficacy of singing on slowing the progression of voice aging based on several voice parameters[11], the association between singing experience and swallowing function remains unclear. To our knowledge, no clinical studies have investigated an association between swallow function and vocal training. Due to this lack of knowledge, no consensus has been reached as to how vocal training should be used in clinical practice.

Based on these challenges the purpose of this study was to understand the impact of vocal training on swallow function. We hypothesized that singing may have a significant impact on deglutitive conditions, and performed a cross-sectional study to test this.

RESULTS

Characteristics of the subjects

In an effort to identify factors that contribute to improved swallow function we performed a study involving 212 subjects aged 40 and over. The flow diagram as shown in Figure 1 summarizes the study selection criteria. The baseline characteristics of included subjects are shown in Table 1. In total, about one-third ($n = 55$) of 196 subjects were classified as experienced singers, having had at least one year of voice training. The EAT-10 screening tool was used to ensure that no subjects had a swallowing disorder. We found a weak correlation between grip strength and RSST in all classifications (Singers: $r = -0.3093$, $p < 0.05$, Non-singers: $r = -0.3150$, $p < 0.0005$, Both: $r = -0.3196$, $p < 0.0005$, Table 2), and between grip strength and BMI (Non-singers: $r = 0.3299$, $p < 0.0001$).

The possibility of bias arises because a difference in training outcome between experienced and unexperienced groups may be caused by a factor that predicts the training rather than the training itself. Taken together, propensity score matching (PSM)[12-14] was used to adjust for gender, age, BMI and grip strength (Table 3: Before matching). The MPT data was excluded as a matching factor due to its high likelihood of modifying RSST. The criteria used in our matching procedure were based on variables considered to be important determinants and predictors of swallowing ability, which were matched by gender, age, BMI, and grip strength. The 1:1 nearest neighbor within the caliper was defined as the matching allowable area[15], with an initial caliper coefficient of 0.2 and a caliper value of 0.143. Two cases were rejected, while 53 were accepted. The final study population included 106 case-control pairs, with 53 subjects each in the singer group and the non-singer group. Categorical gender comparisons were performed using Pearson's chi-squared test while continuous variables (age, BMI and grip strength) were compared using the t-test. The p-values for gender, age, BMI, and grip strength after matching were larger than ones measured before matching. The standardized difference allowed us to identify differences in the range and mean. Statistical significance was measured using an unpaired t-test for RSST and MPT between singers and non-singers.

Analysis of propensity score matching

The RSST score was significantly higher in the singer group than in the non-singer group (singer: 7.1 ± 2.4, n =53 vs non-singer: 5.9 ± 1.9, n = 53, $p < 0.05$, Figure 2). Singers had higher mean RSST scores and had a result that met the criterion for vocal training. Table 4 shows the results of univariate analyses in which the dependent variable is the RSST score. No significant correlations were measured in the singer group while the RSST was significantly associated with age and MPT in the non-singer group (RSST vs age: $p = 0.0115$, RSST vs MPT: $p = 0.0173$).

The above results can be attributed to baseline imbalance. ANCOVA adjusted for age and grip strength on RSST yielded a statistically significant p-value of 0.01 (Figure 3).

DISSCUSSION

This is the first report to our knowledge that found that singers have better swallowing function than non-singers. Of particular note is that vocal training experience was associated with an increased rate of swallowing function improvement. Our findings underscore the fact that vocal training may also affect intervention efficiency. In this study we have shown that vocal training experience affected RSST score and singers are statistically superior in their swallowing function. We conducted a cross-sectional study of singers and non-singers to gain insight into the clinical significance of little functional deterioration of singers due to aging. Our results support a hypothesis that vocal training experience is associated with swallowing ability, and that vocal training interventions focused on improved swallowing function will be better candidates for the treatment and rehabilitation of dysphagia. Understanding the changes in swallowing function that accompany age is of critical importance. Our results suggest that vocal training decreased the risk of developing dysphagia over the course of aging. The elderly population would therefore be better served by vocal treatment.

Unlike previous studies these results confirmed that vocal training can make a significant contribution to improving swallowing function in an aging population.

Dysphagia treatment of swallowing therapy

Many studies and case reports evaluate swallowing training practice, such as feeding and basic exercise. However, few studies with a high level of evidence exist regarding the usefulness of these treatments[16-17]. A systematic review in collaboration with the American Speech-Language-Hearing Association and the Department of Veterans Affairs summarized how to incorporate Evidence-based Medicine

(EBP) into clinical studies by providing an overview of swallowing posture and voluntary swallowing[18]. Although this work reported that compensatory methods had statistically significant beneficial effects, the management of exclusion bias remains a major challenge. The elderly responded to a head-raising exercise, resulting in augmentation of a deglutitive upper esophageal sphincter (UES) opening[19-20]. The outcome of this work could not exclude the influence of variability attributable to individual training effort. It has been previously shown that decline in voice stability is more frequently observed in non-singers compared with singers, and that singing is associated with aging[6]. Vocalization supports the respiratory musculature, including pharyngeal and laryngeal units. It is therefore conceivable that vocalization increases the influence of swallowing movements by using the same muscles as vocalization and elevating the larynx. This may therefore have great promise in the treatment of the internal laryngeal muscles naturally used during singing[11].

Study limitation

The sample size in our study was relatively small, especially of male patients. Our findings should be interpreted with caution due to uncertainties around some of the model parameters and baseline data. There is a need for further studies to test our findings in a larger population in the future. While the physiologic mechanism of cation of vocal training need to be explained, it is important to note that it offers many clinical benefits. Further research is needed to investigate the relationship between vocal training and brain activity[21] and understand the mechanisms behind swallowing function and disorder.

CONCLUSION

In summary, we found a difference in swallowing function between singers and non-singers. Our new findings provided evidence that vocal training may be correlated with improved swallowing regulation. To our knowledge, this is the first study to demonstrate the impact of vocal training on swallowing function.

METHODS

Study design and oversight

The Institutional Review Board at the National Institute of Information and Communications Technology(05/09/2019, Non-Registration Nunmber), Himeji Dokkyo University (13/11/2019, Registration No. 19-13) and Osaka University (04/07/2017, Registration No. 16469-2) approved the study protocol. Written informed consent was obtained from all subjects before enrollment. Study procedures were carried out in accordance with the Declaration of Helsinki and the Good Clinical Practice guidelines. The subject's information was anonymized and de-identified prior to analysis. All anonymized reports; gender, vocal training experience, age, and Body Mass Index (BMI) were reviewed for a history associated with impaired swallowing ability. Dysphagia screening was performed using the Japanese version of the 10-item Eating Assessment Tool (EAT-10). A score of 3 or more was defined as a swallowing difficulty[22]. We recorded clinical data along with Repetitive Saliva-Swallowing Test (RSST), Maximum Phonation Time (MPT) and grip strength scores.

A clinical trial was performed on 212 subjects from Tanba City Cohort in September 2019. Inclusion criteria were defined as follows: (1) subjects with no history of aspiration pneumonia; (2) no clinically evident cerebrovascular or respiratory disease; (3) no hospitalization within one year; and (4) aged between 40 and over. Exclusion criteria were: (1) no basic-information available; (2) full dentures; (3) EAT-10 score >= 3; (4) Repetitive Saliva-Swallowing Test (RSST) score <= 2; (5) not given accurate instructions. In this cross-sectional study we identified and enrolled 196 subjects (55 males and 141 females) with a mean ± SD age of 60.1 ± 11.7 years old (range 40 to 93 years).

Procedure

Three clinical assessments were performed: RSST, MPT, and grip strength.

(1) RSST

The RSST score measures swallowing function. The speech therapist counts the number of times that saliva is swallowed over thirty seconds. Less than three swallows indicates dysphagia, and is highly correlated with video fluorographic diagnosis with a sensitivity of 0.98 and a specificity of 0.66[23-24]. This is one of the most widely used swallowing assessment tests.

(2) MPT

The MPT of aerodynamic inspection measures the longest time in seconds over three attempts that the patient sustains the vowel “a:” as a clinical evaluation of vocal and laryngeal function[25]. The average duration for healthy subjects is 20 seconds or more, and men can hold it longer. Less than 10 seconds often interferes with daily conversation. The MPT is affected by general health and lung function[26].

(3) Grip strength

To assess muscle strength we recorded grip strength using a hand dynamometer GT-1201D (OG Wellness Technologies Co., Ltd., Okayama, Japan). A single measurement was obtained using the dominant hand while standing.

To avoid enrollment bias we put subjects into two groups based on vocal training experience; singers and non-singers. To ensure the objectivity of the analysis both vocal training and inexperienced participants were studied with a large sample size. We then compared differences in clinical outcomes between the subjects with and without vocal training.

Statistical Analysis

Results are expressed as mean ± standard deviation and range for continuous data and frequencies for categorical data. Pearson's correlation coefficient was used to assess the relationship between each parameter. Comparisons between subjects with/without vocal training experience were performed using the chi-squared test for categorical variables and two-sided t-tests for continuous variables. A P value < 0.05 was considered statistically significant. Statistical analyses were performed using JMP Pro 14.2 (SAS Institute Inc., Cary, NC, USA). The assignment of subjects in this cross-sectional study is typically not random. For randomization we matched to ensure that the two groups were similar[27]. Propensity scores assisted with matching variables or covariates. The factors used for matching are described in the results section. Confirming the matching balance provides an absolute standardized difference[28-29], $asd_{continuous}$ and $asd_{nominal}$.

(1) The continuous variable covariate case:

$$asd_{continuous} = \frac{\left|\overline{x_{singers}} - \overline{x_{non-singers}}\right|}{\sqrt{\frac{s_{singers}^2 + s_{non-singers}^2}{2}}} \quad (1)$$

where $\overline{x_{singers}}$ is the mean of the singer group, $\overline{x_{non-singers}}$ is the mean of the non-singer group, $s_{singers}$ is the standard deviation of the singer group and $s_{non-singers}$ is the standard deviation of the non-singer group.

(2) The nominal variable covariate case:

$$asd_{nominal} = \frac{\left|p_{singers} - p_{non-singers}\right|}{\sqrt{\frac{p_{singers}(1 - p_{singers}) + p_{non-singers}(1 - p_{non-singers})}{2}}} \quad (2)$$

where $p_{singers}$ is the rate of the singer group and $p_{non-singers}$ is the rate of the non-singer group.

To evaluate swallowing ability univariate analyses between the RSST score and patient characteristics were performed. The RSST scores in the singer group and the non-singer group were compared using an unpaired t-test. An analysis of covariance (ANCOVA) revealed a baseline imbalance, and the RSST rank reports underscored and highlighted the significant odds ratio.

REFERENCES

1. Clavé, P. Shaker, R. Dysphagia: current reality and scope of the problem. *Nature Reviews Gas Hep* **12**, 259-270 (2015). https://doi.org/10.1038/nrgastro.2015.49

2. Roy, N. et al. Dysphagia in the elderly: preliminary evidence of prevalence, risk factors, and socioemotional effects. *Ann. Otol. Rhinol. Laryngol.* **116**, 858-865 (2007). https://doi.org/10.1177/000348940711601112

3. Hashimoto, H. et al. Non-invasive quantification of human swallowing using a simple motion tracking system. *Sci Rep* **8**, 5095 (2018). https://doi.org/10.1038/s41598-018-23486-0

4. Jayatilake, D. et. al. Smartphone-Based Real-time Assessment of Swallowing Ability From the Swallowing Sound. *IEEE Journal of Translational Engineering in Health and Medicine* **3** (2015). https://doi.org/10.1109/JTEHM.2015.2500562

5. Yagi, N. et al. A noninvasive swallowing measurement system using a combination of respiratory flow, swallowing sound, and laryngeal motion. *Medical & biological engineering & computing* **55**, 1001-1017 (2017). https://doi.org/10.1007/s11517-016-1561-2

6. Schwartz, S. R. et al. Clinical practice guideline: hoarseness (dysphonia). *Otolaryngol Head Neck Surg.* **143**, 175-180 (2018). https://doi.org/10.1177/0194599817751030

7. Yagi, N. et. al. Inappropriate timing of swallow in the respiratory cycle causes breathing-swallowing

discoordination. *Frontiers in Physiology* **8**, 1-11 (2017). https://doi.org/10.3389/fphys.2017.00676

8. Nagami, S. et. al. Breathing-swallowing discoordination is associated with frequent exacerbations of COPD. *BMJ Open Respiratory Research* **4**, 1-10 (2017). http://doi.org/10.1136/bmjresp-2017-000202

9. Maezawa, H. et. al. Effects of bilateral anodal transcranial direct current stimulation over the tongue primary motor cortex on cortical excitability of the tongue and tongue motor functions. *Brain stimulation* **13**, 270-272 (2020). http://doi.org/10.1016/j.brs.2019.10.005

10. Maezawa, H. et. al. Contralateral dominance of corticomuscular coherence for both sides of the tongue during human tongue protrusion: an MEG study. *NeuroImage* **101**, 245-255 (2014). https://doi.org/10.1016/j.neuroimage.2014.07.018

11. Lortie, C. L. et. al. The moderating effect of frequent singing on voice aging. *Journal of Voice* **31**, 112.e1-112.e12 (2017). https://doi.org/10.1016/j.jvoice.2016.02.015

12. Rosenbaum, P. R. and Rubin, D. B. The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrika* **70**, 41-55 (1983). https://doi.org/10.1093/biomet/70.1.41

13. Guo, S. Y. and Fraser, M. W. Propensity Score Analysis: Statistical Methods and Applications. *SAGE Publications* **11** (2014).

14. Rosenbaum, P. R. and Rubin. D. B. The central role of the propensity score in observational studies for

causal effects. *Biometrika* **70**, 41-55 (1983).
https://doi.org/10.1093/biomet/70.1.41

15. Austin P. C. Optimal caliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies. *Pharm Stat.* 10, 150-161 (2011). https://doi.org/10.1002/pst.433
16. Logemann, J. A. Evaluation and Treatment of Swallowing Disorders, *American Journal of Speech-Language Pathology* **3**, 41-44 (1994). https://doi.org/10.1044/1058-0360.0303.41
17. Clinical Practice Guidelines for the Diagnosis and Management of Dysphagia 2018, *The Oto-Rhino-Laryngological Society of Japan* (2018).
18. Wheeler-Hegland K. et. al. Evidence-based systematic review: Oropharyngeal dysphagia behavioral treatments. Part V - Applications for clinicians and researchers. *J Rehabil Res.* **46**, 215-222 (2009). https://doi.org/10.1682/JRRD.2008.08.0093
19. Shaker, R. et. al. Augmentation of deglutitive upper esophageal sphincter opening in the elderly by exercise. *Am J Physiol*. **272**, G1518-1522 (1997). https://doi.org/10.1152/ajpgi.1997.272.6.G1518
20. Shaker, R. et. al. Rehabilitation of swallowing by exercise in tube-fed patients with pharyngeal dysphagia secondary to abnormal UES opening. *Gastroenterology* **122**, 1314-1321 (2002). https://doi.org/10.1053/gast.2002.32999
21. Belkacem, A. N. Nishio, S. Suzuki, T. Ishiguro, H. Hirata, M. Neuromagnetic Decoding of Simultaneous Bilateral Hand Movements for Multidimensional Brain-Machine Interfaces. *IEEE Trans Neural Syst*

Rehabil. Eng. **26**, 1301-1310 (2018). https://doi.org/10.1109/TNSRE.2018.2837003

22. Belafsky, P. C. et. al. Validity and reliability of the Eating Assessment Tool (EAT- 10). *Ann. Otol. Rhinol. Laryngol*. **117**, 919-924 (2008). https://doi.org/10.1177/000348940811701210
23. Oguchi, K. et. al. The repetitive saliva swallowing test (RSST) as a screening test of functional dysphagia (2) Validity of RSST. *Jpn. J. Rehabil. Med*. **37**, 383–388 (2000). https://doi.org/10.2490/jjrm1963.37.383
24. Oguchi, K. et. al. The repetitive saliva swallowing test (RSST) as a screening test of functional dysphagia (1) Normal Values of RSST. *Jpn. J. Rehabil. Med*. **37**, 375-382 (2000). https://doi.org/10.2490/jjrm1963.37.375
25. Maslan, J. Leng, X. Rees, C. Blalock, D. Butler, S. G. Maximum phonation time in healthy older adults. J Voice. 2011 Nov;25(6):709-13. https://doi.org/10.1016/j.jvoice.2010.10.002
26. Umeno, H. A summary of the clinical practice guidelines for the diagnosis and management of voice disorders, 2018 in Japan. *Auris Nasus Larynx* **47**, 7-17 (2020). https://doi.org/10.1016/j.anl.2019.09.004
27. Bland, J. M. and Altman, D. G. Statistics notes: Matching. *The BMJ* **309**, 1128 (1994). https://doi.org/10.1136/bmj.309.6962.1128
28. Rosenbaum, P. R. and Rubin, D. B. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *The American Statistician* **39**, 33-38 (1985).

https://doi.org/10.2307/2683903

29. Yang, D. and Dalton, J. A unified approach to measuring the effect size between two groups using SAS. *Mathematics* (2012). http://support.sas.com/resources/papers/proceedings12/335-2012.pdf

Acknowledgements

We thank the speech therapists and Tanba city for providing the opportunity for us to acquire cohort data. This study was funded in part by the National Institute of Information and Communications Technology and the Hyogo COE Research Program.

Author Contributions

Substantial contributions to the conception or design of the work: Y.S., Y.H., M.H., H.K. and T.Y. Substantial contributions to the acquisition of data for the work: N.Y., N.K., and H.M. Substantial contributions to the analysis, or interpretation of data for the work: N.Y., N.K., Y.S., and Y.H. Final approval of the version to be published: N.Y., Y.S., N.K., H.M., Y.H., M.H., H.K., and T.Y. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: N.Y., Y.S., N.K., H.M., Y.H., M.H., H.K., and T.Y.

Competing interests

All authors declare no competing interests.

Table 1. Full Cohort Demographic and Clinical Data

		All Subjects			
N		196			
		Male			Female
Vocal training	Experience	6			51
	No-experience	49			90
		Mean	±	SD	range
Age	[years]	60.1	±	11.7	(40 – 93)
BMI	[kg/m^2]	22.4	±	3.2	(16.2 – 38.8)
Grip strength	[kg]	29.9	±	8.9	(15.7 – 55.3)
RSST	[times]	6.4	±	2.2	(3 – 16)
MPT	[sec]	23.7	±	9.2	(6 – 62)

Continuous variables are presented as the mean ± SD (range).

Table 2. Correlations between parameters associated with swallowing ability.

		RSST	**Age**	**BMI**	**Grip strength**	**MPT**
Singers	RSST	1.0000	-0.1815	-0.2037	0.2219	0.2605
	Age	-0.1815	1.0000	0.2306	-0.3093*	-0.0192
	BMI	-0.2037	0.2306	1.0000	0.1317	-0.1448
	Grip strength	0.2219	-0.3093*	0.1317	1.0000	0.2402
	MPT	0.2605	-0.0192	-0.1448	0.2402	1.0000
Non-singers	RSST	1.0000	-0.2344**	-0.0335	0.2446#	0.1778*
	Age	-0.2344**	1.0000	-0.1096	-0.3150†	-0.2043*
	BMI	-0.0335	-0.1096	1.0000	0.3299††	-0.0284
	Grip strength	0.2446#	-0.3150†	0.3299††	1.0000	0.2829##
	MPT	0.1778*	-0.2043*	-0.0284	0.2829##	1.0000
Both	RSST	1.0000	-0.2042#	-0.0884	0.1815*	0.1859**
	Age	-0.2042#	1.0000	-0.0382	-0.3196††	-0.1696*
	BMI	-0.0884	-0.0382	1.0000	0.2965††	-0.0501
	Grip strength	0.1815*	-0.3196††	0.2965††	1.0000	0.2811††
	MPT	0.1859**	-0.1696*	-0.0501	0.2811††	1.0000

**p < 0.05, **p < 0.01, #p < 0.005, ##p < 0.001, †p < 0.0005, ††p < 0.0001.*

Table 3. Covariate imbalance prior to matching and matched samples.

A: Before matching.

			Before matching			
Matching Factor			**Singers**	**Non-singers**	**p-value**	**Standardized difference**
	N		55	141		
Used	Gender				0.0005	0.6237
		Male ([%])	6 (10.9)	51 (36.2)		
		Female ([%])	49 (89.1)	90 (63.8)		
	Age	[years]	61.5 ± 10.2	59.6 ± 12.2	0.3039	0.1704
		(range)	(40 – 82)	(40 – 93)		
	BMI	[kg/m^2]	22.2 ± 2.9	22.6 ± 3.3	0.4302	0.1289
		(range)	(16.9 – 29.8)	(16.2 – 38.8)		
	Grip Strength	[kg]	26.0 ± 5.8	31.4 ± 9.5	0.0001	0.6843
		(range)	(15.7 – 44.3)	(15.9 – 55.3)		
Non-used	RSST	[times]	7.0 ± 2.5	6.2 ± 2.1	0.0430	0.3134
		(range)	(3 – 16)	(3 – 13)		
	MPT	[sec]	22.7 ± 7.9	24.1 ± 9.7	0.3651	0.1504
		(range)	(8 – 45)	(6 – 62)		

The continuous variables are presented as the mean ± SD (range).

B: After matching.

Matching Factor			Singers	Non-singers	p-value	Standardized difference
			After matching			
	N		53	53		
Used	Gender				1.0000	0.0000
		Male ([%])	5 (9.4)	5 (9.4)		
		Female ([%])	48 (90.6)	48 (90.6)		
	Age	[years]	61.4 ± 10.3	61.2 ± 13.5	0.9292	0.0173
		(range)	(40 – 82)	(40 – 93)		
	BMI	[kg/m^2]	22.1 ± 3.0	22.5 ± 3.6	0.5175	0.1262
		(range)	(16.9 – 29.8)	(16.8 – 38.8)		
	Grip Strength	[kg]	26.2 ± 5.8	26.4 ± 5.9	0.9149	0.0208
		(range)	(15.7 – 44.3)	(15.9 – 43.0)		
Non-used	RSST	[times]	7.1 ± 2.4	5.9 ± 1.9	0.0109	0.5039
		(range)	(3 – 16)	(3 – 11)		
	MPT	[sec]	22.7 ± 7.8	22.1 ± 8.7	0.7162	0.0708
		(range)	(8 – 45)	(10 – 52)		

The continuous variables are presented as the mean ± SD (range).

Table 4. Univariate analysis of RSST score.

	Singers			Non-singers		
Factor	**r**	**95% CI**	**p-value**	**r**	**95% CI**	**p-value**
Age	-0.1590	-0.4116 – 0.1163	0.2554	-0.3447	-0.5626 – -0.0821	0.0115
BMI	-0.1930	-0.4404 – 0.0815	0.1661	-0.1442	-0.3989 – 0.1312	0.3030
Grip strength	0.1859	-0.0889 – 0.4344	0.1826	0.2576	-0.0137 – 0.4935	0.0626
MPT	0.2458	-0.0263 – 0.4839	0.0761	0.3258	0.0609 – 0.5478	0.0173

r: Pearson's correlation coefficient.

Figure Legends:

Figure 1: Flow diagram summarizing study selection criteria

Figure 2: RSST and MPT scores before and after matching

Figure 3: ANCOVA of age (A) and grip strength (B) plotted as a function of RSST score

Figure 1.

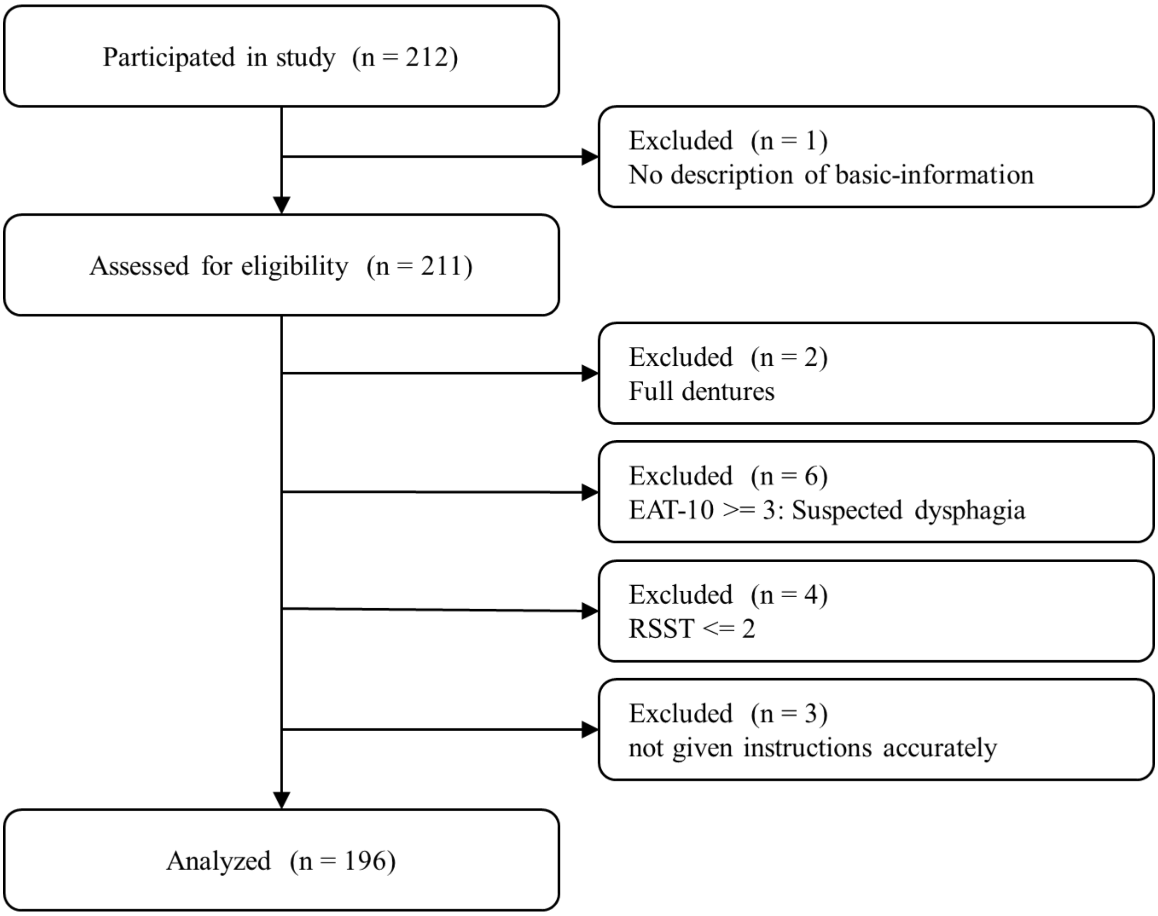

Participated in study (n = 212)
Excluded (n = 1)
No description of basic-information
Assessed for eligibility (n = 211)
Excluded (n = 2)
Full dentures
Excluded (n = 6)
EAT-10 >= 3: Suspected dysphagia
Excluded (n = 4)
RSST <= 2
Excluded (n = 3)
not given instructions accurately
Analyzed (n = 196)

Figure 2.

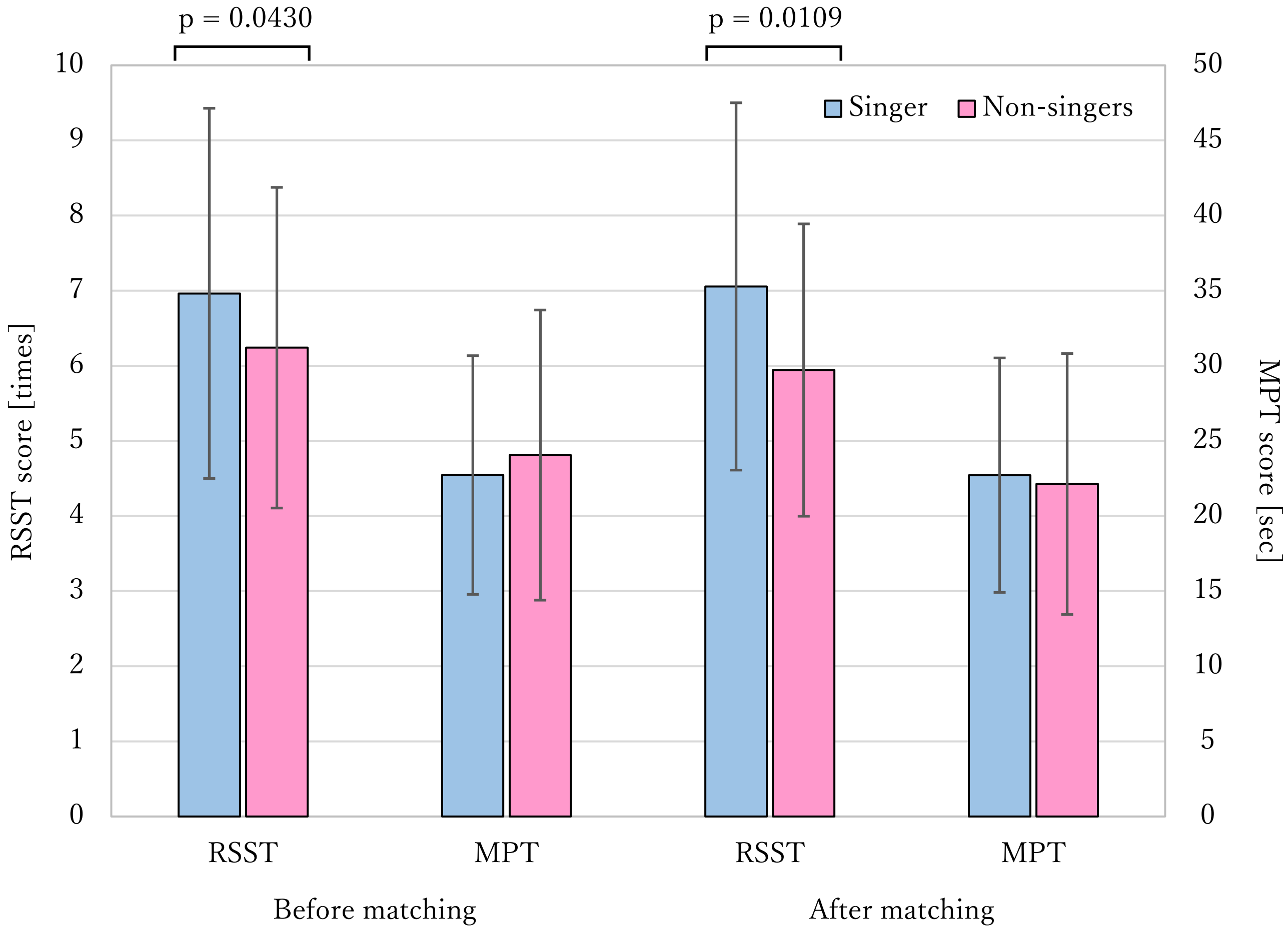
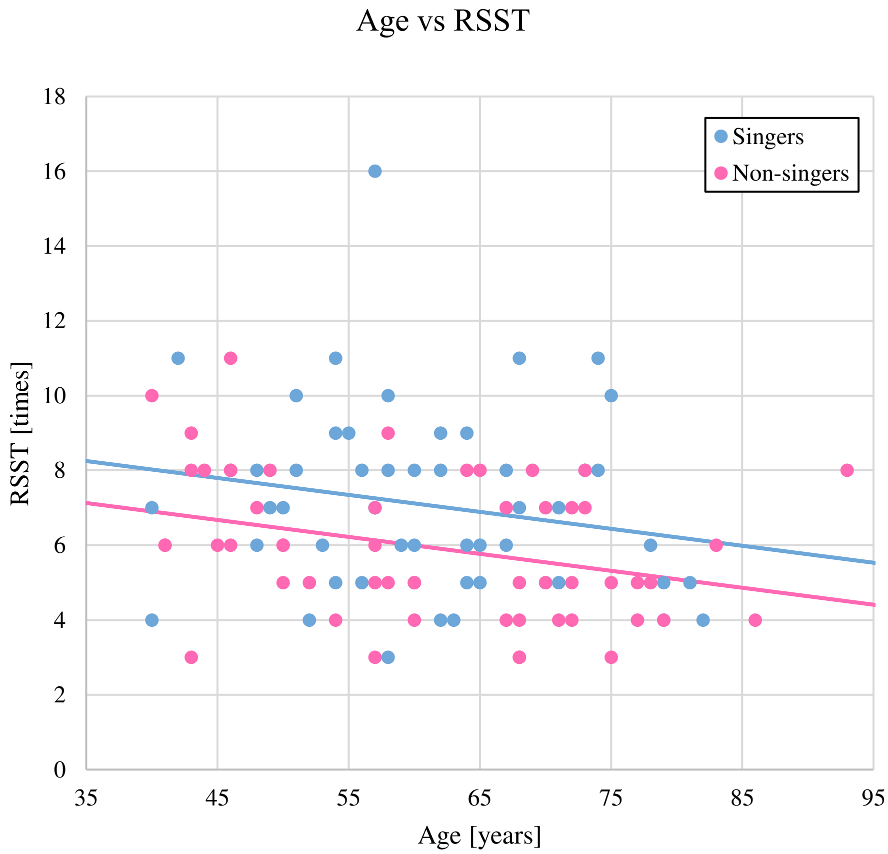

p = 0.0430
p = 0.0109
Singer
Non-singers
RSST score [times]
MPT score [sec]
10
9
8
7
6
5
4
3
2
1
0
50
45
40
35
30
25
20
15
10
5
0
RSST
MPT
RSST
MPT
Before matching
After matching

Figure 3.

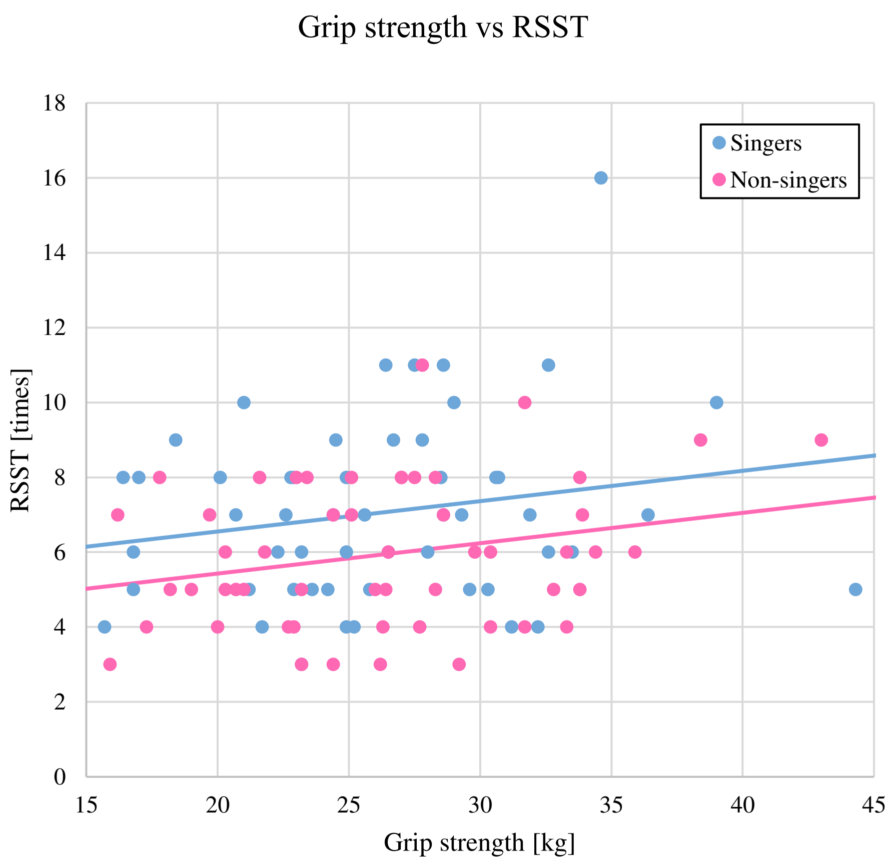
A



$$RSST = -0.045 \times Age + 9.837 - 1.122 \times Group$$

(Singers: Group = 0, Non-singers: Group = 1, p = 0.0084)

B



$$\text{RSST} = 0.081 \times \text{Grip strength} + 4.931 - 1.124 \times \text{Group}$$

(Singers: Group = 0, Non-singers: Group = 1, p = 0.0089)

Figures

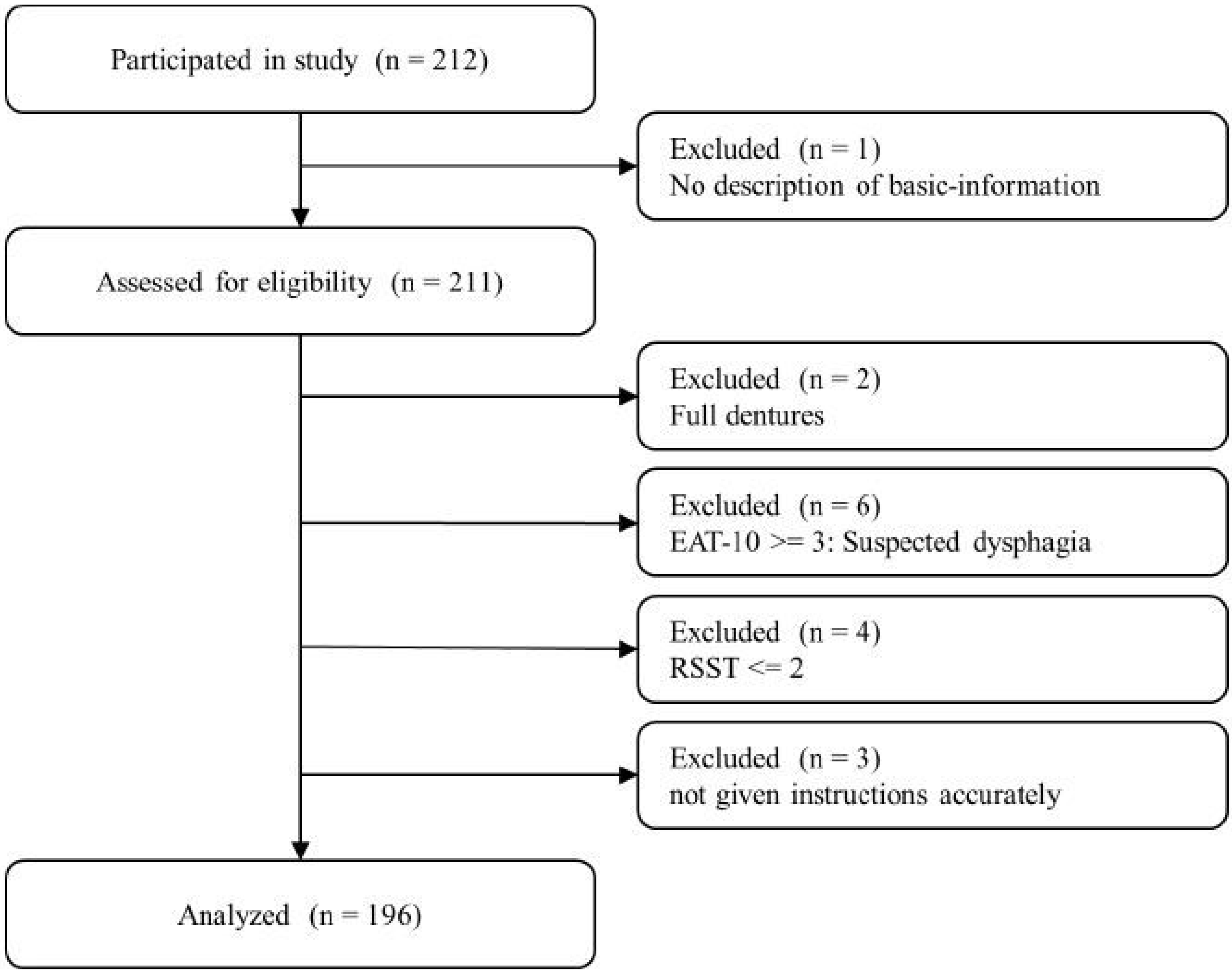


Figure 1

Flow diagram summarizing study selection criteria

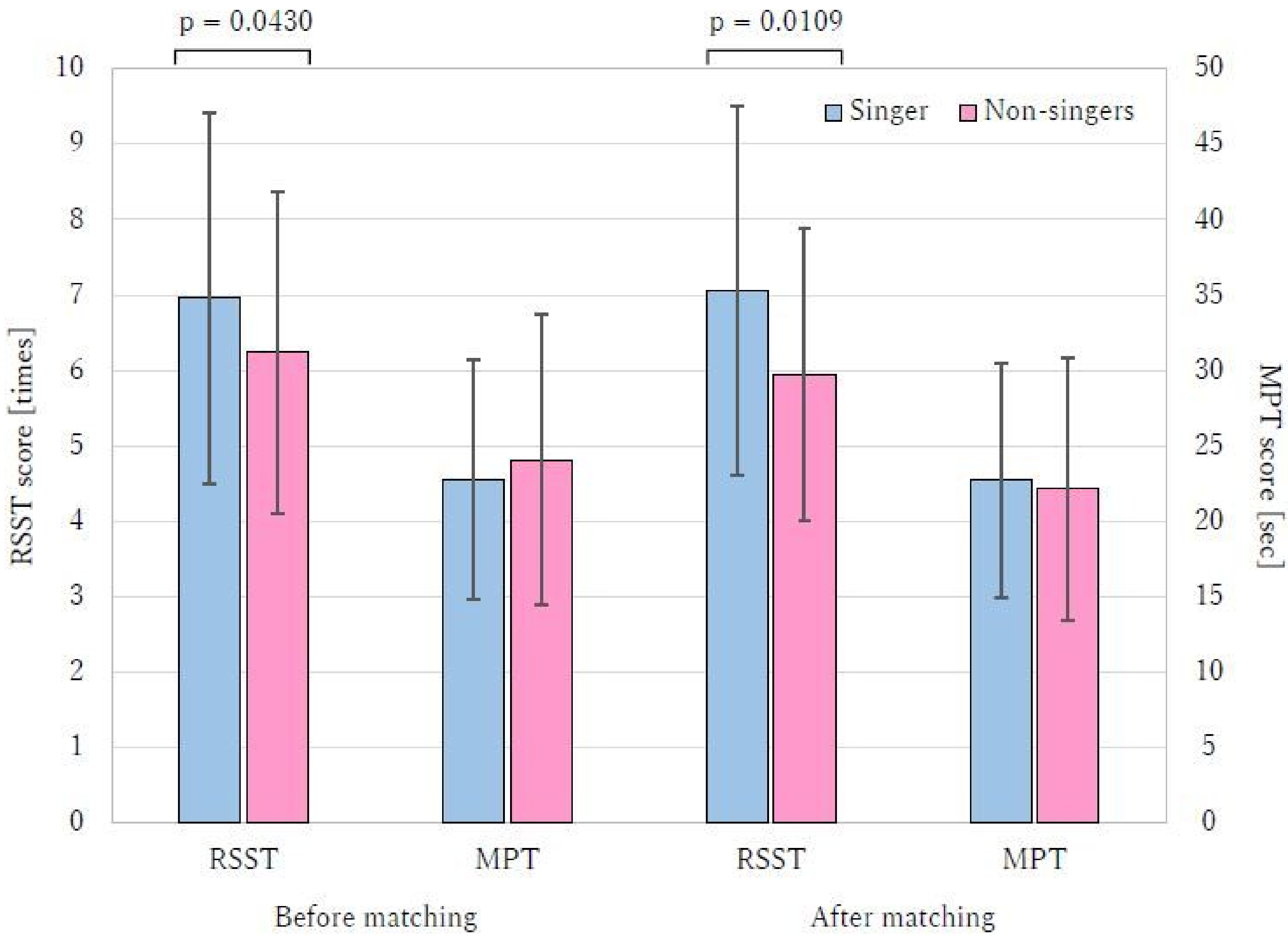
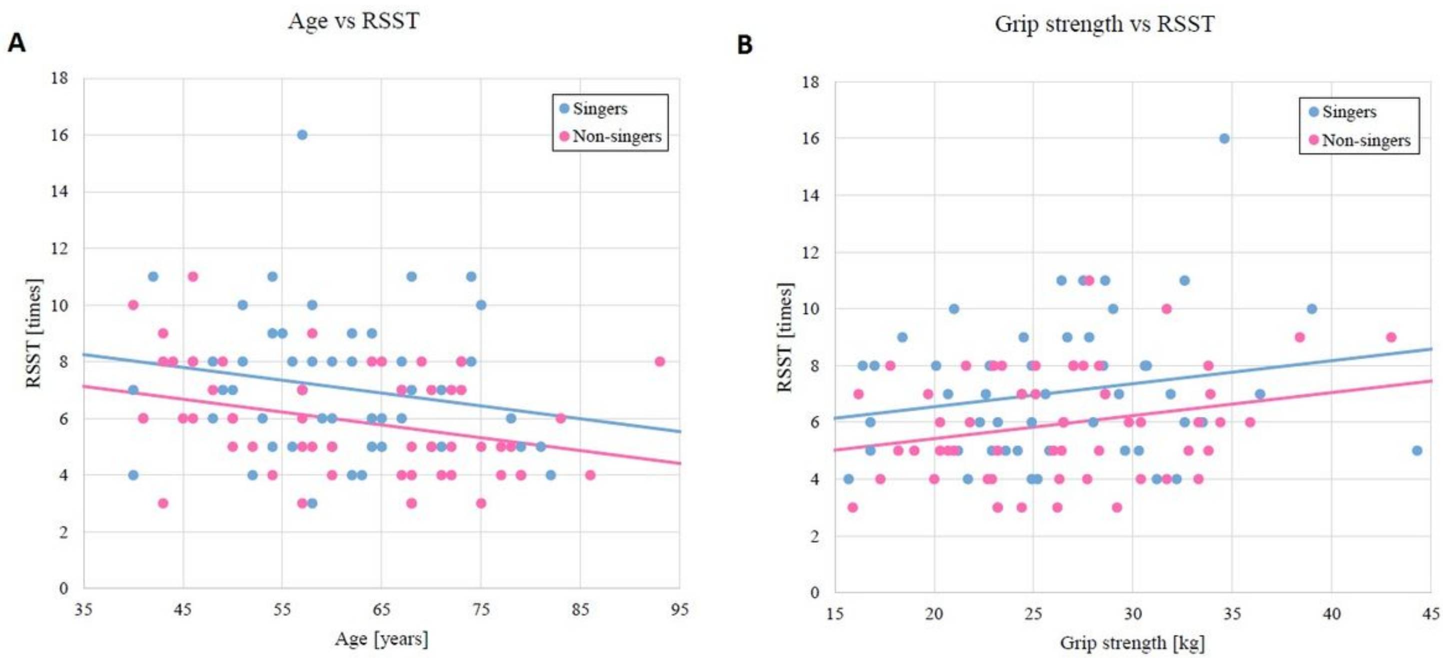


Figure 2

RSST and MPT scores before and after matching



$$RSST = -0.045 \times Age + 9.837 - 1.122 \times Group$$

(Singers: Group = 0, Non-singers: Group = 1, p = 0.0084)

$$RSST = 0.081 \times Grip\ strength + 4.931 - 1.124 \times Group$$

(Singers: Group = 0, Non-singers: Group = 1, p = 0.0089)

Figure 3

ANCOVA of age (A) and grip strength (B) plotted as a function of RSST score