Oral function, nutritional status, and physical status in Japanese independent older adults

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ABSTRACT

Objectives: To clarify the associations among oral status, nutritional status, and physical status in Japanese independent older adults.

Background: It is important to focus on factors affecting physical status associated with life dysfunction, long-term care, and mortality. However, there are very few reports of the associations among oral status, nutritional status, and physical status.

Materials and Methods: Patients who visited the Preventive Dentistry Clinic at Okayama University Hospital from November 2017 to January 2019 participated in this cross-sectional study. Number of teeth, periodontal condition, and oral function were recorded. Bacteria counts in tongue dorsum, oral wettability, tongue pressure, tongue and lip movement function [oral diadochokinesis (ODK)], masticatory ability, bite force, and swallowing function were measured. Nutritional status was assessed by the Mini Nutritional Assessment. Physical frailty status and Elderly Status Assessment Set were also evaluated. These variables were analyzed by structural equation modeling (SEM).

Results: Data from 203 patients were analyzed (63 males, 140 females). Patients ranged in age from 60 to 93 years. The final model of the path diagram was completed by SEM. ODK was positively associated with nutritional status and nutritional status was negatively associated with frailty. Age was associated with ODK, nutritional status, and frailty.

Conclusion: Based on the associations among age, ODK, nutritional status and frailty, maintaining tongue movement function may contribute to good nutritional status and physical status in Japanese independent older adults.

Key words: oral function, nutritional status, physical status, path diagram

INTRODUCTION

Frailty is a state of vulnerability associated with life dysfunction, long-term care, and mortality due to age-related decrease in various functions.[1] Physical frailty is typically defined by Fried's phenotype model.[2] Previous studies have reported that factors affecting physical frailty include nutritional status,[3] social frailty,[4] and oral frailty.[5]

Oral frailty is a decrease in oral function. Oral function decreases due to various changes in the oral environment with aging. Tanaka et al. (2018) reported that accumulated poor oral status predicted the onset of adverse health outcomes, including mortality.[5] They reported six indices, i.e., number of natural teeth, chewing ability, articulatory oral motor skill for /ta/, tongue pressure, subjective difficulty in eating tough foods, and subjective difficulty in swallowing to predict future physical frailty. In their report, for community-dwelling older adults (≥ 65 years old) in Japan, oral frailty was defined as co-existing poor status with ≥ 3 of the 6 indices. However, the definition of oral frailty is still debatable and there is no consensus.

There are some ways by which oral status can affect physical frailty. A review suggested that severe tooth loss and problems with chewing and swallowing can lead to dietary restriction and malnutrition in older adults, leading to frailty and sarcopenia.[6] Because poor oral status affects malnutrition, which is a cause of sarcopenia, poor oral status may affect physical status. Using a path diagram, a cross-sectional study reported that the number of teeth present affected denture use, which affected swallowing function. Swallowing function affected nutritional status, which ultimately affected activities of daily living (ADL).[7] However, the number of indices for oral frailty was limited. There are other possible indices for oral frailty, such as masticatory ability, tongue and lip movement function [oral diadochokinesis (ODK)], tongue pressure, and periodontal status. In addition, the study participants were those using care services. Thus, few studies have comprehensively investigated oral status for older adults and conducted pathway analyses. In the present cross-sectional study, additional possible indicators for oral status were investigated, and relationships among oral status, nutritional status, and physical status were examined. In addition, participants included only independent older adults. Furthermore, structural equation modeling (SEM) was performed to create a path diagram, and relationships among oral status, nutritional status, and physical status were clarified rather than simply checking the correlation.

An association between oral status and physical frailty status through nutritional status has been suggested.[8] Therefore, we hypothesized that oral status is associated with physical status through the pathway of nutritional status. The purpose of this study was to clarify the associations among oral function, nutritional status, and physical status in Japanese independent older adults.

METHODS

Participants

Patients who visited the Preventive Dentistry Clinic at Okayama University Hospital from November 2017 to January 2019 participated in this cross-sectional study. Patients aged 60 years and older were included, and patients who could not answer the questionnaire independently or walk independently were excluded. Based on the preliminary analysis using statistical software (SamplePower, version 3, IBM, Tokyo, Japan), estimated sample size of 190 was needed to meet the following conditions: correlation coefficient = 0.20, alpha = 0.05 (2-tailed), and power = 0.80, rejecting the null hypothesis that the population correlation is 0.00. All patients provided their written, informed consent for study participation. The STROBE guidelines were followed. The study protocol was approved by the Ethics Committee of the Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences and Okayama University Hospital (No. 1708-028).

Assessments of demographic characteristics and comorbidities

Age, gender, and comorbidities associated with frailty were investigated using a questionnaire. Comorbidities associated with frailty included cerebrovascular disease,[9] cardiovascular disease,[10] diabetes mellitus,[11] chronic obstructive pulmonary disease,[12] cancer,[13] rheumatism,[14] and Parkinson's disease.[15]

Assessment of oral status

The number of teeth, periodontal condition, and oral functional status were assessed. The number of teeth and periodontal condition were examined in a horizontal position using a dental unit under artificial lighting. The examination was conducted by 16 well-calibrated dentists. The number of teeth present did not include residual roots. The number of functional teeth included dental implants, pontics, and dentures. Probing pocket depth (PPD) and clinical attachment level (CAL) were determined at six sites (mesiobuccal, mid-buccal, distobuccal, mesiolingual, mid-lingual, and distolingual) on all teeth using a color-coded probe (Hu-Friedy, Chicago, IL, USA). As measures of oral functional status, bacteria counts in tongue dorsum, oral wettability, tongue pressure, tongue and lip movement function (ODK), masticatory ability, bite force, and swallowing function were examined.[16] Samples of bacteria counts in tongue dorsum were collected by rubbing the central part of the tongue with a sterile cotton swab. A 1 cm distance was rubbed back and forth three times. The swab was set in a constant-pressure sample collection device. The rubbing pressure was about 20 g. Then, the total number of bacteria in 1 mL of sample was measured using a bacterial counter (Panasonic Healthcare, Osaka, Japan). Oral wettability was measured using an oral moisture meter (Mucus®, LIFE, Saitama, Japan). The measurement sites were the central part of the tongue mucosa 10 mm from the tongue tip and the left and right buccal mucosa 10 mm from the corner of the mouth. The sensor was manually pressed at a pressure of about 200 g. Maximum tongue pressure was measured by the JMS tongue pressure meter (JMS, Hiroshima, Japan). The tongue pressure probe was placed between the hard palate and tongue and the balloon on the probe was crushed for a few seconds. ODK is a method used to evaluate movement of the lips and tongue. Patients were made to repeat the monophonic syllables of /pa/, /ta/, and /ka/ for 5 seconds each as quickly as possible, and the number of pronunciations per second was measured using a measuring instrument with a microphone (KENKOU-KUN® handy, Takei Scientific Instruments Co., Ltd., Niigata, Japan). The pronunciation of /pa/ is associated with lip motor function, /ta/ is related to anterior tongue motor function, and /ka/ is related to posterior tongue motor function. Masticatory ability was assessed by the glucose concentration after chewing gummy jellies. Patients chewed a glucose-containing gummy jelly (Glucolumn®, GC, Tokyo, Japan) for 20 seconds. Thereafter, 10 mL of water was held in the mouth, gargled lightly, and discharged into a filtration kit. The glucose concentration in the filtrate was measured using a glucose sensor (Gluco sensor® GS-II, GC). The maximum bite force was measured using pressure measurement film (Dental Prescale® II, GC), bite force analysis software (Bite Force Analyzer, GC), and a dedicated reading scanner (GT-X830, Seiko Epson Corp., Suwa, Japan). The film was inserted into the oral cavity to fit with the entire dentition, and it was occluded for 3 seconds. Denture users were assessed while wearing the denture. The 10-item Eating Assessment Tool (EAT-10) (Nestlé Nutrition Institute, Vevey, Switzerland) was used to evaluate swallowing function. There are 5 options (0 to 4 points) for each question, and the points of 10 questions are summed (minimum, 0 points; maximum, 40 points). Higher bacteria counts in tongue dorsum and a higher EAT-10 score indicate worse oral status. Higher oral wettability, tongue pressure, ODK, masticatory ability, and bite force indicate better oral status.

Assessment of nutritional status

Nutritional status was assessed using the Mini Nutritional Assessment (MNA®) (Nestlé Nutrition Institute). The MNA® is a validated nutrition screening and assessment tool that can identify geriatric patients aged 65 years and older who are malnourished or at risk of malnutrition. The nutritional status is evaluated by 18 evaluation items (minimum, 0 points; maximum, 30 points), and a higher total score indicates better nutritional status.[17]

Assessment of physical status

Frailty and the Elderly Status Assessment Set (E-SAS) (Japanese Physical Therapy Association, Tokyo, Japan) were assessed.

Frailty

The Japanese version of the Cardiovascular Health Study (J-CHS) criteria, which is the Japanese version of Fried's phenotype model for evaluating frailty, was used.[18] Five items were evaluated: muscle weakness (grip strength), walking speed, weight loss, exhaustion, and physical activity. Grip strength was measured by a digital grip dynamometer (Grip-D, Takei Scientific Instruments Co., Ltd.). Walking speed was measured at a distance of 5 m using a measurement mat and multi-timer (Takei Scientific Instruments Co., Ltd.). Questions about weight loss and exhaustion were “Have you lost weight more than 2-3 kg in 6 months?” and “Have you felt tired for the last 2 weeks for no particular reason?”, respectively. Lack of physical activity was confirmed as a negative answer to either of the following two self-reported questions: “Do you do light exercise or gymnastics at least once a week?” and “Do you do regular exercise or sports at least once a week?” Those who did not fit any of the five items were categorized into the robust group. Those who fit one or two items were categorized into the pre-frailty group, and those who fit three or more items constituted the frailty group.

E-SAS

The E-SAS is a questionnaire survey to measure various factors necessary for older adults to live actively in the community.[19] In Japan, the E-SAS is used to determine the preventive care effect of older adults. In this study, three items were evaluated: confidence in not falling, bathing at home, and walking distance without rest. Confidence in not falling reflects self-efficacy for falls and is evaluated with 10 questions. Bathing at home reflects bathing ability and is evaluated with 5 questions. Walking distance without rest was scored by continuous walking distance.

Statistical analysis

SEM was used to evaluate demographic characteristics, comorbidities, oral status, nutritional status, and physical status. The variables were age, gender, comorbidities, number of teeth present, number of functional teeth, PPD, CAL, bacteria counts in tongue dorsum, oral wettability, tongue pressure, ODK /pa/, ODK /ta/, ODK /ka/, masticatory ability, bite force, swallowing function (EAT-10 score), nutritional status (MNA® score), frailty, confidence in not falling, bathing at home, and walking distance without rest. Figure 1 shows the ideal model. The periodontal condition was not included in the ideal model because there was no correlation with any other variables.

SEM was performed using the method of weighted least squares means and variance adjusted estimator. For the comparative fit index (CFI) and Tucker-Lewis index (TLI), fit indices of > 0.90 (preferably > 0.95) indicate a well-fitting model.[20] For root mean square error of approximation (RMSEA), a fit of < 0.05 indicates a well-fitting model.[21] A significance level of $p < 0.05$ was used for regression coefficients. In mediation analysis, the bias-corrected bootstrapping method was used. The significance level was set to $p < 0.05$, and indirect effects were considered significant if the 95% confidence interval (CI) did not include 0.[22] Mplus Version 8.2 software (Muthén & Muthén, Los Angeles, CA, USA) was used for these analyses.

Demographic characteristics and comorbidities, number of teeth, oral function, and physical status were set as latent variables. Demographic characteristics and comorbidities included age, gender, and comorbidities. Those with one or more comorbidities were included in the comorbidities group. Number of teeth included number of teeth present and number of functional teeth. Oral function included bacteria counts in tongue dorsum, oral wettability, tongue pressure, ODK /pa/, ODK /ta/, ODK /ka/, masticatory ability, and bite force. Physical status included frailty, “confidence in not falling,” “bathing at home,” and “walking distance without rest.” Frailty was divided into two groups, a robust group and a pre-frailty/frailty group. The robust group was set to 0, and the pre-frailty/frailty group was set to 1.

RESULTS

Of the 219 patients, 16 were excluded due to missing data, and 203 patients were finally included in the analyses [male, n = 63 (31.0%); female, n = 140 (69.0%)] (Figure 2). Table 1 shows the characteristics of the patients. The overall median patient age was 74.0 years (male, 73.0 years; female, 74.5 years). There were 45 patients with comorbidities. The overall median number of teeth present and functional teeth was 22 and 27, respectively.

Figure 3 shows the final model. In SEM, ODK was set as a latent variable including /ta/ and /ka/. A path coefficient greater than 0 indicates a positive correlation, and a path coefficient less than 0 indicates a negative correlation. ODK was positively associated with nutritional status and nutritional status was negatively associated with frailty. This means that a higher frequency of ODK was associated with better nutritional status, and good nutritional status was associated with robustness. In addition, age was associated with ODK, nutritional status, and frailty. CFI, TLI, and RMSEA values indicated good model-data fit (1.000, 1.000, and 0.000, respectively). All pathways were significant ($p < 0.05$). Model-data fits were not good when considering the following variables: gender, comorbidities, number of teeth present, number of functional teeth, bacteria counts in tongue dorsum, oral wettability, tongue pressure, masticatory ability, bite force, swallowing function, "confidence in not falling," "bathing at home," and "walking distance without rest." These were excluded from the final model.

In the final model, mediation analysis was used. The independent variable was ODK, the dependent variable was frailty, and the mediator was nutritional status. Table 2 shows estimates and 95% CIs. The total effect of ODK on frailty was significant ($p = 0.045$). The direct effect was not significant ($p = 0.179$) and the indirect effect was significant (-0.043, 95% CI: -0.110, -0.006). Based on this, it was also confirmed that ODK was associated with frailty, with nutritional status as a mediator.

DISCUSSION

In this study, better tongue motor function was associated with better the nutritional status, and good nutritional status was negatively associated with frailty.

The ODK /ta/ rate represents motor function of the anterior tongue, and the /ka/ rate represents motor function of the posterior tongue. Okada et al. (2012) reported that decreased tongue movement leads to future malnutrition.[23] Other studies reported that oral frailty including impairment of ODK is associated with nutritional status in Japanese community-dwelling older adults.[24,25] These previous findings support the present results. Therefore, higher ODK rates might be related to physical status through improvement of nutritional status. In the future, it may be possible to prevent frailty by intervening to improve tongue movement function.

The previous studies reported that malnutrition was associated with oral status including saliva flow,[26] properties of tongue,[27] and chewing ability.[28] Okada et al. (2010) reported that masticatory disorder had a negative impact on general health by leading to restricted dietary selection and nutrition.[28] Although the types of participants in these studies differed from those of the present study, the possible mechanism with respect to the relationship between oral status and nutritional status may support the present findings.

Reviews of the relationship between nutritional status and frailty reported associations between the MNA® score and frailty,[3] energy intake and frailty, protein intake and frailty, and vitamin D and vitamin B12 deficiencies and physical status.[29] These reports support the present findings. However, weight loss overlapped in the evaluation of frailty and nutritional status. Therefore, the observed association between nutritional status and frailty in the present study could be considered due to a relevant overlap in the contents of the J-CHS criteria and MNA®.

There have been some previous studies of oral health, nutrition, and frailty.[30–32] Shwe et al (2019) reported associations among the Geriatric Oral Health Assessment Index (GOHAI), MNA®, and the Reported Edmonton Frailty Scale (REFS).[30] Poor self-reported oral health was found to be independently associated with frailty. Furthermore, Bassim et al (2020) reported that poor subjective oral health was associated with poor diet and frailty.[31] These studies evaluated subjective oral function, which is different from that evaluated in the present study. However, the findings of these studies may support the present results.

In the present study, there was no direct association between ODK and frailty, which was different from other studies.[33,34] The reason may depend on a mediator of nutritional status. The previous studies did not include nutritional status to assess the association between ODK and frailty. On the other hand, a previous study reported that a direct association of ODK was excluded when both ODK and nutritional status were treated as independent variables at the same time.[35] Based on the possible underlying mechanism between ODK and frailty, ODK can have indirect effects on frailty through nutritional status, rather than direct effects.

There are discrepancies between the present study and a previous review. The review reported that the number of teeth, periodontal condition, bite force, number of occlusal pairs, and dry mouth were associated with physical frailty.[8] However, these studies did not investigate the association with nutritional status. The present study investigated the mediating role of nutritional status to address the complex relationships across oral health, nutrition and frailty. Considering nutritional status, it is possible that ODK as an indicator of oral status was indirectly related to frailty in the present study.

There are limitations to this study. First, social frailty, which has been associated with physical frailty, was not evaluated.[4] Second, factors related to socioeconomic status, which may be associated with this path diagram, were not investigated. Third, gender and comorbidities could not be considered sufficiently. Fourth, weight loss overlapped in the evaluation of frailty and nutritional status. Fifth, because this was a cross-sectional study, causal relationships could not be confirmed. Last, independent older adults who visited an outpatient university clinic were evaluated. Thus, whether they were representative of community-dwelling older adults was not known.

In conclusion, the present findings suggest that maintaining tongue movement function may contribute to good nutritional status and good physical status in Japanese independent older adults.

ACKNOWLEDGMENTS

We thank the members of the Department of Preventive Dentistry of Okayama University Graduate School and Okayama University Hospital for their cooperation in recruiting participants.
This work was supported by the Japan Society for the Promotion of Science, JSPS KAKENHI Grant Numbers JP17K12046 and JP17H04421.

CONFLICT OF INTEREST

None reported.

AUTHOR CONTRIBUTIONS

All authors designed the study and collected the data. NS and NT analyzed the data. All authors interpreted the data. NS drafted the first version of the manuscript. NT, DE, and MM revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

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Table 1. Study participants' characteristics

Variable	Total (n = 203)	Male (n = 63)	Female (n = 140)
Age (years)	74.0 (70.0, 79.0)[a]	73.0 (69.0, 80.0)	74.5 (70.0, 79.0)
Number of teeth present	22.0 (16.0, 26.0)	22.0 (16.0, 26.0)	23.0 (15.3, 25.8)
Number of functional teeth	27.0 (26.0, 28.0)	27.0 (25.0, 28.0)	27.0 (26.0, 28.0)
Probing pocket depth (mm)	2.09 (1.86, 2.35)	2.18 (1.97, 2.49)	2.05 (1.80, 2.24)
Clinical attachment level (mm)	2.91 (2.33, 3.57)	3.27 (2.40, 4.14)	2.75 (2.29, 3.44)
Bacteria counts in tongue dorsum (CFU×10^6/mL)	13.4 (5.1, 28.4)	12.5 (4.9, 31.4)	13.4 (5.1, 27.4)
Oral wettability	29.1 (27.9, 30.3)	29.1 (27.6, 30.4)	29.1 (27.9, 30.3)
Tongue pressure (kPa)	31.8 (25.7, 36.4)	32.2 (25.5, 37.3)	31.6 (25.8, 36.0)
ODK (times/s)			
/pa/ sound	6.0 (5.4, 6.5)	5.9 (5.4, 6.5)	6.0 (5.4, 6.5)
/ta/ sound	6.0 (5.5, 6.5)	6.0 (5.4, 6.6)	6.0 (5.5, 6.5)
/ka/ sound	5.6 (5.2, 6.2)	5.5 (5.0, 6.2)	5.7 (5.3, 6.2)
Masticatory ability (mg/dL)	172.3 (130.3, 210.8)	176.7 (133.5, 216.0)	168.6 (129.5, 209.8)
Bite force (N)	485.4 (228.9, 773.0)	626.1 (275.1, 869.4)	424.6 (205.3, 697.0)
Swallowing function (EAT-10)	0.0 (0.0, 1.0)	0.0 (0.0, 0.0)	0.0 (0.0, 1.0)
Nutritional status (MNA®)	28.0 (26.0, 29.5)	28.5 (27.4, 30.0)	27.5 (25.5, 29.0)
Frailty	118 (58.1)[b]	27 (42.9)	91 (65.0)
E-SAS			
Confidence in not falling	39.0 (34.0, 40.0)	39.0 (33.0, 40.0)	40.0 (34.0, 40.0)
Bathing at home	10.0 (10.0, 10.0)	10.0 (10.0, 10.0)	10.0 (10.0, 10.0)
Walking distance without rest	6.0 (5.0, 6.0)	6.0 (5.8, 6.0)	6.0 (5.0, 6.0)

[a] Data are expressed as median (25 percentile, 75 percentile)

[b] Number of participants in pre-frailty/frailty group (%)

CFU: colony forming unit; ODK: oral diadochokinesis; EAT-10: the 10-item Eating Assessment Tool; MNA®: Mini Nutritional Assessment; E-SAS: Elderly Status Assessment Set

Table 2. Estimates and 95% confidence intervals for the final model

Pathway	Estimate	95%CI
ODK → Frailty		
Total effect	0.000	-0.015, 0.000
Direct effect	-0.052	-0.338, 0.058
Indirect effect	-0.125	-0.138, -0.007
Age → ODK	-0.030	-0.046, -0.012
Age → Nutritional status	-0.071	-0.122, -0.021
Age → Frailty	0.040	0.014, 0.071

CI: confidence interval

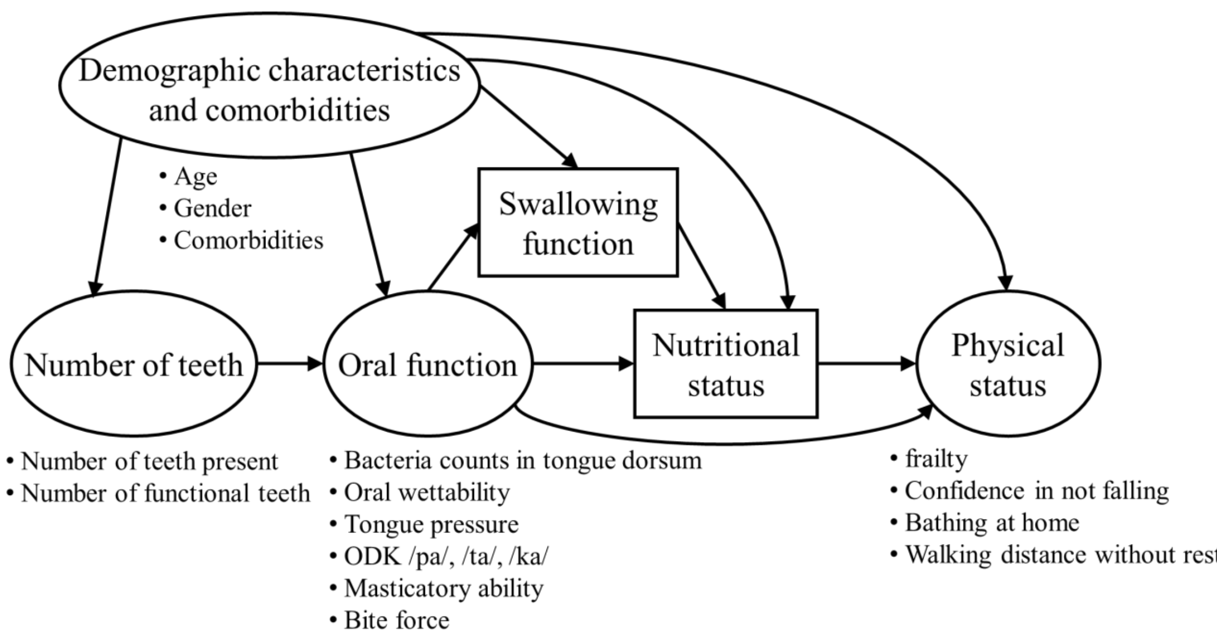

Figure 1. Ideal model showing associations among demographic characteristics and comorbidities, oral status, nutritional status, and physical status. Rectangles indicate observed variables, and ovals show latent variables. ODK: oral diadochokinesis; E-SAS: Elderly Status Assessment Set

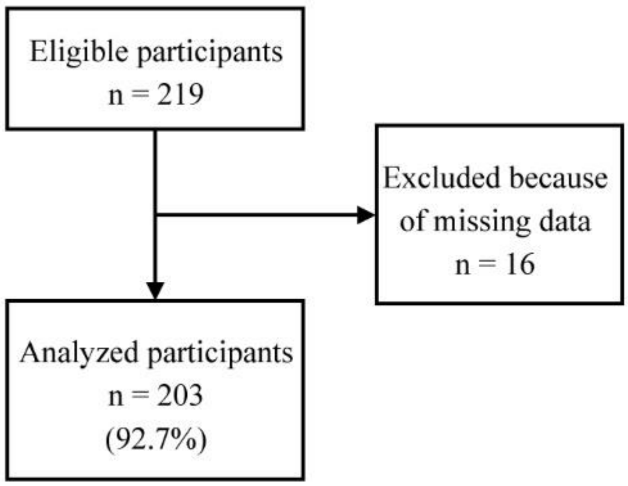

Figure 2. Flowchart of study participants

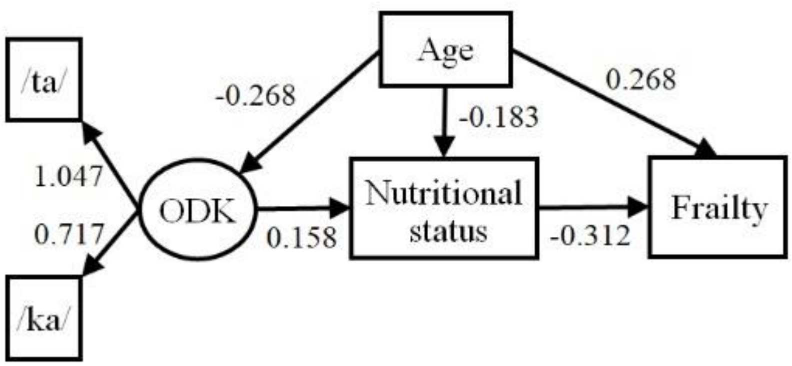

Figure 3. Final structural model. Rectangles indicate observed variables, and ovals show latent variables. Values of single-headed arrows indicate standardized coefficients. All pathways are statistically significant ($p < 0.05$). ODK: oral diadochokinesis