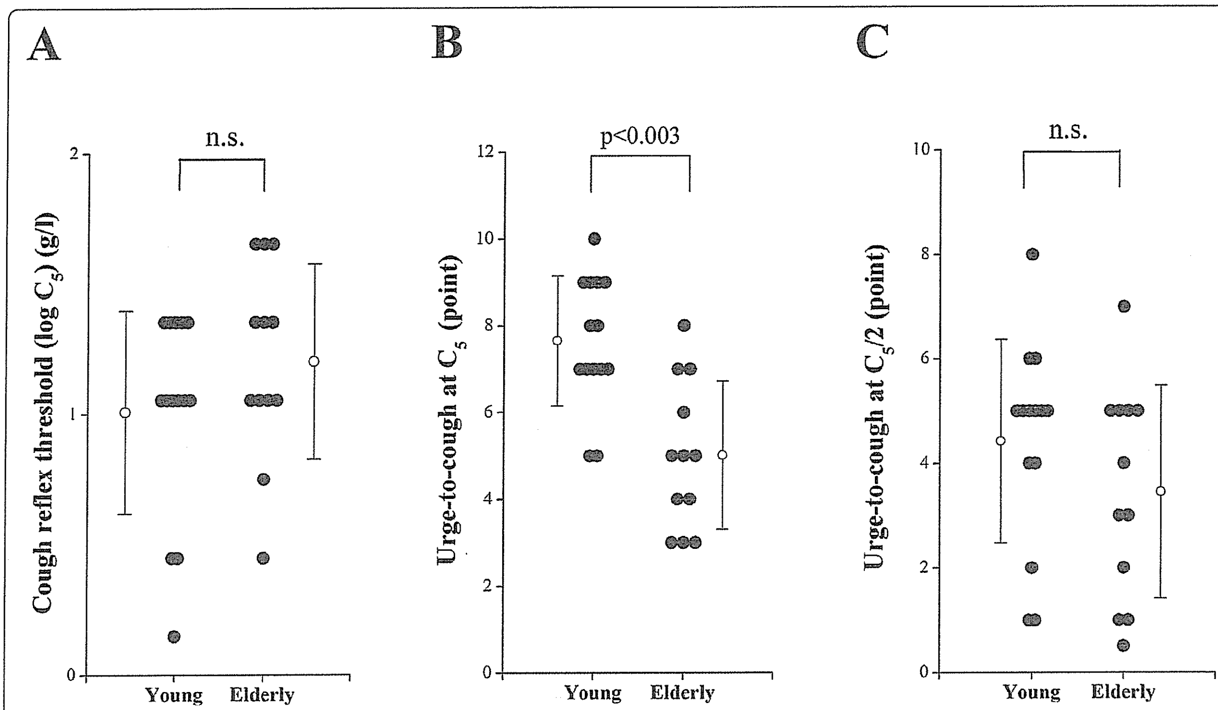

Figure 2 Comparisons of cough reflex sensitivity and urge-to-cough between young and elderly subjects. (A) Cough reflex sensitivities expressed as the log transformation of the lowest concentration of citric acid that elicited five or more coughs (C_5). (B) The urge-to-cough estimated by the Borg scores at C_5 of each subject. (C) The urge-to-cough estimated by the Borg scores at the concentration of two times dilution of C5 ($C_5/2$) of each subject. Closed circles indicate the value of each subject. Open circles and error bars indicate the mean value and the standard deviation in each group, respectively. n.s. denotes not significant.

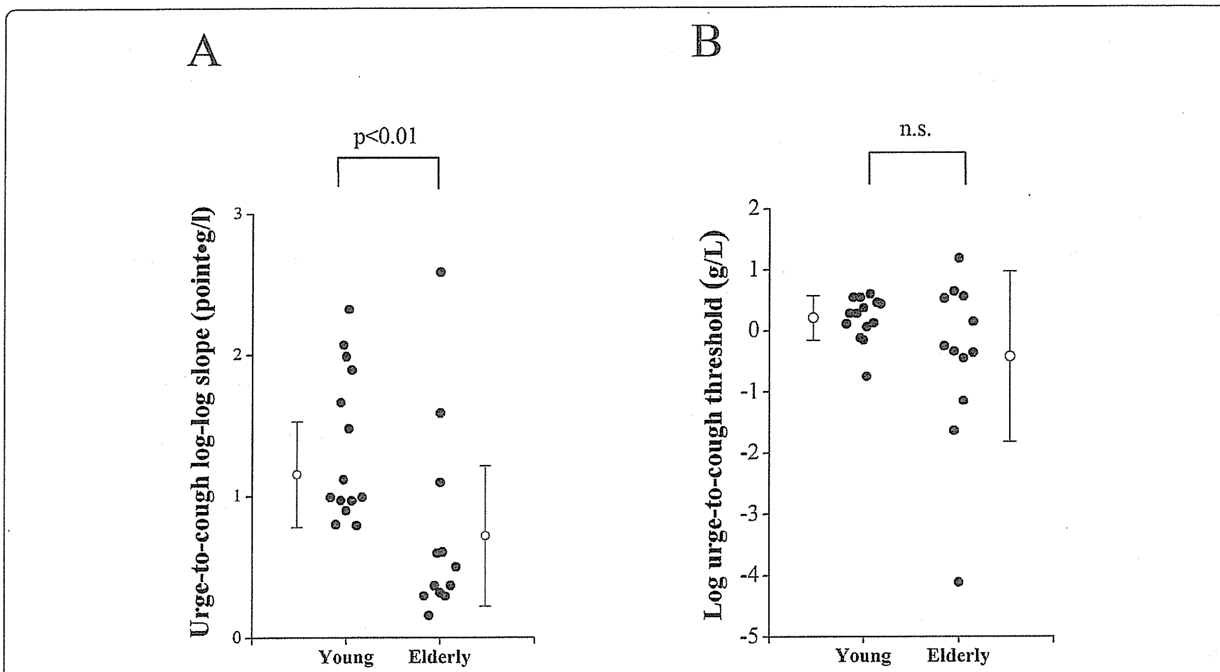

Figure 3 Comparisons of urge-to-cough between young and elderly subjects. (A) The urge-to-cough log-log slope by linear regression between log citric acid concentration and the log Borg scores. (B) The urge-to-cough threshold estimated by log citric acid concentration at the log Borg Score of urge-to-cough = 0. Closed circles indicate the value of each subject. Open circles and error bars indicate the mean value and the standard deviation in each group, respectively. n.s. denotes not significant.

aging or a consequence of potentially existing brain disorders. In addition, the study had some limitations due to small sample size. The studies of larger sample size with brain imaging data are warranted.

Conclusions

The cough reflex threshold did not differ between young and elderly subjects whereas cognition of urge-to-cough was significantly decreased in elderly subjects in female never-smokers. Our study has some clinical implications. Elderly people may not complain of excessive cough because of lack of the cognitive component of cough. Therefore, it might be of importance to monitor cough objectively in order to detect early sign of respiratory infections for elderly people.

List of abbreviations used

C_2: the lowest concentration of citric acid that elicited two or more coughs; C_5: the lowest concentration of citric acid that elicited five or more coughs; GERD: gastro-esophageal reflux diseases.

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Authors' contributions

SE and TE participated in the design of the study, collected and analyzed data, and drafted the manuscript. KM, PG and MY participated in the design of the study and collected the data. HA and MK participated in design of the study and helped to draft the manuscript. All the authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Impact of physical activity and performance on medical care costs among the Japanese elderly

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Aim: Physical activity (PA) is known to be inversely associated with medical care costs. The amount of PA is strongly associated with the level of physical performance among the elderly population. Therefore, it is possible that known relation between PA and medical care merely shows the relation between physical performance and medical care. To know whether PA itself relates to medical care, considering physical performance is necessary. The aim of this study was to ascertain the impact of PA on medical care expenditure by considering the physical performance in an elderly community-dwelling population.

Methods: We investigated 483 subjects who did not have any history of diseases relating to limited PA and who completed both a self-administered questionnaire including questions on PA and underwent a physical performance measurement. We ascertained the total medical care costs through a computerized linkage with claims lodged between August 2002 and March 2008 with the Miyagi National Health Insurance Association.

Results: The physical performance was positively associated with their level of PA. After multivariate adjustment for covariables including the levels of physical performance, the per capita medical care costs were found to be $US 827.3 (598.0–1056.7) (mean, 95% confidence interval), $US 711.1 (476.4–945.8) and $US 702.0 (461.6–942.4) (*P* for linear trend = 0.02) per month for those who had the lowest, average and the highest level of PA, respectively.

Conclusion: This prospective study indicates that a higher level of PA is associated with lower medical care costs among the Japanese elderly irrespective of physical performance. **Geriatr Gerontol Int 2011; 11: 157–165.**

Keywords: community-dwelling elderly population, medical care costs, physical activity, physical performance.

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Introduction

The rising medical care costs associated with the growth of the elderly population is an ongoing problem worldwide.[1,2] In the 2005 Japanese census report, the proportion of the elderly population in the total population of the country was 20.1%. This proportion is expected to

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reach 35.7% by 2050.[3] In the 2002 Health and Welfare Statistics Association survey, 50.4% of the total national medical care costs were incurred by elderly individuals over 65 years of age.[4] According to the survey, the average per capita monthly medical care costs were $US 1284 for the under-65 age group and $US 5536 for the over-65 age group; that is, the costs for the latter group were five times higher than those for the former.

A sedentary lifestyle has been found to be associated with an increased risk of developing various chronic diseases and mortality.[5–8] Actually, several studies have reported that physical activity (PA) is inversely associated with medical care costs.[9–11] The promotion of regular PA may lead to a reduction in medical care costs. The amount of PA, however, is strongly associated with the level of physical performance, especially in the elderly population.[12–17] Therefore, it is natural to assume that physical performance would be an important mediator in the relationship between PA and medical care costs. Thus, careful consideration of this potentially important confounding or effect-modifying factor is needed when analyzing the data. However, to our knowledge, no previous studies have investigated the impact of physical activity on medical care expenditure using stratified analyses of physical performance levels.

We thus designed a cohort study of National Health Insurance (NHI) beneficiaries to investigate the link between PA levels and medical care costs in association with physical performance in an elderly Japanese community-dwelling population.

Methods

Study participants

Our data were derived from a prospective observation of NHI beneficiaries in suburban Japan through August 2002 to March 2008. In 2002, there were 2730 individuals aged 70 years and older living in Tsurugaya, a residential area in one of the major cities in northern Japan, Sendai City. We invited all of these individuals to participate in a comprehensive geriatric assessment[18] in which the physical, mental and social functioning of elderly people was examined to assess the early deterioration that could result in the need for long-term care and thus to promote healthy aging. Of those invited, 1178 gave written informed consent to being included in the structured survey. Of these 1178, we investigated 969 persons who agreed to respond to a questionnaire on medical care costs, the coverage of these costs under the NHI system, and medical care utilization derived from claim history files. The comprehensive health and lifestyle information for each subject at baseline allowed us to adjust for a variety of potential confounders. The protocol of this study was approved by the Institutional Review Board of the Tohoku University Graduate School of Medicine.

We excluded the subjects who provided incomplete data in the PA questionnaire ($n = 130$), or who had not been tested for physical performance ($n = 70$). Furthermore, we excluded all potential subjects with notable comorbidities that could influence the frequency and degree of PA, that is, those who reported being incapable of walking 50 m independently ($n = 58$) and those with a history of arthritis ($n = 107$). Of the remaining 604 subjects, we further excluded those who reported a history of stroke ($n = 26$), coronary heart disease ($n = 61$), cancer ($n = 33$), and the one subject reporting cognitive dysfunction (Mini-Mental State Examination [MMSE] score <18) in the baseline survey. As a result of these exclusions, the final study population comprised 483 (231 male and 252 female) subjects. The mean age was 75.5 years (standard deviation [SD] = 4.2).

Data on medical care costs

We prospectively collected data on medical care use and costs for all individuals in the cohort study that extended from August 2002 to March 2008. We obtained the NHI claims history files from the Miyagi NHI Association. These files included the total number of outpatient visits, the total number of days of inpatient care, and the charges for outpatient and inpatient care, respectively.

When a beneficiary was withdrawn from the NHI, the date and reason were coded on an NHI withdrawal history file. This file identified the survival and emigration status for each subject. Both the NHI claims and withdrawal history files were linked with our baseline survey data file, with the beneficiary's ID number functioning as the key code. Monthly medical expenditures for each subject were calculated by dividing the total medical expenditures throughout the observation period by the number of months observed. We used monthly values rather than cumulative values to avoid underestimating medical expenditures for subjects who died or emigrated during the follow up.

Assessment of PA

A self-reported single-item questionnaire was used to estimate the different levels of PA in each subject. The subject was asked whether he or she had performed any activities from the following categories in the previous 12 months: walking, brisk walking, or sports (e.g. aerobics, tennis, swimming, jogging, etc.). If they had participated in a given activity, the frequency of and duration of time spent in performing the activity were ascertained using the following categories: for frequency

Table 1 Definition of physical activity level ($n = 483$)

	Low		Moderate		High	
No. of participants	115	90	114	46	66	52
Walking	None	Low	High	Any	Any	Any
Brisk walking	None	None	None	Low	High	Any
Sports	None	None	None	None	None	Low and high
Walking						
None	115	0	0	14	41	22
Low	0	90	0	15	1	14
High	0	0	114	17	24	16
Brisk walking						
None	115	90	114	0	0	32
Low	0	0	0	46	0	7
High	0	0	0	0	66	13
Sports						
None	115	90	114	46	66	0
Low	0	0	0	0	0	48
High	0	0	0	0	0	4

High, at least 3–4 times/week for at least 30 min each time; low, reporting some activity in the past year, but not enough to meet high levels; none, no physical activity.

(i) 1–2 times/month; (ii) 1–2 times/week; (iii) 3–4 times/week; or (iv) almost every day; and for duration (per walk or workout) (i) 0–30 min (<30 min); (ii) 0.5–1 h (≥0.5 h, <1 h); (iii) 1–2 h (≥1 h, <2 h); (iv) 2–3 h (≥2 h, <3 h); (v) 3–4 h (≥3 h, <4 h); or (vi) 4 h or more (≥4 h). Among the levels of exercise intensity, sports were considered the highest, followed in order by brisk walking and walking. Each of the three types was further classified into three subcategories according to the frequency and duration of the walks or workouts as follows:[19,20] (i) high, at least 3–4 times/week for at least 30 min each time; (ii) low, some activity in the past year, but not enough to meet the criteria for the high group; and (iii) none, no PA. Finally, we used these categories and subcategories to define the following three levels of PA (Table 1): (i) low, no sports, no brisk walking, low amount of walking; (ii) moderate, no sports, low amount of brisk walking, any amount of walking; and (iii) high, any amount of sports, any amount of brisk walking, any amount of walking. Table 1 also shows the number of participants according to the PA levels.

Assessment of physical performance measurement

Leg muscle power (w/kg)

Bilateral leg muscle power was measured on a horizontal leg extension apparatus (Combi Anaeropress 3500, Tokyo, Japan). Participants were positioned well back on a seat, supported at the waist by a belt, and their feet were placed on a sliding board with the knee joints angled at 90°. The resistance of the sliding board was adjusted according to the bodyweight. Participants were asked to extend their knees to push away the sliding board as hard as they could. The leg extension power was then measured. The trials were separated by 15-s rest intervals. The average of the two highest leg power measurements among five trials conducted was recorded as the "leg muscle power" and the resulting power was divided by the bodyweight.

Functional reach (cm)

Participants were asked to reach as far forward as possible while maintaining a fixed base of support, with their feet placed comfortably apart (approximately shoulder-width) but in symmetrical sagittal alignment. The distance reached was measured (in cm) on a tape measure fixed to the wall. This test was repeated three times and the longest distance measured was recorded.[21]

Timed "Up & Go" test (s)

Participants were seated in a free-standing padded armchair (46 cm high) and asked to rise (with or without using the armrests), walk to a mark 3 m away, turn around, walk back to the chair and sit down. The time between consecutive risings from the seat and contact made with the back of the seat was measured (s). This test was repeated three times and the fastest walk was recorded.[22]

10-m maximum walk test (m/s)

Each participant was asked to walk 10 m at his or her maximum walking speed. A stopwatch was used for timing the walk, and a counter was used to ascertain the number of steps. To eliminate the periods of acceleration and deceleration, subjects started their laps 3 m before the beginning of the walkway and concluded them 3 m beyond its end. The test was repeated three times, and the data of the fastest walk were recorded. These data were used to determine each subject's maximum walking speed (m/s).[23]

As regards the assessment of physical performance, the results of the four tests described above were each stratified into tertiles. We assigned, for each category of physical performance tests, a score of 3 for those in the highest tertile, 2 for those in the moderate and 1 for those in the lowest tertile. These scores were then added, so that they ranged 4–12. Those with scores in the ranges of 4–6, 7–9 or 10–12 were categorized as having a low, moderate or high level of physical performance, respectively.

Assessment of other variables

Anthropometric measures (e.g. height, bodyweight) were recorded by a standardized protocol. Blood pressure (BP) was measured at home with an HEM747IC device (Omron Life Science, Tokyo, Japan) that uses the cuff-oscillometric method to generate a digital display of systolic and diastolic pressures. The mean of 15.6 ± 10.5 (SD) BP measurements was used as the BP value. Participants who did not measure their home BP on at least 3 days were treated as having missing information on hypertension.

Blood samples were drawn from the antecubital vein of the seated subject with minimal tourniquet use. Specimens were collected in siliconized vacuum glass tubes containing sodium fluoride for blood glucose and no additives for lipid analyses.

The total cholesterol (T-C) and blood glucose levels of the subjects were measured by enzymatic methods (T-C, Denka Seiken, Tokyo, Japan; blood glucose, Shino-Test, Tokyo, Japan). Data on smoking status, alcohol consumption and history of liver or renal disease were obtained from the questionnaire survey. A well-trained pharmacist confirmed the drug information.

History of physical illness was evaluated on the basis of the responses ("yes" or "no") to questions concerning the history of liver and renal disease. Depressive symptoms were assessed according to the Japanese version of the 30-item Geriatric Depression Scale (GDS).[24] The participants were further tested for cognitive ability based on the MMSE.[25] Information on smoking (never, former and current smoking) and drinking (never, former and current drinking) status of the participants was obtained from a questionnaire survey.

Definitions of variables

Hypertension was defined as a home systolic BP reading of 135 mmHg or above and/or a home diastolic BP reading of 85 mmHg or above or use of antihypertensive agents.[26] Diabetes was defined as a casual blood glucose concentration of 200 mg/dL or above or the current use of antidiabetic medication. Hyperlipidemia was defined as a T-C level of 220 mg/dL or above, or the current use of a lipid-lowering agent. A GDS score of 14 or more or the use of an antidepressant was taken to indicate depressive symptoms.[27] An MMSE score of less than 24 was taken to indicate cognitive impairment.[28]

Medical care use and its costs were indicated by the number of hospital days, number of physician visits and medical care costs (total, inpatient and outpatient). Inpatient medical care costs included the cost of almost all the medical treatment received at hospitals, such as that incurred in diagnostic tests, medication, surgery, supplies and materials, paying the physician's fees and other personnel costs, but did not include hospital meal fees. Outpatient medical care costs included the money spent in medical treatment at outpatient clinics, prescribed drugs and home care services provided by physicians, but did not include dental care.

The number of hospital days, the number of physician visits and the medical care costs were calculated as per capita per month indices, including all subjects and months of observation irrespective of whether or not the former had received care.

Statistical analysis

Descriptive data are presented as means (95% confidence interval [CI]) or percentages. The variables' differences according to the levels of PA were examined by the ANCOVA for continuous variables or by the multiple logistic regression analysis for variables of proportion. The impact of PA or physical performance on the medical costs and number of outpatient visits and hospital days, respectively, were examined using ANCOVA after adjustment for age, sex, body mass index (BMI), hypertension, hyperlipidemia, diabetes mellitus, history of liver or renal disease, depressive symptoms, cognitive status, smoking and drinking habits/history, and physical performance score. All *P*-values for linear trends were calculated by using the applicable category of the PA levels (low, 1; moderate, 2; high, 3). The interactions between the PA and covariables were assessed by testing the interaction term added to the adjusted model as a covariate. The impact of PA on medical costs and the number of outpatient visits and hospital days was

Table 2 Baseline characteristics of subjects by levels of physical activity ($n = 483$)

	Physical activity levels Low	Moderate	High	*P* for trend
No. of participants	205	160	118	–
Age (years)	76.0 (75.4–76.6)	75.6 (74.9–76.2)	74.4 (73.6–75.1)	<0.001
Sex (female)	61.0	48.1	42.4	<0.001
BMI (kg/m²)	23.8 (23.3–24.2)	23.4 (22.9–23.9)	23.4 (22.8–23.9)	0.26
Hypertension	70.2	67.5	60.2	0.07
Hyperlipidemia	45.4	44.4	39.0	0.29
Diabetes	7.3	9.4	8.5	0.65
Impaired cognitive function (18 ≤ MMSE < 24)	8.8	6.9	8.5	0.84
Depressive symptoms (GDS ≥14 or use of antidepressant)	20.0	16.9	9.3	0.02
Smoking status				
Current smoker	17.1	12.5	11.9	0.16
Ex-smoker	23.4	38.5	39.0	<0.01
Non-smoker	56.7	47.5	49.2	0.14
Drinking status				
Current drinker	40.0	41.9	50.9	0.07
Ex-drinker	11.2	12.5	15.3	0.30
Non-drinker	44.4	39.4	31.4	0.02
Self-reported illness				
Renal	6.8	5.0	3.4	0.18
Liver	6.3	6.9	5.1	0.71
Physical performance				
Knee extension power (w/kg)	9.3 (8.8–9.9)	11.3 (10.7–11.9)	13.1 (12.3–13.8)	<0.0001
Functional reach (cm)	30.2 (29.5–31)	31.3 (30.4–32.1)	32.1 (31.1–33.2)	<0.01
Timed "Up & Go" test (s)	9.3 (9.1–9.5)	8.9 (8.7–9.1)	8.3 (8.1–8.6)	<0.0001
10-m maximum walking (m/s)	1.7 (1.6–1.7)	1.8 (1.7–1.8)	1.9 (1.9–2.0)	<0.0001
Log-transformed total physical performance score	1.9 (1.9–2.0)	2.0 (2.0–2.1)	2.2 (2.1–2.2)	<0.0001

Variables are presented as least squares mean (95% confidence interval) or %. BMI, body mass index; GDS, Geriatric Depression Scale; MMSE, Mini-Mental State Examination.

examined in association with physical performance levels after adjustment for the above mediator.

In this paper, monetary values were converted into $US using the exchange rate of $US 1.00 = 115 ¥. $P < 0.05$ was regarded as statistically significant. SAS software ver. 9.1 was used for all statistical calculations.

Results

Descriptive

Of the 483 subjects, 205 (42.4%) were categorized at the lowest level of PA, 160 (33.1%) at the moderate level and 118 (24.4%) at the highest level. Table 2 shows the baseline characteristics of subjects categorized by the PA level. The mean age was significantly lower at the highest PA level (*P* for trend <0.001). Although not statistically significant, the BMI was highest at the lowest PA level (*P* for trend = 0.26). Physical performance (including the results of the four tests and the total physical performance score) and PA were found to be positively associated (*P* for trend <0.01). Generally, participants with a higher PA had a better physical performance score. The proportion of subjects who were female, had depressive symptoms and were non-drinkers was significantly lower in the higher PA levels (*P* for trend <0.001, =0.02 and 0.02, respectively). Although the difference was not statistically significant (*P* for trend = 0.07), the proportion of subjects with hypertension was lowest at the highest PA level. In contrast, the proportion of ex-smokers was significantly higher at the higher PA levels (*P* for trend <0.01). Other than the above-mentioned, no significant difference was observed among the PA levels.

Table 3 Association between total medical care costs and physical performance levels ($n = 483$)

Physical performance	Physical performance levels Low	Moderate	High	P for trend†
Leg muscle power (w/kg)	0.8–8.7	8.8–12.6	12.7–23.4	–
No. of participants	160	162	161	–
Total medical costs, $US	892.4 (652.7–1132.2)‡	858.0 (631.2–1084.9)	718.2 (481.5–954.8)	0.01
Functional reach (cm)	6.3–29.1	29.2–33.5	33.6–45.6	–
No. of participants	159	161	163	–
Total medical costs, $US	847.5 (616.5–1078.4)	816.5 (583.6–1049.5)	806.1 (568.9–1043.2)	0.46
Timed "Up & Go" test (s)	16.8–9.4	9.4–8.1	8.1–5.6	–
No. of participants	161	162	160	–
Total medical costs, $	857.6 (626.9–1088.3)	819.8 (583.6–1056.0)	794.8 (561.4–1028.2)	0.25
10-m maximum walking (m/s)	0.9–1.6	1.7–1.9	1.9–3.1	–
No. of participants	160	162	161	–
Total medical costs, $US	898.6 (664.1–1133.0)	801.2 (572.1–1030.3)	795.5 (559.6–1031.5)	0.08
Total physical performance score	4–6	7–9	10–12	–
No. of participants	138	192	153	–
Total medical costs, $US	898.0 (662.0–1134.1)	823.4 (595.7–1051.1)	724.1 (485.1–963.2)	0.01

†Adjusted for age, sex, body mass index, hypertension, hyperlipidemia, diabetes, history of liver disease or renal disease, depressive symptoms, impaired cognitive function, smoking status, drinking status; ‡Variables are presented as least-squares mean (95% confidence interval) (all such values).

Association between physical performance and PA or medical care costs per person

Table 3 shows the relationship between medical care costs and physical performance measurements. Levels of physical performance tests were stratified into tertiles. Although medical care costs tended to be higher in the poorer physical performance tertiles, the leg muscle power and total physical performance score were found to be the only statistically significant measures (P for trend = 0.01) among the four tests administered after adjustment for covariables. Although not statistically significant, the medical care costs were lowest in the highest 10-m maximum walking group (P for trend = 0.08).

Association between PA levels and medical care costs per person

Table 4 shows the adjusted association between the PA level and the medical care costs and the average number of days of hospital stay or visits. After adjustment for covariables, the significant inverse relation of PA levels with inpatient cost, average number of days of hospital stay and total cost was observed (P for trend = 0.02, 0.046, and 0.02, respectively). No significant interaction was observed between the physical performance score and PA levels for inpatient, outpatient or total medical care costs (data not shown). In contrast, no relation was found between the levels of PA and outpatient expenditures or average number of hospital visits in all models. Similar results were also observed when men and women were analyzed separately. No significant interaction was observed between the physical performance score and the sex of the patient regarding inpatient, outpatient or total medical care costs. Stratified association between the PA levels and the total medical care costs (least-squares mean, 95% CI) by physical performance levels after adjustment for variables in the full multivariate model in Table 4 are shown in Figure 1. Except for a small sample ($n = 14$) group characterized by high PA with lower physical performance, the PA was inversely associated with medical cost in all the physical performance categories.

Discussion

The main finding of this study was that higher PA levels were associated with lower medical care costs and hospitalization days among Japanese community-dwelling elderly individuals. Higher physical performance levels were also associated with lower medical care costs. However, the inverse association between PA and medical care costs persisted even after adjustment for the level of physical performance (P for interaction = 0.48). These results suggested that the beneficial effect of PA on medical cost might be consistently observed irrespective of their baseline physical performance.

The strength of our study lies in the fact that we have measured both the PA and the physical performance. The unique characteristics of the study enabled us to clarify whether the PA itself predicts the medical cost or whether it merely marks the physical performance.

Table 4 Association between physical activity levels and medical care costs (n = 483)

	Physical activity levels Low	Moderate	High	P for trend
No. of participants	205	160	118	–
Inpatient data, $US				
Model 1†	421.8 (227.4–616.1)‡	323.7 (123.4–524.0)	297.3 (90.0–504.5)	<0.01
Model 2§	389.3 (190.8–587.8)	296.7 (93.7–499.8)	282.3 (74.3–490.4)	0.02
No. of hospital days†				
Model 1†	1.9 (1.1–2.7)	1.5 (0.7–2.3)	1.4 (0.6–2.3)	0.02
Model 2§	1.7 (0.9–2.6)	1.4 (0.5–2.2)	1.4 (0.5–2.2)	0.046
Outpatient data, $US				
Model 1†	453.4 (346.6–560.3)	427.7 (317.6–537.9)	426.1 (312.2–540.1)	0.28
Model 2§	438.0 (328.9–547.2)	414.4 (302.7–526.0)	419.7 (305.3–534.0)	0.48
No. of physician visits†				
Model 1†	6.5 (4.6–8.4)	6.6 (4.6–8.5)	6.6 (4.5–8.6)	0.87
Model 2§	6.4 (4.4–8.3)	6.5 (4.4–8.5)	6.5 (4.4–8.6)	0.76
Total costs, $US				
Model 1†	875.2 (650.2–1100.2)	751.4 (519.5–983.4)	723.4 (483.4–963.4)	<0.01
Model 2§	827.3 (598.0–1056.7)	711.1 (476.4–945.8)	702.0 (461.6–942.4)	0.02

†Adjusted for age, sex, body mass index, hypertension, hyperlipidemia, diabetes, history of liver disease or renal disease, depressive symptoms, impaired cognitive function, smoking status, drinking status. ‡Variables are presented as least-squares mean (95% confidence interval) (all such values). §Adjusted for model 1 + total physical performance score.

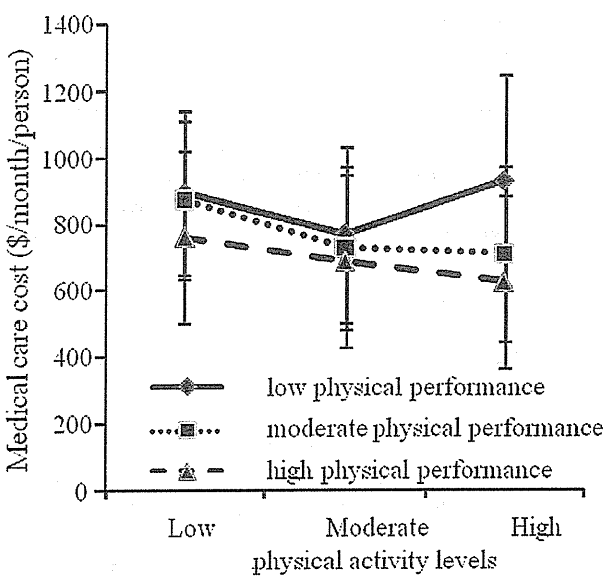

Figure 1 Association between physical activity levels and total medical care costs stratified by physical performance levels. Results from an analysis of covariance model adjusting for age, sex, body mass index, hypertension, hyperlipidemia, diabetes mellitus, history of liver disease or renal disease, depressive symptoms, impaired cognitive function, smoking status and drinking status. Variables indicate the adjusted least-squares mean. Error bars indicate 95% confidence intervals. Currency $US.

Individual reasons for medical treatment were not identified, but the fact that inpatient but not outpatient costs were higher among the community-dwelling subjects with lower levels of PA implies that these subjects may have suffered acute medical conditions requiring inpatient treatment. The outpatient care costs did not differ among the groups. The outpatient care costs were not influenced by the level of PA, partly because the proportion of elderly patients receiving medication for chronic diseases that did not affect their daily PA (e.g. hyperlipidemia or hypertension) did not differ among the groups, and such medication was mostly prescribed regularly for a long period of time. It should be noted that only one-fifth of the subjects in each group were not medicated.

As we have previously reported, it was found in a population study involving 27 431 Japanese men and women aged 40–79 years that those who walked for more than 1 h per day paid less for medical care.[10] We reported that both inpatient and outpatient costs taken cumulatively were smaller among the active walkers, which seems to conflict with our present result. This is probably because in the earlier study the population was younger and more than 70% of the participants reported that their health was good or excellent. Another factor responsible for the conflict in results might be the difference in the methods employed for estimating PA. Therefore, it is most likely that the majority of the previous study population was non-medicated and did not suffer from chronic diseases, which stands in remarkable contrast with the present study population. Wang *et al.* also reported in their cross-sectional study that the frequency of PA had a strong dose–response effect on health-care costs in those above the age of 65 years.[9] A 10-year follow up of the participants in a randomized clinical trial of walking in the USA revealed that the subjects in the walking group continued to walk longer and had lower hospitalization rates than those in the control group.[29] However, the physical performance of the participants was not evaluated in any of the previous studies.

By excluding the subjects with a history of stroke, cancer or coronary heart disease who potentially incur greater medical care costs than those without a similar history, the study population's selection bias was sufficiently minimized. The fact that the accumulated medical care cost during the initial 6 months did not differ among the groups shows that leading bias was minimized.

A stratified analysis by physical performance levels showed that the inverse dose–response relationship between total medical care costs and PA was observed in the moderate and high physical performance levels (Fig. 1). In the low physical performance level, the total medical care costs were highest at the highest PA level. Although we cannot validly explain this result, the number of subjects in the highest PA level was very small ($n = 14$), and therefore the mean medical care cost for that level would be imprecise.

This study has several limitations. First, because all the assessment were carried out in a public facility, the participants were sufficiently active and healthy to participate in the survey; therefore, it is possible that the current results would not be applicable to subjects at a higher risk. Moreover, because arthritis and remarkably low physical function might influence the frequency and degree of PA, and many diseases such as stroke, coronary heart disease and cancer can be a reason for large medical care cost at baseline, we also excluded these participants. Therefore, our results may not represent the general elderly population. However, we believe that these exclusions were necessary to investigate the relation of PA with medical care cost. Second, the diagnosis for each instance of medical care use was not available. This prevented an examination of the effects of exercise on particular diseases. Third, the intensity of walking, brisk walking and sports were not directly measured. Therefore, the proportional amount of PA in terms of the energy expenditure required for reducing medical care costs cannot be determined. However, because a person can easily discriminate his or her own "brisk walking" from ordinary walking,[30] it was suggested that the categorization of relative walking intensity based on the subjects' own perceptions was reliable.

In conclusion, this prospective study indicates that a higher level of PA was associated with lower medical care costs irrespective of physical performance among the elderly Japanese.

Acknowledgments

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Books

Infectious disease in the aging

Despite of the recognition of infection as a serious health problem in older adults, textbooks on infectious diseases often do not address issues relevant to elderly and frail people. Guidelines do not always sufficiently account for individual variation among patients, with aging being one of the largest factors affecting this variation. Therefore, I have been looking forward to the updated edition of *Infectious Disease in the Aging: A Clinical Handbook*—the first edition, published in 2001, was an excellent review of the pertinent infectious diseases issues in the geriatric population. Since Thomas T Yoshikawa is the chief editor of the *Journal of the American Geriatrics Society*, a leading journal of geriatric medicine, the concept of geriatrics is evident throughout the book.

In the second edition, the editors have once again assembled leading experts in infectious diseases of elderly people. The book, subdivided into three well organised sections, goes from the general to the particular. Part 1 addresses the concepts and principles of infection in elderly people; part 2 contains 18 chapters on common infectious diseases, which includes infection with multidrug-resistant organisms; and part 3 addresses infectious disease problems unique to older adults, such as management of infections in the long-term care setting. Moreover, part 3 contains newly added chapters for infections such as severe acute respiratory syndrome and West Nile virus infection. Because of advances in medical science prolonging the lives of people with chronic infections, such as HIV/AIDS, infections that were more common in younger adults have now become important in older adults—this issue is also newly included in part 3.

The greatest strengths of this book are found in subjects not covered in most texts: immunisation, prevention, and altered pharmacodynamics (long-term care-related problems). The importance of functional assessment in older adults with infections is stressed by Thomas Yoshikawa and Robert Palmer in part 1. Without assessing the functional status of older adults, it would be difficult to cure the patient. For example, without assessing swallowing function and appropriate food modification, aspiration pneumonia might never be cured. The chapter on nutrition and infection gives a nice overview of nutrition in the elderly population and its effect on the immune system.

It is imperative that primary-care physicians and infectious diseases specialists gain knowledge of the special and unique aspects of infections in the geriatric population. Since the prevention of infectious diseases should be comprehensive, I would like to recommend this book not only to all physicians who treat elderly patients but also to the caregivers such as nursing-home staff.

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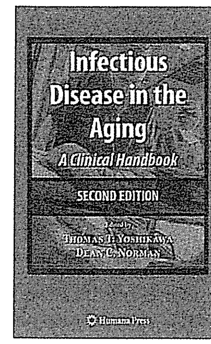


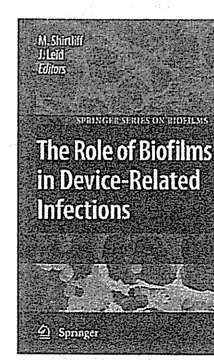
Infectious Disease in the Aging: A Clinical Handbook
Edited by Thomas Yoshikawa and Dean Norman. Humana Press, 2010. Pp 520. €139·95.
ISBN 978-1-60327-533-0

The role of biofilms in device-related infections

It is a pleasure to review an academic textbook that is as timely as Mark Shirtliff and Jeff Leid's contribution to the subject. What immediately strikes me is how little is conclusively known about bacterial-biofilm infections, and yet how rapidly the subject is progressing. This book leaves you with no doubt of the importance of bioflms in device-related infections. Even in diagnoses of aseptic loosening, there is a strong argument for an infectious basis, at least in some of the cases. In a subject that is changing so rapidly and in which effective therapies are still ill-defined, we can only hope that the editors and authors will be willing to update their work often—possibly online.

The book begins with a fitting initiation to the subject: a short, well written, and informative chapter on the microbial ecology of human skin and wounds. The next seven chapters discuss device-related infections, with the second chapter introducing the reader to prosthetic-implant infections. The rapid transition to the molecular basis for regulation of virulence factors and quorum sensing is not for the faint hearted, and an understanding of microbial genetics is definitely needed to fully enjoy the text. The information is primarily focused on *Staphylococcus aureus* biofilms—understandable in view of the epidemic of meticillin-resistant *Staphylococcus aureus* and that most prosthetic-implant infections seem to be dominated by *Staphylococcus* spp. I was concerned when the third chapter—on aseptic loosening—seemed also to focus on *Staphylococcus aureus*, but other pathogens are adequately addressed in later chapters. After some rather dense but extremely informative reading chapter four is a pleasure, introducing readers to ventilator-associated pneumonia, and engaging them with short sections, short paragraphs, and colour illustrations. In the next edition, authors of other chapters might consider shorter paragraphs—some are well over a page in length—and the positive effect of colour illustrations.

Throughout the book the message is very clear: failing to recognise the likelihood of biofilm-related infections



The Role of Biofilms in Device-Related Infections
Edited by Mark Shirtliff and Jeff G Leid. Springer, 2010. Pp 272. €119·95.
ISBN 978-3-540-68113-7

—Review—

Stimulating Oral and Nasal Chemoreceptors for Preventing Aspiration Pneumonia in the Elderly

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Aspiration pneumonia remains a major cause of death in the elderly. However, fundamental and effective treatment has not been established yet. Onset of aspiration pneumonia is based on the presence of dysphagia, such as delayed triggering of the swallowing reflex. The swallowing reflex in the elderly is temperature sensitive, even if it is impaired. Swallowing reflex was delayed when the temperature of the food was close to body temperature. The actual swallowing time shortened when the temperature difference increases. The improvement of swallowing reflex by temperature stimuli could be mediated by the temperature-sensitive TRP channel. Administration of the TRPV1 agonists improves the delay of the swallowing reflex. Red wine polyphenols have been suggested to improve the swallowing reflex by increasing TRPV1 response. Food with menthol, an agonist of TRPM8 which is a cold temperature receptor, also decreased the delay in swallowing reflex. Olfactory stimuli, such as black pepper, can be a useful tool to improve swallowing reflex in people with lower ADL and consciousness levels. By combining these various sensory stimuli, we developed a protocol to start oral intake in patients with aspiration pneumonia This protocol shall continue to contribute to the ingestion of many older people.

Key words——dysphagia; swallowing reflex; aspiration pneumonia

INTRODUCTION

Morbidity and mortality from aspiration pneumonia continues to be a major health problem in the elderly. A swallowing disorder, such as a delayed triggering of the swallowing reflex, exists in patients with aspiration pneumonia. Swallowing is a complex phenomenon that involves tightly coupled interdependence among ongoing sensory and motor events before food enters the oral cavity until the swallow is complete. Dysphagia (swallowing difficulty) often leads to aspiration (ingested material entering the trachea), and may result from impairment of one or more of the many sensory-motor events that comprise normal swallowing. The oral cavity, pharynx, and larynx contain some of the richest and most diverse sensory receptors of the body, represented by dense intricate nerve supply to these regions.[1]

Exact timing for movement of structures important for swallowing (i.e., tongue, larynx, pharynx) is imperative and highly sensory-reliant, such that even a one-second delay in movement can result in airway invasion of ingested material.[2] Therefore, maintaining sensory input and its neural process to trigger swallowing is crucial to prevent aspiration pneumonia in elderly people. Swallowing can be divided into three phases: (1) the oral phase, when the tongue propels food posteriorly until the swallowing reflex is triggered; (2) the pharyngeal phase, when the reflexive swallow carries the bolus through the pharynx; and (3) the esophageal phase, when esophageal peristalsis carries the bolus through the cervical and thoracic esophagus into the stomach. Each phase has differential sensory input.

SENSORY INPUT TO INITIATE SWALLOWING

The oropharyngeal region has sensory fibers innervating the mucosa, submucosal, and muscle regions that provide mechanical receptors sensitive to touch and pressure, chemical receptors that respond to taste and water, stretch or length receptor as well as sensory fibers and receptors responding to pain and temperature.[3] In initiating the oral phase of swallowing, stroking the soft plate, innervated by trigeminal

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nerve, will evoke a rhythmic movement of the tongue similar to the oral phase of swallowing. Sensory input from regions of the oropharynx and hypopharynx will evoke the pharyngeal phase of swallowing which is followed by the esophageal phase. The swallowing reflex, the main component of the pharyngeal phase, is elicited from specific areas of the pharynx and larynx, which are innervated by the glossopharyngeal nerve, the pharyngeal blanch of the vagal nerve, and the superior laryngeal nerve.

ENHANCEMENT OF SENSORY INPUTS ELICITING THE SWALLOWING REFLEX

Effective stimuli eliciting swallowing are mechanical stimuli, chemical and thermal stimulations. In the laryngeal regions, water stimulation is effective in eliciting swallowing reflex in healthy people.[4] However, in patients with aspiration pneumonia or dysphagia due to stroke, water cannot evoke swallowing reflex effectively.[5]

We found that the swallowing reflex was delayed the most around body temperature (30–40°C) and the delay shortened as the difference in temperature apart from body temperature even in elderly patients with aspiration pneumonia.[6] Based on the finding concerning the temperature sensitivity of swallowing reflex in the dysphagic elderly, we also found the agonists for temperature-sensitive transient receptor potential (TRP) channels improve swallowing reflexes in dysphagic patients. The administration of a pastille with capsaicin as an agonist stimulus of TRPV1, a warm temperature receptor, decreased the delay in the swallowing reflex.[7] Water containing menthol, an agonist of TRPM8 which is a cold temperature receptor also decreased the delay in swallowing reflex.[8] These results suggest that the food containing these spices may prevent the elderly from aspiration pneumonia by improving the swallowing reflex.

However, spices such as capsaicin and menthol often induce too strong chemesthesis to use on a regular basis. Therefore, we contrived the means to stimulate TRPV1 without inducing a pungent sensation. One is to use a capsaicin homologue, named capsiate, an extract from non-pungent cultiver of red peppers named CH-19 Sweet.[9] The other mean is to use red wine polyphenol compounds as a flavor in mixture with a small amount of capsaicin.[10]

BRAIN STEM CONTROL OF SWALLOWING

Swallowing movements are produced by a central pattern generator located in the medulla oblongata. Three separates sets of brain stem nuclei mediate the oral, pharyngeal, and esophageal phases of swallowing.[11] The trigeminal nucleus and reticular formation probably contain the oral phase pattern generating neural circuitry. The nucleus tractus solitaries is nuclei for a primary sensory relay and contain the pattern generating circuitry of both the pharyngeal and esophageal phases of swallowing.[12] Like any other central pattern generator, the swallowing central pattern generator and its rhythmic and sequential activity is based on the endogeneous pacemaker properties.[13] On the other hand, the sensory input from the oropharynx is also necessary to initiate and to feedback during discrete and/or sequential swallowing.[14]

CORTICAL CONTROL OF SWALLOWING

For many years, medical literature has asserted that swallowing is controlled primarily by the brainstem. However, advances in human brain imaging has provided evidence that cortical and subcortical structures play a critical role in swallowing control, showing consistent activity in the primary motor cortex, the primary sensory cortex, insular cortex and the anterior cingulated gyrus.[15] Because of its nature, reflexive swallowing activates both sensory and motor areas in the cortex (Fig. 1). The most consistent areas in neuroimaging studies include the primary sensorimotor cortex, sensory motor integration areas, the insula and frontal operculum, the anterior cingulated cortex, and supplementary motor areas.[16] Malandraki and colleagues found that, in cortical areas involved in swallowing, the sensory processing areas were deteriorated by aging rather than motor processing areas.[17]

Swallowing impairment is more common with bilateral hemispheric strokes, but can also occur with unilateral infarction of either hemisphere.[18] The

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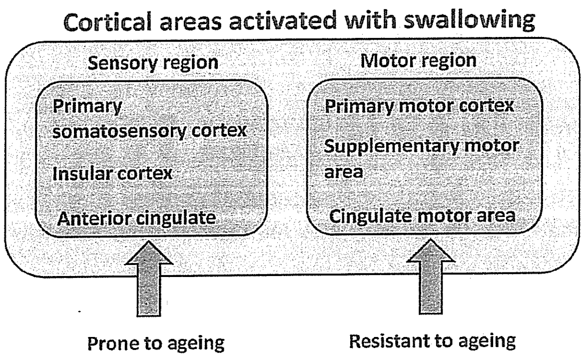

Fig. 1. Cortical Areas Activated with Swallowing

results suggest that one side of the cortex may play a dominant role, and that role would include more control over the initiation and intensity of the swallow. Damage to subcortical regions including the basal ganglia can also induce dysphagia.[19]

ENHANCEMENT OF CORTICAL AREAS INVOLVED IN THE SWALLOWING REFLEX

We found that the swallowing reflex is continuously improved by chronic stimulation of TRPV1 using a troche containing capsaicin, which is a TRPV1 agonist. The mechanism of why chronic stimulation of thermoreceptors improve swallowing and cough reflexes is speculative. Afferent neuronal pathways provide for discriminative sensation and for homeostatic control of body temperature. In discriminative sensation, the lamina-I neurons carry temperature signals to the final insular cortex with one or two relays.[20] Since the insular cortex is the crucial cortical area involved in swallowing, we speculate that repeated thermoreceptor stimulation may restore the function of the insular cortex, resulting in restoration of the functions of the swallowing reflex and cough reflex.

Oral care has long been recognized as helping to keep the bacteria in the mouth, leading to preventing pneumonia. We investigated the effects of oral care on airway protective reflexes and found that one-month daily oral care significantly improved both swallowing and cough reflexes in the elderly nursing home patients.[21,22] Our data suggest that oral care may improve the swallowing reflex and the ability to perform ADLs among elderly patients. Toothbrushing, pain stimuli to gingiva, is known to activate the insular cortex in a functional MRI study.[23] The insular cortex function is crucial in swallowing and is impaired in patients with aspiration pneumonia and severe dysphagia.[24] We speculate that repeated oral nociceptive sensory stimulation may restore the function of the insular cortex, resulting in restoration of the functions of swallowing reflex and cough reflex.

When we investigated the effect of black pepper essential oil inhalation on nursing residents, we found that black pepper oil improved the swallowing reflex and serum substance P concentration, suggesting that olfactory stimulation using black pepper is an effective method to treat feeding and swallowing disorders and to prevent aspiration pneumonia.[25] In a single photon emission tomography study, we found that olfactory stimulation with black pepper oil increased cerebral blood flow in the anterior cingulate cortex and the insular cortex.[25]

AFFERENT AND CORTICAL PATHWAYS OF OLFACTION

The primary olfactory neuron is a bipolar cell with cell bodies in the olfactory epithelium of the nasal mucosa. The axons, originating in the basal pole of the primary olfactory neurons, are gathered in bundles of some hundred fibers in an envelope of glial cells known as "sheath cells." These guide the neurons, the constant renewal of which innervates the olfactory bulb in a targeted manner. The olfactory bulb is the first relay in the olfactory system; it comprises about 8000 glomeruli, which receive the primary olfactory neuron axons. All messages from sensory neurons expressing a given receptor protein converge on a single glomerulus. The efferent (mitral) glomeruli cells transmit this information to the piriform cortex. There is thus an authentic map of neuronal activation, known as the glomerular odotopic map.[26] The axons of the olfactory bulb mitral cells successively cross the olfactory peduncle and olfactory tract before projecting onto the primary olfactory cortex; the information processed in the piriform cortex then projects to various brain areas: the orbitofrontal cortex, amygdala, hypothalamus, insula, entorhinal cortex and hippocampus.[27] The secondary olfactory cortex receives fibers from the primary olfactory areas, and is situated mainly in the insula and entorhinal cortex, the input area of the hippocampus attached to the parahippocampal cortex (Fig. 2).[28,29] Since the insular cortex is a common pathway of olfactory sysem, other odors as well as black pepper have the possibility to improve the swallowing reflex.

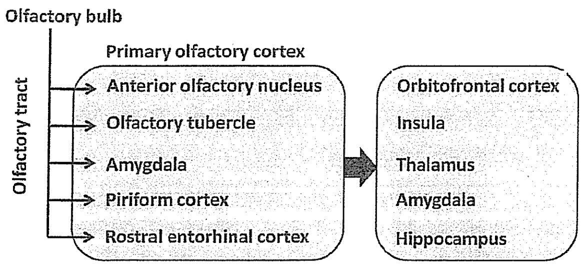

Fig. 2. Afferent Path Way of the Olfactory System from Olfactory Bulb to Cortical Areas

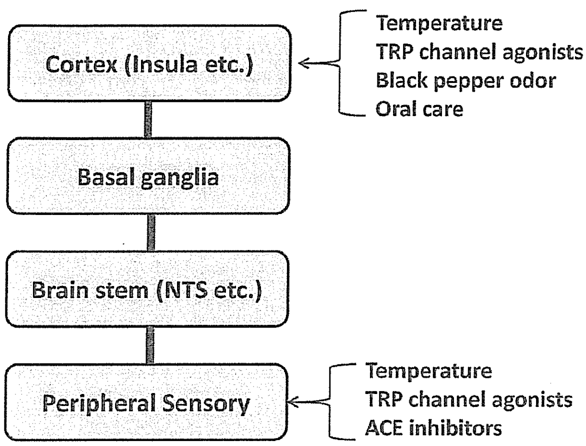

Fig. 3. A Hierarchy of Neuronal Control of Swallowing and Sites of Means to Improve Swallowing Reflex

CONCLUSIONS

In this manuscript, we showed the hierarchical structure of neuronal control of swallowing. Figure 3 shows the site of action in the remedies to improve the swallowing reflex. Using these remedies, we developed a protocol to start eating more efficiently and safely as an intensive stepwise method to start oral intake. Using this protocol, the incidence of pneumonia and the number of febrile days for 1 month from the start of oral intake were significantly reduced.[30] Implementation of this protocol would help avoid re-aspiration in many elderly people with aspiration pneumonia. In addition, this protocol is also applicable to feeding training and rehabilitation of all feeding and swallowing disorders.

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Current Perspective

Sensory Stimulation to Improve Swallowing Reflex and Prevent Aspiration Pneumonia in Elderly Dysphagic People

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Abstract. Morbidity and mortality from aspiration pneumonia continues to be a major health problem in the elderly. A swallowing disorder, such as a delayed triggering of the swallowing reflex, exists in patients with aspiration pneumonia. We found that the swallowing reflex in elderly people was temperature-sensitive. The swallowing reflex was delayed when the temperature of the food was close to body temperature. The actual swallowing time shortened when the temperature difference increases. The improvement of swallowing reflex by temperature stimuli could be mediated by the temperature-sensitive transient receptor potential (TRP) channel. The administration of a pastille with capsaicin as an agonist stimulus of TRPV1, a warm-temperature receptor, decreased the delay in swallowing reflex. Food with menthol, an agonist of TRPM8, a cold-temperature receptor, also decreased the delay in swallowing reflex. Olfactory stimulation such as black pepper was useful to improve the swallowing reflex for people with low activity of daily living (ADL) levels or with decreased consciousness. Oral care also shortened the latent time of swallowing reflex presumably due to stimulating the nociception of the oral cavity. A combination of these sensory stimuli may improve the swallowing disorders and prevent aspiration pneumonia.

Keywords: elderly, olfactory stimulation, swallowing reflex, drug delivery system, aspiration pneumonia

1. Introduction

The demographic trend in both developed and developing countries is moving towards a society with an increasing percentage of people above 65 years of age (1). More significant will be the shift in composition of the elderly population over the 4 decades towards more people above 80 years of age, attributed to increased life expectancy and the baby-boomer generation passing the age of 65 years. Therefore, it is important to draw special attention to this generation in terms of their specific health and management (2). Medicines and medication management are much more complex and challenging in the elderly than younger adults due to the age-associated change of homeostatic mechanisms, the co-morbidity, and the increasing number of the drugs for the treatment of different conditions. Medication of the elderly will not only be judged by their efficacy to treat disease conditions, but also should be judged on their ability to manage the disease by reducing morbidity and mortality (3). Moreover, in addition to the scientific aspect of the elderly, research on the social aspects such as needs of the elderly and health care system for the elderly are warranted (4).

Pneumonia is a major medical problem in the elderly. The mean age of hospitalized patients with community-acquired pneumonia is usually around 65 years, an age that is considered the onset of old age (5). Consequently, about 50% of admitted patients with pneumonia can be defined as elderly. Moreover, about 20% are older than

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75 – 80 years and have been deemed very elderly patients. In patients with dementia and in very old people, aspiration was the commonest cause of pneumonia (6, 7). In a multicenter prospective study, the incidence of aspiration pneumonia was 80.1% (306/382) among hospitalized Japanese patients aged ≥70 years (8). Therefore, it is proposed that most pneumonia in the very old is aspiration pneumonia. Aspiration pneumonia results from the aspiration of colonized oropharyngeal or gastric contents, leading to an infectious process. The high rate of aspiration in the elderly presumably is related to an increased incidence of dysphagia due to strokes and other degenerative neurologic diseases (9).

2. Bacteriology of aspiration pneumonia — normal flora pneumoniae

Data about microbiological diagnosis of aspiration pneumonia are disparate for the following three reasons: First, several studies enrolled patients relatively late, when complications such as necrotizing pneumonia, lung abscess, or empyema had already occurred; and in these patients, anaerobic organisms were found to be the predominant pathogens isolated alone or with aerobes (10, 11), whereas most common pathogens isolated in relatively early enrolled patients with aspiration pneumonia are *Streptococcus pneumonia,* gram-negative bacilli, anaerobes, and *Staphylococcus aureus* (12). Second, in many cases, it is impossible to isolate the responsible pathogens. Mier et al. (13) studied the bacteriology of early aspiration pneumonia with the use of protected brushing. Positive results were obtained for only 9 of 42 patients (47%). In another study, the cultures were positive in 60% of patients (14). Notably, significant isolation of anaerobic bacteria in patients suffering from lower respiratory tract infection is difficult because it requires specific sampling techniques, adequate transport conditions, and specific growth media. Third, and this might be most crucial, the diagnosis of aspiration pneumonia is not really certain in many studies.

Although, to date, there are several studies describing the microbiology of aspiration pneumonia (12, 14), in these studies, the criteria for dysphagia is not really clear. Recently, aspiration pneumonia was defined by the Japanese Study Group on Aspiration Pulmonary Disease as pneumonia in a patient with predisposition to aspiration because of dysphagia or swallowing disorders (8). We diagnosed one aspect of dysphagia by evaluating swallowing reflex sensitivity. This type of dysphagia is known to be closely related to silent aspiration. Here, the swallowing dysfunction was assessed by evaluating the latent time of the swallowing reflex, induced by an injection of a 1 ml solution into the pharynx (15), and the etiology of aspiration pneumonia was investigated (16). We found that most of the cases in this study with aspiration pneumonia could not show obvious respiratory pathogens. When we highlighted bacteria representing more than 10^6 cfu/ml, which are more likely to be a pathogen, 31 patients did not show more than 10^6 cfu/ml bacteria. Among the bacteria that represent more than 10^6 cfu/ml, the normal flora is still dominant bacteria with a detected ratio reaching 48.4% (16). Figure 1 shows the detected ratio of bacteria that represent more than 10^6 cfu/ml. It ought to be noted that even normal flora should not present in tracheal fluid. Therefore, the pathogen of aspiration pneumonia could be oral and/or pharyngeal normal flora, suggesting that a large portion of aspiration pneumonia is normal flora pneumonia. Therefore, in the treatment of aspiration pneumonia, management of aspiration may be of importance rather than choice of antibiotics (17).

This review is based on the symposium at the 83rd Annual Meeting of The Japanese Pharmacological Society held on March 17, 2010.

3. Management of food for aspiration

The management of elderly patients with dysphagia requires an interdisciplinary team approach coordinated by a number of health professionals, including the patients' primary care physician, pulmonologist, speech and language therapist, clinical dietitian, occupational therapist, physiotherapist, nurse, and dentist, as well as caregivers (9). The management should be directed towards not only maintaining adequate nutrition and hydration but also to enhancing the quality of life by optimizing the safety, efficiency, and effectiveness of oropharyngeal swallowing. The management plan is developed according to the clinical and instrumental assessment results.

However, the evidence available on the effectiveness of many preventive strategies is limited. Although there

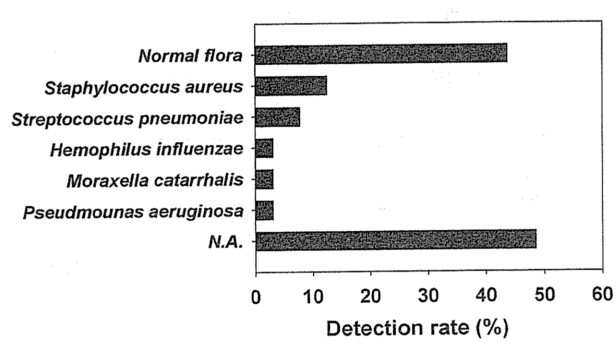

Fig. 1. Detected ratio of bacteria representing more than 10^6 cfu/ml. NA: Not applicable. The graph was constructed from the data of reference 16.

are several medicines that modulate swallowing and cough reflexes in the elderly (18 – 20), manipulation of diet is one of the most common strategies facilitating swallowing in dysphagic people. Patients vary in their ability to swallow thin and thick liquids, semi-solids, and solids. The consistency of patients' food should be individualized according to the findings from clinical testing. Heretofore, dietary modification to help swallowing has focused only on texture matters such as inconsistency and thickness. We found several elements of meals that should be individualized for elderly people with dysphagia. The swallowing reflex was delayed the most around body temperature (30°C – 40°C) and the delay shortened as the difference from body temperature became greater (21). The results of this research suggest that the food should be prepared immediately prior to consumption for dysphagic people. Based on the above finding concerning the temperature sensitivity of the swallowing reflex in the dysphagic elderly, we also found spices play important roles in improvement of swallowing in dysphagic patients. The improvement of the swallowing reflex by temperature stimuli could be mediated by the temperature-sensitive transient receptor potential (TRP) channel. The administration of a pastille with capsaicin as an agonist stimulus of TRPV1, a warm-temperature receptor, decreased the delay in swallowing reflex (22 – 24). Food with menthol, an agonist of TRPM8, a cold-temperature receptor, also decreased the delay in swallowing reflex (15).

4. Improvement of swallowing reflex by temperature stimulation

Peripheral sensory fibers such as vagal c-fibers are known to have TRPV1 and/or TRPM8. Direct stimulation of these TRP channels on peripheral neurons activates the neurons by opening the large-cation channels (25).

The mechanism for how chronic stimulation of TRP channels improves swallowing even without direct applications of those agonists is speculative. By using a single photon emission study, we found significant cerebral blood flow reduction in the bilateral anterior insular cortex compared with the group without a history of pneumonia, suggesting the involvement of dysfunction of the bilateral insular cortex in impaired cough reflex sensitivity (26). Afferent neuronal pathways provide for discriminative sensation and for homeostatic control of body temperature. In discriminative sensation, the lamina-I neurons carry temperature signals to the final insular cortex with one or two relays (27). Since we found that the function of the insular cortex is impaired in patients with aspiration pneumonia, we speculate that repeated TRP channel thermoreceptor stimulation may restore the function of the insular cortex, resulting in restoration of the functions of the swallowing reflex.

Therefore, we speculate that TRP channel thermoreceptor agonists such as capsaicin and menthol have dual effects on the neural circuit of swallowing reflex (Fig. 2). One is the direct (acute) effects on peripheral sensory neurons and the other is indirect (chronic) effects by repetitive thermal sensory stimuli to the insular cortex. Based on the elucidation of the neural circuit of the swallowing reflex, we also found that smell should be modified for the elderly with difficulty in swallowing.

5. Swallowing improvement by olfactory stimulation using black pepper oil

Medicine for oral intake or food to improve dysphagia patients is not applicable for individuals at risk of aspiration with very low activity or decreased consciousness. Therefore, olfactory stimulation is proposed to improve feeding and aspiration of elderly people who cannot orally consume food. The effectiveness of olfactory stimulation known as aromatherapy is yet to be scientifically proven, but some evidence exists that essential oils may have therapeutic potential (28). When we investigated the effect of black pepper essential oil inhalation on nursing residents, we found that black pepper oil improved the swallowing reflex and serum substance P concentration, suggesting that olfactory stimulation using black pepper is an effective method to treat feeding and swallowing disorders and to prevent aspiration pneumonia (29). This beneficial effect of black pepper aromatherapy is confirmed not only in the elderly but also in children (30). The single photon emission tomography study showed that olfactory stimulation with black pep-

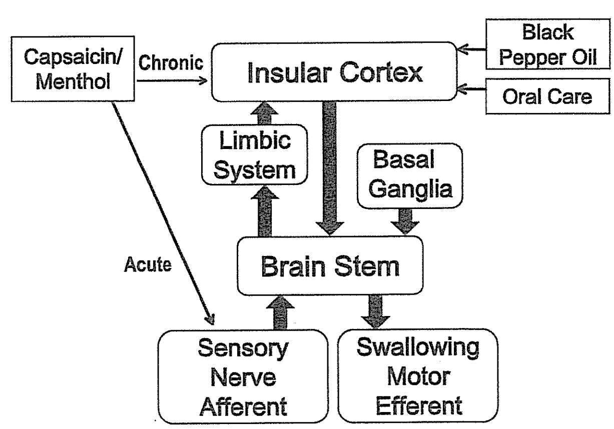

Fig. 2. Neural circuit involved in the swallowing reflex. The sites of action of capsaicin/menthol, black pepper oil olfactory stimulation, and oral care painful stimuli are indicated by thin arrows.