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Functional Status of Centenarians in Tokyo, Japan: Developing Better Phenotypes of Exceptional Longevity

Yasuyuki Gondo,[1] Nobuyoshi Hirose,[2] Yasumichi Arai,[2] Hiroki Inagaki,[1] Yukie Masui,[1] Ken Yamamura,[2] Ken-ichirou Shimizu,[2] Michiyo Takayama,[2] Yoshinori Ebihara,[2] Susumu Nakazawa,[2] and Koji Kitagawa[3]

[1]Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan.
[2]Department of Geriatric Medicine, Keio University School of Medicine, Tokyo, Japan.
[3]Gumma Paz College, Gumma, Japan.

Background. Centenarians are sometimes said to be representative of lifelong healthy aging. Whether they are, in fact, examples of healthy aging remains a subject of debate. The existence of heterogeneity in functional status has been reported repeatedly in previous studies of centenarians. However, there is as yet no standardized classification system with which to describe their functional phenotype.

Methods. As part of a dynamic cohort study, we studied 304 centenarians (65 men and 239 women) living in Tokyo. Their functional status (sensory, physical, and cognitive), which we used to represent their phenotype, was assessed and subsequently classified by standard assessment methods (simple questionnaire, Barthel index, Mini-Mental State Examination, and the Clinical Dementia Rating, respectively).

Results. We classified participants into 4 categories according to their functional status. Only 5 (2%) were classified as ''Exceptional,'' with all of their functions graded as excellent, and 56 (18%) were ''Normal,'' exhibiting maintenance of fine cognitive and physical functions. One hundred sixty-seven (55%) were ''Frail,'' exhibiting impairment of either cognitive or physical functions, and the remaining 76 (25%) were ''Fragile,'' exhibiting deterioration of both physical and cognitive functions.

Conclusions. The relationships between biochemical marker, mortality rates, lifestyle, and functional phenotypes demonstrated by this classification method indicate that the system is reliable to address the functional status of extremely old persons. Thus, this framework would be a useful tool for exploring the factors that contribute to exceptional longevity as well as those that help to maintain the functional status of the extremely old population.

CENTENARIANS are sometimes said to represent lifelong healthy aging (1,2), although whether they are, in fact, examples of healthy aging is a subject that is currently under discussion (3,4). The literature describes declines in sensory, cognitive, and physical functions in centenarians (4–11). Scientific studies of centenarians have focused on explorations of their environmental and genetic backgrounds. However, the recent proliferation of centenarians (12) and the heterogeneity in their phenotype has introduced confusion into the consensus that, as a whole, they are representative of healthy aging (4,13). An advisory panel on exceptional longevity, which was set up by the National Institute on Aging (14), noted that the identification of intermediate phenotypes, and hence homogenous subgroups, would increase the likelihood of finding the genes that contribute to longevity.

The majority of previous reports have noted the functional status of the centenarians that were studied, but they were separated into different domains with different definitions. If we wish to explore efficiently the factors involved in longevity, then a more parsimonious evaluation method with standardized measures is needed (13). Two centenarian studies proposed the classification method of centenarians. Using retrospective morbidity profiles, the New England study (15) categorized people into three phenotypes: the ''Escapers,'' who could accomplish disease-free aging until they reached 100 years, the ''Delayers,'' who developed disease only very late in life, and the ''Survivors,'' who survived with disease. By adopting a more complicated categorizing system, the Italian study (13) categorized people into three different phenotypes: ''A,'' who had good functional status without specific morbidity history; ''B,'' who were in intermediate condition; and ''C,'' who had poor functional status with a history of morbidity. In addition, they subdivided group ''C'' into ''C1,'' where cognitive impairment was evident; ''C2,'' where both physical and cognitive impairment were observed; and ''C3,'' where physical impairment was evident.

New England and Italian groups noted that this framework was helpful for exploring the factors underlying exceptional longevity. However, both classification systems have advantages and disadvantages. As both systems emphasize participants' medical history, they will allow exploration of the effect of disease-associated factors on longevity, under the ''compression of morbidity'' hypothesis (15,16), which suggests that the onset of illness is delayed among centenarians. At the same time, these systems have a disadvantage in that they cannot be used to identify those factors that either protect or delay the aging process, if indeed they exist. If a person possesses a strong protective factor against aging, he may be a ''Survivor'' with high functional status. The phenotype of these people should be different to that of people who classify as ''Survivor'' but with frailty. Likewise, as the phenotype in the latter study is affected by a

Table 1. Background Characteristics of Participants

Characteristic	Sex				Total	
	Male		Female			
	N	%	*N*	%	*N*	%
No. of participants	65	21.4	239	78.6	304	100.0
Age group, y						
100	38	58.5	134	56.1	172	56.6
101–102	16	24.6	62	25.9	78	25.7
103–107	11	16.9	43	18.0	54	17.8
Mean (standard deviation)	101.0	(1.7)	101.2	(1.7)	101.1	(1.7)
Living arrangements						
Alone	2	3.1	6	2.5	8	2.6
With family	49	75.4	149	62.3	198	65.1
Institutionalized	14	21.5	84	35.1	98	32.2
Education						
No education	0	0.0	3	1.3	3	1.0
Elementary education	37	56.9	130	54.4	167	54.9
Secondary education	3	4.6	63	26.4	66	21.7
Higher education	24	36.9	36	15.1	60	19.7
Unknown	1	1.5	7	2.9	8	2.6
Occupation						
Blue collar	19	29.2	45	18.8	64	21.1
White collar	46	70.8	85	35.6	131	43.1
Housewife, or no occupation	0	0.0	100	41.8	100	32.9
Unknown	0	0.0	9	3.8	9	3.0
Birth area						
Kanto (around Tokyo)	25	38.5	121	50.6	146	48.0
Other regions	40	61.5	117	49.0	157	51.6
Unknown	0	0.0	1	0.4	1	0.3

mixture of causative factors (medical, biological status, environmental, and stochastic) and effects (cognitive or physical function), the role of phenotype as an independent variable in research into those persons who live an exceptional healthy long life becomes ambiguous. The purpose of the study reported here was to propose a new framework for evaluating functional characteristics in centenarians in addition to describing their functional status.

Methods

Participants

A total of 304 Japanese centenarians (65 men, 239 women) living in the 23 wards of metropolitan Tokyo participated in a survey in which they were visited by Tokyo Centenarian Study staff between July 2000 and May 2002. We randomly chose centenarians from the residential list and sent a letter inviting participation to 1194 centenarians, accounting for 68.8% of an estimated 1735 centenarians living in this area in the study period. Five hundred fourteen (43.0%) agreed to participate. Three hundred four persons, representing 25.5% of the letter recipients, participated in the visit survey.

Women outnumbered men in our sample by 1:3.6, which was not significantly different from the ratio for the total centenarian population in this area (1:3.8). Table 1 lists the background information of the participants in this study.

Procedure

After we had received a reply from the centenarian (or proxy) agreeing to participate, we sent a questionnaire that included questions about the participant's functional status. After the questionnaire had been returned, a medical doctor, a psychologist, and a nurse visited the centenarian's residence. After the group had explained the purpose of the study and obtained the permission of the centenarian (or proxy), the doctor examined the patient and took a blood sample. The psychologist conducted a cognitive assessment. The Barthel index (17), was use to assess physical function, and visual and hearing acuity was rated according to the five categories from highest (''No problem'') to lowest (''Blind'' or ''Deaf''; see the detail in Table 2).

Table 2. Distribution of Sensory Functions and Barthel Index in Centenarians by Sex

Sensory and Basic Physical Function		Male		Female		Total	
		N	%	*N*	%	*N*	%
Visual function							
No problem		30	46.2	82	34.3	112	36.8
Incomplete		23	35.4	72	30.1	95	31.3
Big characters		8	12.3	57	23.8	65	21.4
Face outline		3	4.6	25	10.5	28	9.2
Blind		1	1.5	3	1.3	4	1.3
Hearing function							
No problem		19	29.2	64	26.8	83	27.3
Loud voice		14	21.5	65	27.2	79	26.0
Close to ear		6	9.2	29	12.1	35	11.5
Close to ear with a loud voice		25	38.5	78	32.6	103	33.9
Deaf		1	1.5	3	1.3	4	1.3
Barthel Index							
Independent	100	12	18.5	14	5.9	26	8.6
	80–99	16	24.6	32	13.4	48	15.8
Minimal help	60–79	8	12.3	32	13.4	40	13.2
Partially dependent	40–59	7	10.8	36	15.1	43	14.1
Very dependent	20–39	9	13.8	35	14.6	44	14.5
Totally dependent	<20	13	20.0	90	37.7	103	33.9
Mean (standard deviation)		59.2	34.9	40.0	33.7	44.1	34.8*†

Note: *$p < .01$.
†Main effect of sex.

The, Clinical Dementia Rating scale (CDR) (18), Global Deterioration Scale (GDS) (19), two scales that were developed in Japan to assess the mental state of elderly persons (NM scales) (20), and the Mini-Mental State Examination (MMSE) (21) were used to evaluate cognitive status. The NM scales were developed for concomitant use with the N-ADL scale, which assess the basic activities of daily living of the patients (20).The MMSE was conducted on all survey participants who were visited at their residences, but 76 participants were unable to complete it for the following reasons: ''Disagree to participate'' (13.2%); ''Bedridden and unable to give a response'' (42.1%); ''Frailness'' (10.5%); ''Inability to follow instructions'' (15.8%); ''Blind or deaf'' (13.2%); or ''Unable to speak'' (5.3%). We scored those participants who were ''Bedridden and unable to give a response'' and ''Inability to follow instructions'' as MMSE 0; this test was not conducted on the others. Because of their frailty, it was not possible to perform neuropsychological tests on most of the participants. Thus, we collected data regarding the cognitive and mental status of participants by rating the questionnaires to increase the reliability of the cognitive assessment.

Table 3. Distribution of CDR, MMSE Score, and Classified Cognitive Status

		Male		Female		Total	
Classification of Cognitive Status		*N*	%	*N*	%	*N*	%
CDR rating and dementia status							
No dementia	0	28	43.1	46	19.2	74	24.3*†
Probably no dementia	0.5	10	15.4	32	13.4	42	13.8
Dementia	1	11	16.9	46	19.2	57	18.8
	2	5	7.7	24	10.0	29	9.5
	3	5	7.7	45	18.8	50	16.4
	4	2	3.1	25	10.5	27	8.9
	5	4	6.2	21	8.8	25	8.2
MMSE score							
Not impaired	≥21	24	36.9	36	15.1	60	19.7
Impaired	11–20	17	26.2	76	31.8	93	30.6
Severely impaired	0–10	17	26.2	102	42.7	119	39.1
Not scored		7	10.8	25	10.5	32	10.5
Reason							
Visual problem		1	1.5	3	1.3	4	1.3
Hearing problem		1	1.5	5	2.1	6	2.0
Speech problem		1	1.5	3	1.3	4	1.3
Frailty		3	4.6	5	2.1	8	2.6
Disagreed to participate		1	1.5	9	3.8	10	3.3
MMSE mean (standard deviation)		16.1 (8.9)		11.5 (8.3)		12.5 (8.6)*†	
Cognitive status							
Excellent		24	36.9	36	15.1	60	19.7
Good		14	21.5	42	17.6	56	18.4
Moderately impaired		16	24.6	70	29.3	86	28.3
Severely impaired		11	16.9	91	38.1	102	33.6

Note: *$p < .01$.
†Main effect of sex.
CDR = Clinical Dementia Rating; MMSE = Mini-Mental State Examination.

The CDR ratings were achieved as a consensus of three expert geropsychologists at a postvisit meeting. One of the three had interviewed the centenarians by him/herself. The GDS, NM scale rating, and videotaped responses of the centenarians to the MMSE, as well as the answers given by the participant's proxy regarding their daily activity were used as a reference to obtain a CDR rating.

Written informed consent was obtained from all participants or proxy. The ethics committee of Keio University School of Medicine approved this study.

Statistical Analyses

We used chi-square tests and one-way analysis of variance (ANOVA) to compare the functional status between the men and women. We used two-way ANOVA to compare the means of serum albumin concentration, 1-year survival, habitual smoking, and alcohol drinking, with sex and functional categories as independent variables. All statistical analyses were performed using SPSS 13.0J (Chicago, IL).

RESULTS

Sensory Functions

The distributions of sensory function levels are given in Table 2. One hundred twelve (36.8%) and 83 (27.3%) participants had ''No problem'' with vision and hearing function, respectively. The others had moderate to severe problems with these senses, but only 1.3% ($N = 4$) were blind and only 1.3% were deaf ($N = 4$). Most of them ($N = 253$; 83.2%) had either a vision or a hearing problem, and only 51 (16.8%) had intact vision and hearing.

Physical Function

The total Barthel index score and categorized levels of basic ADL are given in Table 2. ''Independent'' was shown by 74 (24.3%) of the participants, 40 (13.2%) ''Needed minimal help,'' 43 (14.1%) were ''Partially dependent,'' 44 (14.5%) were ''Very dependent,'' and 103 (33.9%) were ''Totally dependent.'' Of 74 independent participants, only 26 (8.6%) were ''Fully independent'' (Barthel index score = 100). A one-way ANOVA for the total score revealed a significant main effect of gender ($p < .01$), indicating that the men (59.2; standard deviation [*SD*] = 34.9) were more intact than the women (40.0; *SD* = 33.7).

Cognitive Status, as Assessed by CDR and MMSE

Of the 304 participants, 74 (24.3%) had a CDR score of 0 (''No dementia''), 42 (13.8%) had a score of 0.5 (''Probably no dementia''), and 188 (61.8%) were ''Mildly to severely demented'' (CDR score = 1–5; Table 3). A chi-square test for the frequency of dementia status indicated that women were more likely than men to have dementia ($p < .01$). Cognitive function, as assessed by MMSE, was classified into three levels (Table 3): ''Not impaired'' (score ≥21); ''Impaired'' (score 11–20); or ''Severely impaired'' (score 0–10) by original cutoff point (21). One-way ANOVA for the MMSE total score revealed a significant main effect of gender ($p < .01$), indicating that the men (mean score 16.1; *SD* = 8.9) were generally more cognitively intact than the women (mean score 11.5; *SD* = 8.3).

We classified the cognitive status of centenarians based on those two scales as follows: ''Excellent,'' those who were classified as having ''No dementia'' by CDR and as being ''Not impaired'' by MMSE; ''Good,'' those who were classified as having ''No dementia'' or ''Probably no dementia'' by CDR regardless of the MMSE score; ''Moderately impaired,'' those who had a CDR score of 1–2; and ''Severely impaired,'' those who had a CDR score of 3–5. As a result, of the 304 participants, 60 (19.7%) were classified as ''Excellent,'' 56 (18.4%) as ''Good,'' 86 (28.3%) as ''Moderately impaired,'' and 102 (33.6%) as ''Severely impaired.''

Categorizing Centenarians According to Functional Status

We were able to divide the visit survey participants into 4 categories using sensory, physical, and cognitive functions. First was the category of ''Exceptional,'' for participants who had intact visual and hearing functions (''No problem'' in the questionnaire), were ''Fully independent'' with regard to their basic ADL (Barthel index = 100), and had ''Excellent'' cognitive functions (CDR = 0; MMSE ≥ 21). Second was the category of ''Normal,'' for participants who were somewhat independent with regard to their basic ADL (Barthel index ≥ 80) and had ''Good'' cognitive function (CDR ≤ 0.5). Third was the category of ''Frail,'' for participants who had impaired basic ADL (Barthel index ≤ 79) or impaired cognitive function (CDR ≥ 1). Those who

Table 4. Comparison of External Criteria (Serum Albumin Level, 1-Year Mortality Rate, and Lifestyle) Among the Four Functional Status Groups

	Male								Female								Total							
	Exceptional		Normal		Frail		Fragile		Exceptional		Normal		Frail		Fragile		Exceptional		Normal		Frail		Fragile	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
No. (%)	2	3.1	24	36.9	32	49.2	7	10.8	3	1.3	32	13.4	135	56.5	69	28.9	5	1.6	56	18.4	167	54.9	76	25.0
Age	102.5	3.5	100.7	1.4	101.2	1.8	101.6	2.1	100.3	0.6	100.5	1.0	101.1	1.6	101.6	2.1	101.2	2.2	100.6	1.2	101.1	1.6	101.6	2.1
Serum albumin (g/dl)	4.0	0.3	3.9	0.3	3.6	0.4	3.4	0.4	4.3	0.2	4.0	0.3	3.6	0.4	3.4	0.4	4.2	0.3	3.9	0.3	3.6	0.4	3.4	0.4**†
1-y mortality	0.0	0.0	0.3	0.5	0.3	0.5	0.6	0.5	0.0	0.0	0.1	0.3	0.2	0.4	0.4	0.5	0.0	0.0	0.2	0.4	0.2	0.4	0.4	0.5*†
Lifestyle																								
Drinkers ratio	1.00	0.0	0.74	0.4	0.71	0.5	0.29	0.5	0.67	0.6	0.31	0.5	0.30	0.5	0.16	0.4	0.80	0.4	0.49	0.5	0.38	0.5	0.17	0.4**†‡
Smokers ratio	0.00	0.0	0.30	0.5	0.48	0.5	0.14	0.4	0.00	0.0	0.03	0.2	0.14	0.3	0.14	0.4	0.00	0.0	0.15	0.4	0.20	0.4	0.14	0.4*†

Notes: Serum albumin concentrations were calculated only for visit survey participants ($N = 264$; men = 59, women = 205). One visit survey participant was lost to follow-up within 1 year after participation, so 1-year mortality data were collected from 303 participants. One-year mortality, and the ratios of drinkers and smokers were calculated as 0 for no (alive) and 1 for yes (dead).

*$p < .05$; **$p < .01$.

†Significant effect was observed among the four groups.

‡Significant difference was observed between male and female.

SD = standard deviation.

were ''Totally dependent'' (Barthel index < 20) and had ''Severely impaired'' cognitive function (CDR ≥ 3) were categorized as ''Fragile.'' Table 4 gives the number of centenarians categorized in each of the 4 categories for each gender. Only 5 (1.6%) of the centenarians were categorized as ''Exceptional'' and 56 (18.4%) as ''Normal.'' Of the ''Normal'' centenarians, 19 (33.9%) were ''Fully independent'' (Barthel index score = 100) and 32 (57.1%) had ''Excellent'' cognitive ability. Most of the centenarians (167; 54.9%) were categorized as ''Frail''; of this ''Frail'' group, only 13 (7.8%) were physically ''Independent'' but had cognitive problems, while 23 (13.8%) had ''Good'' cognitive status but had physical problems. Seventy-six participants (25.0%) were categorized as ''Fragile.''

We did not evaluate the psychiatric aspects of these participants. However, five of the ''Exceptional'' centenarians had no adverse psychiatric symptoms: two usually go out of the house for shopping, two participate in the day service program provided by the local government for hobby activities, and one is the chairperson of the Brussels Sprout Association.

Validity of the New Categorization

To confirm the validity of the new categorization, we assessed serum albumin concentration and 1-year mortality after participation in the study as external criteria, and compared these values among the groups (Table 4). We also compared (alcohol) drinking and smoking status among the groups as examples to explore the influences of environmental factors on the functional phenotype (Table 4). Participants were defined as being drinkers or smokers if they ever had or now have a drinking or smoking habit, respectively. No significant effect of age was observed among the groups. A significant effect of group ($p < .01$) was observed for serum albumin concentration. Further multiple comparisons indicated that the ''Exceptional'' and ''Normal'' groups had higher serum albumin concentrations than the ''Frail'' and ''Fragile'' groups did ($p < .05$). The ''Fragile'' group had significantly lower serum albumin concentrations than the ''Frail'' group did ($p < .05$). The same analysis for 1-year mortality revealed a significant effect of group ($p < .05$), indicating that those categorized as ''Normal'' and ''Frail'' survived longer than those categorized as ''Fragile'' did. Quite remarkable is the fact that every one of the ''Exceptional'' centenarians survived for at least 1 year after participation in this survey. Although the differences in serum albumin concentration and 1-year mortality between the ''Exceptional'' and ''Normal'' groups were not significant (because of the small number of centenarians in the former group), our new classification method could appropriately discriminate two higher functional groups (Figure 1). This is a particularly notable characteristic of our classification method in comparison with single-domain classification methods (for example, using CDR, MMSE, and Barthel index alone; Figure 1).

With regard to the influence of lifestyle, the higher functional centenarians included fewer habitual smokers and more drinkers. Statistically, the main effect of group was observed for lifestyle ($p < .01$). Further multiple comparisons identified no group-by-group differences. Although there were few smokers among the centenarians ($n = 47$, 15.4%), three currently smoking centenarians were categorized as ''Frail,'' and all five centenarians categorized as ''Normal'' among the smokers had quit smoking in their early 60s. No such characteristics were found for drinking habit.

Discussion

First, we confirmed the previously reported finding that there is a deterioration of functional status among centenarians in comparison with their younger cohorts (3–11,22–27). We also confirmed that male centenarians outperform female centenarians in both cognitive (6,7,9,22,24) and physical function (4,6–8,27). In addition, we adopted visual, hearing, physical, and cognitive functions as key variables and categorized the centenarians into four phenotypes. Compared with single-domain categorizations of each cognitive and physical function, this functional phenotyping method seems to have distinct advantages. The number of ''Exceptional'' centenarians was small in this study, and so some of the comparative data did not reach statistical significance, yet 1-year mortality and serum albumin concentrations among the ''Exceptional'' centenarians were

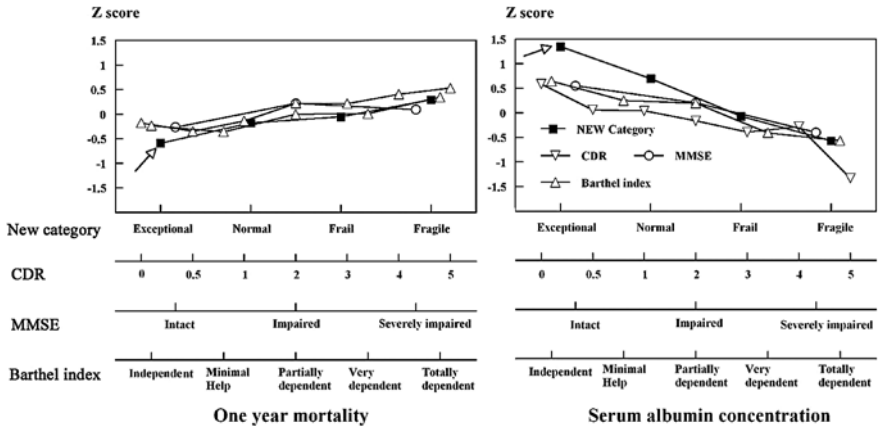

Figure 1. One-year mortality rate (*left*) and serum albumin concentration (*right*) as compared with different categorization systems. Clear differences were observed between the higher functional group (*bold arrow*) among the different classification methods. Data are presented as standardized scores.

higher than among the ''Normal'' centenarians (who were also categorized as being healthy) and, needless to say, among the ''Frail'' and ''Fragile'' centenarians.

Furthermore, we found that retrospective lifestyle also has an influence on the functional status of centenarians. There was a negative relationship between smoking habits and functional status. There were no smokers among the ''Exceptional'' participants, whereas more than 10% of each of the other groups included habitual smokers. In addition, 29% of physically ''Independent'' and 17% of cognitively ''Excellent'' centenarians were smokers. At the same time, there was a positive relationship between drinking habits and functional status. Eighty percent of ''Exceptional'' and 49% of ''Normal'' participants reported having a drinking habit, whereas less than 40% of ''Frail'' and ''Fragile'' centenarians did so. The causal relationship between drinking and functional status seems to be indistinct compared with smoking. The constitutional differences that allow drinking might influence functional status rather than the positive effect of the drinking habit itself (28). Genetic factors are thought to be more important than environmental factors for survival to an extremely old age (29); however, the results presented here indicate that lifestyles are important to the functional status of oldest old, even though they succeeded in surviving to be 100 years old.

With regard to single-domain functional status, we have confirmed the evident deterioration in both physical and cognitive function among centenarians. The New England study, which used the same scale, would be a good reference. Regarding dementia prevalence, 76% Tokyo centenarians suffer from dementia; meanwhile, this rate was 80% in the New England study (CDR $\geq$ 0.5). Regarding physical function, the New England study showed a higher independence ratio (44%) than did our study (20%). Physical frailty might be a significant characteristic of Japanese centenarians.

We adopted MMSE $\geq$ 21 as a cutoff point for a cognitive ability of ''Not impaired.'' This criterion was based on the original MMSE article (21), was used to screen the cognitively intact centenarians in the Georgia centenarian study (11), and is 1 point higher than the criterion used in the Italian centenarian study, which used the term ''absence of severe cognitive impairment'' (13). This cutoff point is lower than that used in other recent studies for younger elderly persons (23,24). Previous studies did not evaluate suitable cutoff points for MMSE scores in centenarians in conjunction with external criteria. Many studies have reported a declining trend of MMSE scores with increasing age (30–32). The average MMSE score of the healthy oldest-old population in Tokyo was 25 (range 14–30) for men and 24 (range 8–30) for women (33). Moreover, MMSE scores tend to underestimate the cognitive ability of centenarians, because of sensory deterioration (22,25). Thus, we combined the MMSE and CDR to define cognitive status. We believe that this combination of assessment methods is suitable for evaluating the cognitive status of the oldest-old population. Comparative studies using the same method are needed to confirm the suitability of the MMSE cutoff-point criterion in other populations.

Compared with the available oldest-old (85+ years) data in Tokyo (34), the number of people who have impairments in cognitive or physical functions was twice as high among our centenarians. This finding indicates that the increasing number of oldest-old persons will be accompanied by a great deal of dependent people. At the same time, among 167 ''Frail'' centenarians, 55 (32.9%) were cognitively labeled as ''Good,'' but had a deteriorated basic ADL score. This indicates that the psychological adaptation to functional deterioration is important in extremely old people (35–37). We need to focus more on the psychological and emotional aspects than on functional status in centenarians.

We should bear in mind the importance of having a standardized method with which to evaluate the functional status of centenarians. In Okinawa, a decline in the physical function of centenarians was reported to have occurred between 1976 and 1994 (38). This evidence led us to investigate the relationship between the increasing number of extremely old persons, the proliferation of centenarians (12), and their functional status. There have been some reports of positive generational improvements in physical and cognitive function (39,40); however, this may not be true for centenarians. The frequency of frail centenarians, who would be assumed to have low genetic advantages for longevity, might increase in the future.

We introduced a new categorization framework for classifying centenarians according to their functional

phenotype by using commonly used measures. We did not examine the influences of medical history (13,15) or other lifestyle factors, and further study is required to determine the factors that differentiate between ''Exceptional'' and ''Normal'' as well as between healthiness and frailty. The phenotypes revealed by this study will be helpful to explore factors that contribute to exceptional longevity (14) and to the discrimination between the influences of genetic and environmental factors on healthy aging.

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Address correspondence to Yasuyuki Gondo, PhD, Tokyo Metropolitan Institute of Gerontology, Human Care Research Team, 35-2 Sakae-cho, Itabashi-ku, Tokyo 173-0015, Japan. E-mail: ygondo@tmig.or.jp

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