J Nutr Health Aging
Volume 21, Number 9, 2017

MEASURING ACTIVE AND HEALTHY AGEING: APPLYING A GENERIC INTERDISCIPLINARY ASSESSMENT MODEL INCORPORATING ICF

P. STUTE[1], N. BITTERLICH[2], J. BOUSQUET[3], F. MEISSNER[4], M. VON WOLFF[1], D. POETHIG[5]

1. Department of Obstetrics and Gynecology, University of Bern, Switzerland; 2. Medizin & Service GmbH, Chemnitz, Germany; 3. MACVIA-France (Contre les Maladies Chroniques pour un VIeillissement Actif en France), France; 4. vital.services GmbH, GerontoLabEurope, Leipzig, Germany; 5. European Association on Vitality and Active Aging eVAA e.V., Leipzig, Germany, EIP-AHA Reference Site Saxony. Corresponding author: Professor Dr. med. Petra Stute, M.D. Department of Gynecologic Endocrinology and Reproductive Medicine, University Clinic of Obstetrics and Gynecology, Inselspital Bern, Effingerstrasse 102, 3010 Bern, Switzerland, Telephone: (0)31-632-1303, Fax: (0)31-632-1332, Email: petra.stute@insel.ch

Abstract: *Objectives:* In this study we compared the chronological and bio-functional age between two German speaking cohorts 30 years apart applying a comprehensive and generic Active and Healthy Aging (AHA) assessment model incorporating ICF. *Methods:* Single-centre, cross-sectional, observational, non-interventional, non-randomized trial at an University based women's hospital, division of Gynecological Endocrinology and Reproductive Medicine. All participants followed a standardized, holistic battery of biopsychosocial assessments consisting of bio-functional status (BFS), bio-functional age (BFA) and additional validated psychometric questionnaires. *Results:* 462 non-pediatric, non-geriatric females were in the BeCS-14 cohort. The measured mean BFA was lower than the chronological age within the BeCS-14 cohort (regression coefficient 0.58) and comparable in the female LeCS-84 subcohort (regression coefficient age 0.85, communality age 76%). In detail, within the decades 35-45 years and 55-65 years the gradient of BFA increase (aging rate) was similar in both cohorts (decade 35-45 years: LeCS-84 4.08 ± 1.03 year equivalents and BeCS-14 4.78 ± 1.67 year equivalents; decade 55-65 years: LeCS-84 6.21 ± 1.29 year equivalents and BeCS-14 5.25 ± 1.18 year equivalents). Remarkably, within the LeCS-84 cohort the mean aging rate within the decade 45-55 years was significantly different from all other aging rates in both cohorts: 13.02 ± 1.05 year equivalents. However, within the BeCS-14 cohort the corresponding value was 4.83 ± 1.02 year equivalents thus indicating a continuous aging process across the adult life course. In BeCS-14, there was a significant age-related effect for cardiovascular performance and social stress exposition and younger age was associated with better cardiovascular performance while level of social stress exposition decreased in aging women. *Conclusion:* When comparing BeCS-14 and LeCS-84, the aging process seemed to be accelerated in women in LeCS-84 between 45 and 54 years of age. We can only speculate on the reasons, such as differences in the health care, political and social system. However, the differences observed support the use of our BFS/BFA assessment tool not only on an individual level (strengths/resources) but also population level following EIP-AHA requirements. Yet, it remains to be developed how the assessed health strengths/resources-profile may be integrated into AHA management.

Key words: European Innovation Partnership on Active and Healthy Ageing EIP-AHA, bio-functional status, bio-functional age, health resources, Bern Cohort Study 2014, International Classification of Functioning, Disability and Health (ICF).

Introduction

Demographic change and aging are significant features of all European countries. Aging influences both, the health status and disease patterns of individuals and populations. Yet, a universal Active and Healthy Ageing (AHA) definition is not available (1-5). Kuh et al. (6) separated healthy biological ageing from active ageing (continued participation in social and cultural activities) and changes in psychological and social wellbeing. Healthy biological ageing includes survival to old age, delay in the onset of non-communicable diseases (NCD) and optimal functioning for the maximal period at individual levels, body systems and cells. According to the World Health Organization (WHO), healthy ageing refers to an individual's capacity to do the things that are important to her or him. Healthy ageing is the process of developing and maintaining the functional ability that enables well-being in older age (7). For over 50 years, gerontologists have postulated a life change theory of human organism and its functions (8-13). Accordingly, physiological functions generally display rapid growth in the first stages of life to reach peaks or plateau in adult life and then decline with age. These trajectories of physiological function may be better predictors of later life health and wellbeing than single measures. Signs of impaired function may act as markers of failure to reach developmental potential ("health resources"), accelerated ageing or underlying disease processes, and offer opportunities for early intervention (1,14, 15). Furthermore, markers of function and wellbeing above average ("health strengths") should also be taken into account if we aim to successfully and sustainably intervene age- and lifestyle-related health status, health problems or NCD in an individual or epidemiological approach.

The conceptual AHA framework (6) includes several items such as functioning (individual capability and underlying body systems), wellbeing, activities and participation, and diseases including NCD. Each functional approach encompasses the idea of resilience, the ability to adapt physiologically, psychologically and socially. In this context Bousquet et al.

Received January 29, 2016
Accepted for publication May 3, 2016

(1, 3-5) emphazise that current research on AHA is limited by distinguishing the least healthy individuals rather than identifying those in best health or discriminating the full spectrum of function or activity. This implies a challenge to develop reference values in Europe of both, best health ("health strengths") and least health ("health resources") across all age stages within the human life course. These reference values can be obtained from trials in a relevant population.

The Bern Cohort Study 2014 (BeCS-14) is a single-centre, cross-sectional, observational, non-interventional, non-randomized trial, which assessed a defined best and least health status across all non-pediatric and non-geriatric age stages (i.e. 18-65 years). The Leipzig Cohort Study 1984 (LeCS-84) was a randomized, cross-sectional, non-interventional study (16-18) comprising 365 mainly working citizens from the Leipzig region (168 men, 197 women) aged 18 to 75 years, in whom the biofunctional status (BFS) and biofunctional age (BFA) (see below) were assessed at the working place (supplementary file 1).

The primary objectives of the current study were (i) to compare biofunctional age (BFA) of BeCS-14 population with LeCS-84 and (ii) to compare the qualitative differences within the biofunctional status (BFS) parameters cardiovascular performance (CP) and social stress exposition (SSE) between the two populations (female sub-cohorts only). The assessment tools applied were based on a generic Active and Healthy Aging (AHA) assessment model incorporating the the ICF classification and ICF concept (19, 20).

Material and Methods

Study design

BeCS-14 is a single-centre, cross-sectional, observational, non-interventional, non-randomized trial. All participants followed a standardized battery of assessments consisting of a personal and family history, BFS, BFA, and validated questionnaires for depression and anxiety (HADS) (21), health-related quality of life (SF-36) (22) and chronic stress (TICS) (23), respectively. For each participant, this assessment battery took about 80 minutes. To assess certain aspects of the BFS more closely, participants were asked to take part in additional assessments (non-randomized subgroup 1-4). Subgroup 1 ("nutrition") comprised overweight and obese participants only. They were asked to answer the validated questionnaires AD-EVA (24) addressing eating and sport behaviour as well as PATEF (25) addressing patient's theory (75 minutes). Subgroup 2 ("employees") comprised participants having a regular job for income only. They were asked to answer the validated questionnaire IMPULS (26) addressing real and favored job life situation (10 minutes). In participants of subgroup 3 ("stress") cardiac autonomic nervous system activity was analyzed by heart rate variability (HRV) based on current guidelines (10 minutes) (27). In subgroup 4 ("cognition") cognitive function was analyzed objectively by the validated test IGD (28) and subjectively by a non-validated list of questions addressing subjective cognitive function (75 minutes).

Assessments were performed by doctoral students (n=14) of the medical school at the university Bern, supervised by the principle investigator (PS). To reduce the inter-assessor variability for BFS and BFA assessment, each student had to perform ten BFS/BFA assessments with subsequent practical exam and certification by the co-investigator (FM) prior to measuring study participants. In order to avoid missing data in the questionnaires applied we used a standardized, PC-guided touch screen assessment (GerontoPoint) which only provided the next question if the previous one was answered.

Study population

German speaking women and men aged 18 to 65 were recruited between 2012-03-04 and 2014-07-04 at the Department of Obstetrics and Gynecology, Inselspital University Bern, Switzerland. Recruitment was performed by the principle investigator (PS), the study nurse (JDW) and 14 doctoral students of the medical school, University Bern, via personal contact (patients, collegues, family, friends) and online advertisement (internet, intranet Inselspital, social media). Exclusion criteria were pregnancy, acute diseases (e.g. fever, acute pain syndrome), and illiteracy. The study protocol (supplementary file 2) was approved by the Cantonal Ethics Committee Bern (Ref.-Nr. KEK-BE: 023112), and written informed consent was obtained from each participant.The study protocol of the LeCS-84 cohort is provided as supplementary file 3.

Assessment procedures

Personal and family history

The whole questionnaire addressing the personal and family history is available via the principle investigator (P. Stute). Briefly, we assessed age, social status (partnership, having children, satisfaction with relationship and sex life), life style (alcohol, tobacco, sport, sleep), and job status (highest educational degree, current field of work, job position, working hours, monthly gross income, presenteeism, absenteeism). Personal and family history further comprised information about malignancy, cardiovascular disease, breathing disorder, abdominal and urogenital disease, metabolic disorder, skin and/or hair disease, neuromuscular and psychiatric disorder as well as bone and joint disease.

Bio-functional status (BFS) and bio-functional age (BFA)

The BFS was assessed by a comprehensive test battery developed by Poethig et al. and reported by others (16-18), respectively, which is commercially available via vital.services (www.vital-expertise.de). The test battery comprises holistic characteristics from physical, mental-emotional and social areas that fit into a complex theoretical model incorporating the ICF and AHA concept (Table 1). The test battery for BFS

Table 1

Synopsis of single diagnostic methods and items corresponding to the AHA and ICF classification and ICF concept providing a complex AHA assessment model. The highlighted (*) functions or capabilities, respectively, are referred to as AHA key markers and ICF related personal (contextual) factors (PF) (19, 20)

European Level: AHA key domains (1)	**German-Swiss-Level: Supplementary allocation to personal contextual factors (19,20)**	**Operational Level: Measurement of functions and capabilities of the AHA-dimensions (present publication)**	**Single methods (16-18, 29)**
Key domain: Physical and cognitive capability across the life course		*BFS dimensions: Physical strengths and resources*	
body function: b420		systolic blood pressure, diastolic blood pressure	sphygmometry (18) (pp. 176-179); (29) (p. 73)
body functions: b410, b730, b4550; activity: d469	factors of cardiovascular and respiratory function: i2201, behavioural patterns and exercise habits: i456 → evidence as PF also: current cardio-fitness (physical endurance capability)	resting heart rate, pulse rate difference, performance time*, performance pulse index*	submaximal ergometry (by squats or bicycle) (18) (pp. 176-179); (29) (pp. 74-76)
body function: b440		vital capacity FVC	spirometry (custo spiro mobile) (29) (p. 73)
body function: b730, d449		hand grip strength (both sides)	dynamometry (18) (pp. 176-179); (29) (pp. 79, 80)
body structure: s7702, s798	body composition: i2102, metabolic factors: i2202 → evidence as PF also: for both, movement and nutrition counseling	body cell mass*,fat mass*	bioimpedance analysis (BIA) (37)
body structure: s3200		decayed missing filled teeth	teeth status (18) (pp. 176-179); (29) (pp. 81, 82)
		BFS dimension: Sensory physiology and psychomotor strength and resources	
body function: b210		vision (both sides)	vision testing (5 m distance) (18) (pp. 176-179); (29) (p. 80)
body function: b230		hearing acuity (both sides)	audiometry (2000 and 4000 Hz) (18) (pp. 176-179); (29) (pp. 80, 81)
mental function: b1470, b760 activity: d4402	attitude toward health-related assistance: i419 → evidence as PF also: adherence	psychomotor activity (start rate and basic rate), test motivation*	tapping (at start, at 10 sec., at 60 sec.) (18) (pp. 176-179); (29) (pp. 77-79)
body function: b760, b1470, activity d440		viseomotor coordination ability (time, mistakes)	tracking (18) (pp. 176-179); (29) (pp. 77-79)
		BFS dimension: Cognitive and mental strength and resources	
body function: b147		optical reaction time	testing optical response (10 times) (18) (pp. 176-179); (29) (pp. 85, 86)
body function: b147		acoustical reaction time	testing acoustical response (10 times) (18) (pp. 176-179); (29) (pp. 85, 86)
body function: b147		pursuing reaction time	testing pursuing reaction time (10 times) (18) (pp. 176-179); (29) (pp. 85, 86)
mental function: b1401 or activity: d160		verbal reaction time, cognitive reaction time, cognitive switching capability	color-word-test (Stroop) (18) (pp. 176-179); (29) (p. 82)
mental function: b1400 or activity: d160		ability to concentrate (time and mistakes)	concentration-time-test (Landolt) (18) (pp. 176-179); (29) (p. 82)
mental function: b140, b144, b1643 activity: d1750		strategic thinking, orientation capability, memory performance, change over capability	stepping stone maze (18) (pp. 176-179); (29) (pp. 83-85)
Key domain: Psychological and social wellbeing		*BFS dimension: Emotional-social strength and resources*	
emotional functions: b152, d2401	life situation: i529; attitude toward social environment/society: i425 → evidence as PF also: stress exposition, stress disposition	social resonance/stress exposition*, self-control/stress disposition*, social dominance, social power	Giessen-Test (18) (pp. 176-179); (29) (pp. 89-93); (30)
emotional functions: b152, d2401	methodical skills: i433; empowerment: i436 → evidence as PF also: coping capability/ resilience	physical wellbeing*, emotional wellbeing*	health complaint questionnaire (Hoeck/ Hess) (18) (pp. 176-179); (29) (pp. 86, 87)
emotional function: b152, d2401	Proaction: i439	sense of coherence	SOCL9 (38)
Participation: d750, d920	relaxation habits: i459 → evidence as PF also: early indicator for devitalization	social activity (leisure*, duties)	social activity questionnaire (18) (pp. 176-179); (29) (pp. 89-93)
General approach		*BFS dimension: Summative Score, hr-QoL across the life course*	
	General personal characteristics/age: i1100; i1101, i1102, i1108 → evidence as PF: difference between bio-functional age and chronological age only (≥ age 35 years)	Chronologic age; Bio-Functional Age (BFA)*, sex differentiation (year equivalents)	Passport; Calculated total age value of all parameters (18) (pp. 176-179); (29) (pp. 93-113); (39,16-18)

Table 2

Fitting quality of the operational model: Comparison of the standardized calculated (1) and model adapted (2) values of the BFA in 10-years age groups (LeCS-84, age-randomized, female), also displaying the widespread area of values between best (B) and least (L) favorable. Abbreviations: BI = Bio-functional Index, SD = standard deviation

Chronological age groups (years)	Mean value BI[1]	Mean value BI[2]	SD[1]	SD[2]	Best/ most favourable value B[1]	Best/most favourable value B[2]	Least favourable value L[1]	Least favourable value L[2]	Coefficient of variation (%)
≤ 29	0.257	0.251	0.03	0.01	0.210	0.228	0.301	0.266	4.84
30–39	0.285	0.289	0.03	0.01	0.231	0.270	0.389	0.305	4.65
40–49	0.308	0.327	0.03	0.01	0.242	0.309	0.381	0.350	3.77
50–59	0.390	0.377	0.05	0.02	0.293	0.355	0.556	0.402	4.04
≥ 60	0.436	0.436	0.06	0.03	0.338	0.407	0.546	0.500	6.35

assessment is a validated age- and sex-specific tool (objectivity 0.96, reliability 0.93, females age validity: total age correlation 85.2 %; total age commonality in the main factor 76.3 %). The BFA is based on a sex-specific regression and factor analysis of functional age (29, 17, 16,1 8).

Cardiovascular performance (CP)

CP was assessed at submaximal stress level to test the individual fitness level and pre-condition for physical endurance performance, respectively (test reliability coefficients p0=0.92, pmax=0.91, Δp=0.90, PT=0.89) (16). During the test, the subject was requested to perform 20 squats as fast as possible (contraindication: acute cardiovascular disease). Endpoints were resting heart rate p0 (n/min), pulse rate difference Δp (n), performance time PT (sec.) and pulse performance index PPI (PPI= Δp/PT). We focused our results on PT.

Social stress exposition (SSE)

SSE was assessed by the validated personality test "Giessen-Test" comprising six dimensions using each six bipolar statements to be answered on a 7-point scale. Social resonance is one of its age-validated dimensions (30) reflecting SSE.

Statistical analysis

To calculate an individual bio-functional index (BI) or BFA, respectively, the measured values of all parameters across the defined age stages were scaled between 0 (most favorable) and 100 (least favorable) (Table 2). Thus for each parameter, a most favorable value B ("best") and a least favorable value L ("least") were set. Using these quantities, a measured value X in an individual case can be converted to a partial index (PI) that allows for comparison of individual parameters (formula: PI=(B–X)/(B–L)). The arithmetic mean of n index values is termed bio-functional index (BI) (formula: BI=ΣPIn/n). The calculated BIs across the defined age stages allow modelling bio-functional age(ing). All data are presented as mean and standard deviation (mean ± SD). The two-sample student's ttest was used to compare the BeCS-14 and LeCS-84. For all comparisons, p values of less than 0.05 were considered statistically significant.

Results

Characteristics of the cohort

Age, social and job status

In total, 462 women were recruited presenting 73.3% of the BeCS-14 cohort. The majority (60.8%) was recruited via personal contact, and 38.5% via online advertisement. The origin of the remainder was unknown. Mean age of women was 39.98 ± 14.78 years. 180 (39.0%) participants were below age 30, and 228 (49.4%) above age 40. For BFA calculation, age 35 is an accepted cut-off value; 255 (55.2%) participants were above age 35. 74.5% recruited women were living in partnership. Almost two thirds of participants (63.2%) were childless, whereas one in five participant had at least two children (29.0%). About one third of participants (39.2%) had a degree from university or advanced technical college, respectively. One in four participants (22.4%) had a degree from vocational business school. Most participants (43.3%) worked in the social field with 88.5% being employees and 11.5% students, respectively. Job occupation was at least 50% in more than half of participants, and at least 90% in about one third (37.7%). The monthly gross income was less than 5000 Swiss Francs for 54.5%. About half (55.3%) of participants reported going to work despite being sick, reflected in the low numbers of sick days.

Life style

About half of women (31.0%) reported regular alcohol consumption at least twice a week. 32.5% had at least one drink per day. In contrast, the majority of participants (65.6%) were never-smoker and physically active (till sweating, 71.6%). The median sleep duration was 7 hours. Sleep quality was good in 391 participants (84.6%).

Personal and family history

The prevalence of being disease free was 36.6% (n=169). Life threatening events were reported by 7 participants (myocardial infarction n=0; stroke n=3; pulmonary embolism n=4). The prevalence of a positive family history varied and was more than 15% for cancer (43.3%), cardiovascular disease (myocardial infarction 27.1%, stroke 19.7%, pulmonary embolism 7.1%), metabolic disorder (dyslipidemia 22.5%, diabetes mellitus 16.5%) and osteoporosis (16.3%).

Medications

In the BeCS-14 cohort, 314 women reported use of any kind of medication (n=659 reports). The major medication groups were dietary supplements (n=191), sexual steroids for contraception (n=128) or menopausal hormone therapy (n=42), psychotropic medication (n=53), analgetics (n=37) and antihypertensives (n=26).

Bio-functional age (BFA)

The BFA modeling of both cohorts ist presented in Figure 1. As the BFS assessment model already incorporates various endogenuous and exogenuous impacts we did not adjust the BFS and BFA results for additional factors. On first sight, the measured mean BFA agreed with the chronological age in LeCS-84 quite well (regression coefficient age 0.85, total commonality age 76% (16). In contrast, the measured mean BFA was lower than the chronological age within BeCS-14 (regression coefficient 0.58). In detail, women's BFA in LeCS-84 and BeCS-14 at age 35 was comparable. Within the decades 35-44 years and 55-64 years the gradient of BFA increase (aging rate) was similar in both, LeCS-84 and BeCS-14. In LeCS-84, the mean gradient of BFA increase within the decade 35-44 years was 4.08 ± 1.03 year equivalents and within the decade 55-64 years 6.21 ± 1.29 year equivalents. In BeCS-14, the corresponding values were 4.78 ± 1.67 year equivalents and 5.25 ± 1.18 year equivalents, respectively. Remarkably, within LeCS-84 the mean aging rate within the decade 45-54 years was significantly different from all other aging rates in both cohorts: 13.02 ± 1.05 year equivalents. However, within BeCS-14 the corresponding value was 4.83 ± 1.02 year equivalents thus indicating a continuous aging process across the whole adult life course.

Cardiovascular performance (CP)

The performance time (PT) in women of BeCS-14 are presented in Table 3. The impact of potential confounders from the personal and family history were proofed by means of analysis of variance. Only age was shown to have a significant impact on CP. The lower the PT the better the CP and the pre-conditions for physical endurance. It may be considered as an indicator for the individual daily mobility.

When comparing age groups within BeCS-14 there were significant differences between the youngest age group (≤ 29) vs. all other age groups (p<0.001). Similarly, the PT was significantly different when comparing age group 30-39 to age groups 50-59 (p=0.005) and ≥ 60 (p=0.011), respectively, as well as when comparing age groups 40-49 and 50-59 (p=0.018). This finding indicates an age-related effect on CP, meaning the younger the better CP.

Figure 1

Modeling bio-functional age (BFA) in LeCS-84 (Fig. 1a; left) and BeCS-14 (Fig. 1b; right) (females only). The individual calculated BFA corresponds to the dimension quality of life (according to AHA questionnaire) as an age- and health related personal contextual factor (according to Grotkamp (19); also see table 1)

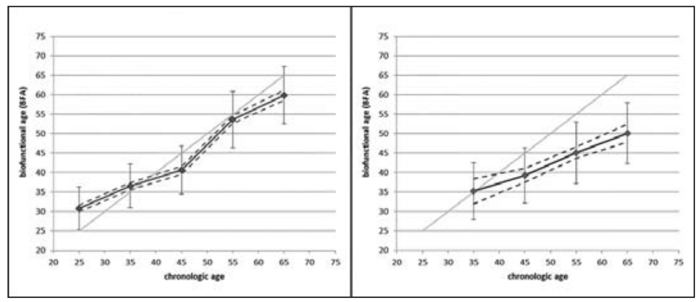
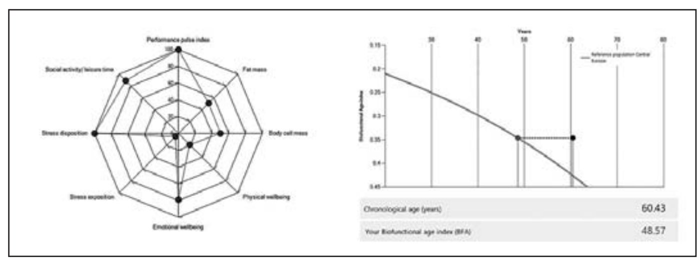


Figure 2

Spider net (left) and BFA (right): BFS key markers demonstrating relevant individual needs for AHA



Social stress exposition (SSE)

The social resonance test results in women of BeCS-14 are presented in Table 4. The impact of potential confounders from the personal and family history were proofed by means of analysis of variance. Only age was shown to have a significant impact on SSE. The higher the test value the higher the individual social resonance or the lower the SSE, respectively.

When comparing age groups within BeCS-14 there were significant differences between the youngest age group (≤ 29) vs. 40-49 (p=0.030), 40-59 (p=0.033) and ≥ 60 (p<0.001), respectively. Similarly, SSE was significantly different when comparing the oldest age group (≥ 60) to age group 30-39 (p=0.002). This finding indicates a decreasing level of SSE in aging women.

BFS and BFA assessment - from theory into practice

The presented complex BFS and BFA assessment tool allows for identifying relevant AHA related individual strengths, needs and resources. For easy diagnosis at a glance, the BFS key markers have been visualized as a spider net representing the fields of lifestyle action and health promotion,

Table 3
Performance time (PT) in BeCS-14 (females only) (16). The BT corresponds to the dimension physical activities and category mobility (according to AHA questionnaire), respectively (also see table 1). Different letters (a-d) indicate significant group differences

age groups (years)	Participants (n)	mean values (sec)	standard deviation (sec)	coefficient of variation (%)	best … least values (sec)
≤ 29	174	22.14[a]	3.90	0.18	15.0 … 39.8
30-39	48	24.28[b]	4.48	0.18	17.5 … 36.2
40-49	66	25.25[b]	4.27	0.17	18.0 … 39.2
50-59	117	27.77[bcd]	7.92	0.29	15.5 … 57.0
≥ 60	44	26.88[bc]	7.92	0.29	17.0 … 37.0
Total	449	24.76	5.91		15.0 … 57.0

Table 4
Social stress exposition (SSE) in BeCS-14 (females only). This corresponds to the dimension psychological and social well-being and category getting along (according to AHA questionnaire), respectively (also see table 1). Different letters (a, b) indicate significant group differences

age groups (years)	Participants (n)	mean values	standard deviation	coefficient of variation (%)	best … least values
≤ 29	178	52.8a	8.4	0.16	72 … 34
30-39	49	52.2a	8.3	0.16	67 … 28
40-49	67	55.5b	8.9	0.16	72 … 34
50-59	119	54.9b	9.1	0.17	74 … 25
≥ 60	45	58.0b	9.3	0.16	74 … 37
Total	458	54.2	8.9		74 … 25

respectively, such as quality of life, mobility, nutrition, stress coping, participation etc. (Figure 2). In addition, the BFA and each single item (supplementary file 4) adding to the BFS are displayed as an age- and sex-validated bio-psycho-social comprehensive standardized profile of strengths and resources supporting the individual AHA approach.

Discussion

In this study we compared the chronological and bio-functional age between two German speaking female cohorts 30 years apart applying a comprehensive and generic AHA assessment model incorporating ICF. Exemplarily, we chose PT and SSE as an objective and subjective BFS item.

While the aging rate within the decades 35-44 and 55-64 years was similar in both female cohorts, there was a significantly higher aging rate within the decade 45-54 years in LeCS-84 compared to all other decades. In contrast, in BeCS-14 there was a continuous aging process across the whole adult life course. We can only speculate on the reasons for age acceleration in midlife women from LeCS-84. BeCS-14 participants were mainly well educated, healthy, living in a childless partnership and working as employee with a mean monthly gross income within the "normal" range for women in Switzerland in 2012 (31). LeCS-84 participants were workers and employees, respectively, randomized from four large firms and institutions in Leipzig including factories and university (16). In contrast to Swiss women, most women in the former German Democratic Republic (> 90%) were married, full time workers/employees (up to 45 hours per week) and had children (on average 2.4) thus carrying double loads with gainful employment plus homemaking and child-raising. Besides the differences between the political and social systems, the health care system may have also differed. While life expectancy of a Swiss 65-year old woman nowadays and a Eastern German 65-year old woman 30 years ago was quite similar with 13 (31) and 15 years (32), respectively, self-rated health status and vitality (e.g. bio-functional age) might have differed. In 2012, 82% of Swiss women aged 45-54 years rated their health to be good or very good, respectively (31). However, we do not have the corresponding data for Eastern German women in the 1980ies.

In respect to CP, we found a significant difference for all age groups but the youngest when comparing BeCS-14 with LeCS-84 (16). This finding indicates a significantly better CP in Swiss women aged 30+ compared to German women assessed 30 years ago. Accordingly, there was a significant difference in respect to SSE for the two age groups 40-49 and 50-59 ($p<0.05$) when comparing BeCS-14 with LeCS-84 (16). This finding indicates a significantly higher SSE in German women assessed

30 years ago compared to Swiss women nowadays.

We are aware that missing data on potential confounders for LeCS-14 may limit the value of the comparison made. However, since the BFS assessment model already incorporates various endogenuous and exogenuous impacts we believe that our BFS/BFA assessment tool still reveals the impact generation and lifestyle have on BFS not only on an individual (strengths/resources) but also populational level.

On an individual level, the BFS/BFA assessment tool has the advantage of incorporating objective and subjective measures avoiding the bias of a "user's good or bad day". Resources may be identified and targeted in an age- and sex adapted, multidisciplinary way (33). By that, the BFS/BFA assessment tool is also compatible with the WHO strategy and action plan for healthy aging in Europe (2012-2010), emphasizing everyone's fundamental right to the enjoyment of the highest attainable standard of physical and mental health, irrespective of age (34). However, targeted resources strategies and their implementation into AHA management still need to be developed.

On a populational level, the BFS/BFA assessment tool may support the development of strategies on a national or regional level to improve its population's strengths- and resources profile. In other words, in our study the question arises if and what specifically has Switzerland done differently to keep the aging rate in women stable besides being a Western country without war in its recent history? And is there anything other countries or regions can learn? And if yes, is the progress measurable with the BFS/BFA assessment tool?

Based on these arguments, we postulate that the BFS/BFA assessment tool meets the EIP-AHA requirements for a diagnostic AHA instrument (2) such as applicability to health and disease across age stages (non-pediatric and non-geriatric lifetime), easy, partly self- and proxy administration, and accordance with the ICF of the WHO. Thus, summative information on age and hrQoL on individual and populational level is provided.

The advantages of the BFS/BFA assessment tool are its objective, validated, standardized, non-invasive, comfortable and safe character that may outweigh its shortcomings such as assessment duration which might render it not easily applicable in all health care settings and countries (29). The BFS/BFA assessment tool may be used in all areas of a patient-, customer- or need-orientated health care setting, e.g., in health promotion and prevention of NCDs, in therapy and rehabilitation of chronic health conditions and multi-morbidity (case and care management). The instrument may also be helpful in gerontology itself (35), in training, clinical practice and research, e.g. health services research and health care technology (36). In this context, it may be used as an Age and Health Monitoring System (Age-HMS) (supplementary file 5) assessing the needs and efficacy of any kind of intervention to improve AHA as well as quality and cost effectiveness in health care systems.

Conclusion

The BFS/BFA assessment tool follows EIP-AHA requirements. It can be used on an individual as well as on a populational level for assessing strengths and resources (case management) and guiding patient-centered care management in AHA. However, it remains to be developed how the assessed health strengths/health resources-profile may be integrated into AHA management.

Acknowledgements: The authors would like to thank J. D. Wanner (JDW) and D. Gafner, study nurses, for her administrative assistance during the study. Also, the authors are thankful to the medical students for conducting the assessments: N. Ammann, M. Anker, S. Berger, S. Blum, G. Capaldo, J. Füri, M. Gahl, V. Heller, L. Hollenstein, L. Kramer, M. Moser, J. Siegenthaler, M. von Bergen, J. von Holzen and V. Widmer.

Conflict of interest: The study was supported by an unrestricted grant by Merck Sharp & Dohme Corp. and Burgergemeinde Bern. P. Stute, M. von Wolff, N. Bitterlich and J. Bousquet declare to have no conflict of interest in context of this manuscript. F. Meissner is managing director of vital.services and D. Poethig is member of the scientific board of vital.services, which provides the technology for BFS measuring. F. Meissner has no involvements that might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated.

References

1. Bousquet J, Michel J, Standberg T, Crooks G, Iakovidis I, Gomez M. The European Innovation Partnership on Active and Healthy Ageing: The European Geriatric Medicine introduces the EIP on AHA Column. Eur Geriatr Med 2014;5 (6):361-362
2. Bousquet J, Malva J, Nogues M, Manas LR, Vellas B, Farrell J, Group MR. Operational Definition of Active and Healthy Aging (AHA): The European Innovation Partnership (EIP) on AHA Reference Site Questionnaire: Montpellier October 20-21, 2014, Lisbon July 2, 2015. Journal of the American Medical Directors Association. 2015;doi:10.1016/j.jamda.2015.09.004
3. Bousquet J, Kuh D, Bewick M, Standberg T, Farrell J, Pengelly R, Joel ME, Rodriguez Manas L, Mercier J, Bringer J, Camuzat T, Bourret R, Bedbrook A, Kowalski ML, Samolinski B, Bonini S, Brayne C, Michel JP, Venne J, Viriot-Durandal P, Alonso J, Avignon A, Ben-Shlomo Y, Bousquet PJ, Combe B, Cooper R, Hardy R, Iaccarino G, Keil T, Kesse-Guyot E, Momas I, Ritchie K, Robine JM, Thijs C, Tischer C, Vellas B, Zaidi A, Alonso F, Andersen Ranberg K, Andreeva V, Ankri J, Arnavielhe S, Arshad H, Auge P, Berr C, Bertone P, Blain H, Blasimme A, Buijs GJ, Caimmi D, Carriazo A, Cesario A, Coletta J, Cosco T, Criton M, Cuisinier F, Demoly P, Fernandez-Nocelo S, Fougere B, Garcia-Aymerich J, Goldberg M, Guldemond N, Gutter Z, Harman D, Hendry A, Heve D, Illario M, Jeandel C, Krauss-Etschmann S, Krys O, Kula D, Laune D, Lehmann S, Maier D, Malva J, Matignon P, Melen E, Mercier G, Moda G, Nizinkska A, Nogues M, O'Neill M, Pelissier JY, Poethig D, Porta D, Postma D, Puisieux F, Richards M, Robalo-Cordeiro C, Romano V, Roubille F, Schulz H, Scott A, Senesse P, Slagter S, Smit HA, Somekh D, Stafford M, Suanzes J, Todo-Bom A, Touchon J, Traver-Salcedo V, Van Beurden M, Varraso R, Vergara I, Villalba-Mora E, Wilson N, Wouters E, Zins M. Operational Definition of Active and Healthy Ageing (AHA): A Conceptual Framework. J Nutr Health Aging 2015;19 (9):955-960. doi:10.1007/s12603-015-0589-6
4. Bousquet J, Bourquin C, Augé P, Domy P, Bringer J, Camuzat T. MACVIA-LR Reference Site of the European Innovation Partnership on Active and Healthy Ageing. Eur Geriatr Med 2014;5 (6):406-415
5. Bousquet J, Kuh D, Bewick M, Strandberg T, Farrell J, Pengelly R. Operational definition of active and healthy ageing (AHA): Report of the meeting held in Montpellier October 2015;21,22-2012. Eur Geriatr Med 7:in press
6. Kuh D, Cooper R, Hardy R, Richards M, Ben-Shlomo YAlcathao. A life course approach to healthy ageing. Oxford, 2014
7. Organization WH. Healthy ageing requires a life-course approach. doi:http://www.euro.who.int/en/health-topics/Life-stages/healthy-ageing/news/news/2015/09/healthy-ageing-requires-a-life-course-approach, 2015
8. von Bertalanffy K. An outline of General System Theory. Br J Philos Sci 1950;1:134-165
9. Buerger M. Biomorphosis - The life change theory of human organism and its functions (dt.). Ärztl Fortbild 1956;5:409-423
10. Beier W. The human life course from a theoretical point (dt.). Z Ges Inn Med 1976;31:90-93
11. Strehler B. Time, cells and aging. Academic Press, London, 1977
12. Beier W, Poethig D. Tradition with important potential for the future - About Measuring Vitality, Age and Aging (dt.). Bewegungstherapie und Gesundheitssport 2013;29:6-10

13. Hochschild R. Can an index of aging be constructed for evaluating treatments to retard aging rates? A 2,462-person study. Journal of gerontology 1990;45 (6):B187-214
14. Lehtisalo J., Lindström J., Ngandu T., Kivipelto M., Ahtiluoto S., Ilanne-Parikka P., Keinänen-Kiukaanniemi S., Eriksson J.G., Uusitupa M., Tuomilehto J., J. L, Study FDP. Association of Long-Term Dietary Fat Intake, Exercise, and Weight with Later Cognitive Function in the Finnish Diabetes Prevention Study. J Nutr Health Aging 2016;20 (2):146-154. doi:10.1007/s12603-015-0565-1
15. Hau C., Reid K. F., Wong K. F., Chin R. J., Botto T. J., Eliasziw M., Bermudez O. I., R.A. F. Collaborative Evaluation of the Healthy Habits Program: An Effective Community Intervention to Improve Mobility and Cognition of Chinese Older Adults Living in the U.S. J Nutr Health Aging 2016;20 (4):391-397. doi:10.1007/s12603-015-0623-8
16. Poethig D. Experimental development of a clinical diagnostic model objectifying bio-functional age(ing) of human being. Habilitation thesis (dt.). German National Library Leipzig, http://d-nb.info/850613108. 1984
17. Ries W, Poethig D (1984) Chronological and biological age - A new method to measure healthy aging. Exp Gerontol 1984.19 (3):211-216
18. Dean W. Biological aging measurement: Clinical applications. The German test battery, University Leipzig, 175-87. The Center for Bio Gerontology Los Angeles. 1988
19. Grotkamp S, Cibis W, Nuechtern E, von Mittelstaedt G, Seger W. Personal Factors in the International Classification of Functioning, Disability and Health: Prospective Evidence. Australian Journal of Rehabilitation Counselling 2012.18 (1):1-24
20. Viol M. Bio-psychosocial aging - Positioning of the vitality concept in the ICF (dt.). Bewegungstherapie und Gesundheitssport 2011.27:74-79
21. Hamilton M. A rating scale for depression. Journal of Neurology, Neurosurgery and Psychiatry 1960.23:56-62
22. Bullinger M, Kirchberger I, Ware J. Der deutsche SF-36 Health Survey. Übersetzung und psychometrische Testung eines krankheitsübergreifenden Instrumentes zur Erfassung der gesundheitsbezogenen Lebensqualität. Zeitschrift fuer Gesundheitswissenschaften 1995;1:21-36
23. Schulz P, Schlotz W, Becker P. Trierer Inventar zum chronischen Stress (TICS). Hogrefe, Göttingen. 2004
24. Ardelt-Gattinger E, Meindl M. AD-EVA. Interdisziplinäres Testsystem zur Diagnostik und Evaluation bei Adipositas und anderen durch Ess- und Bewegungsverhalten beeinflussbaren Krankheiten. Huber, Bern. 2010
25. Zenz H, Bischoff C, Hrabal V. Patiententheorienfragebogen (PATEF). Handanweisung. Hogrefe, Göttingen. 1996
26. Molnar M, Haiden C., Geißler-Gruber B. IMPULS-Broschüre und IMPULS-Test. Betriebliche Analyse der Arbeitsbedingungen. AUVA, AK, ÖGB, WKÖ (Hg.) Wien. 2012
27. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology; Circulation 1996;93 (5):1043-1065
28. Kalbe E, Baller G, Brand M, Kessler J; Das Inventar zur Gedächtnisdiagnostik: Vorstellung der endgültigen Version. vol 33 Akt Neurol 2006; . doi:10.1055/s-2006-953127
29. Meissner-Poethig D, Michalak U. Vitalitaet und aerztliche Intervention. Vitalitaetsdiagnostik: Grundlagen - Angebote - Konsequenzen. Hippokrates-Verlag, 1997
30. Beckmann D, Brähler E, Richter H-E. Der Gießen-Test (GT), vol 4. erweiterte und überarbeitete Auflage mit Neustandardisierung 1990. Huber, Bern. 1991
31. http://www.bfs.admin.ch.
32. http://www.bib-demografie.de/EN/Facts_Figures/Mortality/Figures/a_08_25b_lebenserwartung_geburt_erreichbares_alter65_o_geschlecht_ab1958.html?nn=3214682. 2015. Accessed 10.11.2015
33. Pfeifer K, Huber G, Baldus A, Poethig D, Schule K. [Resource management: ICF-oriented exercise programs for patients with diabetes mellitus type 2. Chronic illnesses and biopsychosocial status]. Zeitschrift fur Gerontologie und Geriatrie 2012;45 (2):119-127. doi:10.1007/s00391-011-0276-0
34. Europe WHOROf. Strategy and action plan for healthy aging in Europe, 2012-2020. Paper presented at the Regional committee for Europe, sixty-second session, Malta,
35. Poethig D, Gerdes W, Viol M, Wagner P, Simm A. [Biofunctional age diagnosis in humans. Potentials and limits]. Zeitschrift fur Gerontologie und Geriatrie 2011;44 (3):198-204. doi:10.1007/s00391-011-0171-8
36. Stute P, Meissner F, Sudeck G. Natural health resource use, vitality analysis and vitalisation in practice: The Bern Model. B&G – Bewegungstherapie und Gesundheitssport 2011;27 (2):80-85. doi:10.1055/s-0031-1271376
37. GmbH DI. Das B.I.A.-Kompendium 3. Ausgabe, 2005.
38. Schumacher J, Wilz G, Gunzelmann T, Brahler E. [The Antonovsky Sense of Coherence Scale. Test statistical evaluation of a representative population sample and construction of a brief scale]. Psychotherapie, Psychosomatik, medizinische Psychologie 2000;50 (12):472-482. doi:10.1055/s-2000-9207
39. Poethig D, Ries W. Sex differences of biological aging - Experimental study outcomes. Z Alternsforsch 1985;40 (4):235-244