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MEASURES OF INDIVIDUAL AND GROUP CHANGES IN ORDERED CATEGORICAL DATA: APPLICATION TO THE ADL STAIRCASE

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ABSTRACT. The aim was to describe the application of a non-parametric method to a study of changes in activities of daily living (ADL) measured by a 10-level ordinal scale, the Staircase of ADL, in a population of 70-year-old persons followed to the age of 76 (n=371). The statistical method takes account of the fact that change cannot be defined by differences and can separately measure the level of change for the group and for the individuals. This is demonstrated step by step. Measures of change for the subgroups, men and women, are also given. As a group, there was a systematic increase in ADL dependence between the ages of 70 and 76 years. The individual pattern of change was more dispersed between 73 and 76 years of age. Individual variations in ADL changes with increasing age were small compared to the systematic change for ADL for the subgroups of men and women. The systematic change in ADL follows a pattern with "one step at a time" for women and "many steps at a time" for men. In conclusion, this new statistical method provides a valuable tool for detailed information of individual as well as group changes in longitudinal studies.

Key words: ADL, elderly, non-parametric statistics, ordinal data, repeated measurements, responsiveness.

INTRODUCTION

In rehabilitation medicine, the term functional assessment is commonly used and can be defined as the planned process of obtaining, interpreting, and documenting the functional status of an individual. Data can be collected through a review of records, observations, interviews and administration of test procedures. The various instruments have often been developed to improve documentation of impairment, functional limitation, disability and/or handicap (6, 39). Thus, they involve an endless array of different variables.

Assessments of ability/disability in daily life activities (ADL) are commonly used at the disability level for discriminative, predictive or evaluative purposes (6, 14, 17, 21). Most of the ADL instruments include assessment of some personal activities of daily life (P-ADLs), such as bathing, dressing and eating. During the 1970s, the ADL concept was extended to consider problems more typically experienced by those living in the community, that is, instrumental activities (I-ADLs), such as shopping, transportation, and cooking, etc. As the criteria for instruments used in clinical practice and in research differ, the purpose of using a specific instrument must by carefully delineated (4–7, 15, 18).

Assessments of ADL can be operationalized to be uni- or multidimensional by the use of rating scales, recording each attribute of interest in two or more ordered categorical levels. The main property of ordered categorical data is that the categories represent a rank order according to the amount or intensity of the particular concept. As distances between the scale categories are indeterminate, the categorical labels do not represent any mathematical value but only an order, therefore, arithmetics cannot be applied to ordered categorical data (11, 12, 25). Merbitz et al. proposes that numerical labels of categories should be called non-numbers (19). Whatever the type of label and the number of categories, the lack of additivity of ordinal data demands *non-parametric rank-invariant statistical methods*, which means that the methods should be unaffected by any kind of ordered relabelling of scale categories (11, 32).

In longitudinal or follow-up studies, the repeated measurements of the same individual must detect clinically important changes over time. A change in quantitative objective responses, representing interval or ratio measurement levels, is often defined by the difference between data. However, in ordered categorical data, change in response cannot be defined by differences, as arithmetic is not permissible. Therefore, the non-parametric Wilcoxon's signed-rank test is not relevant, as

this test is based on differences (23). Statistical methods for analysis of change in ordered categorical data should take account of the property of non-additivity. Svensson (32) and Svensson & Holm (33) have proposed a family of non-parametric methods that consider different aspects of inter- and intra-judgmental variability in paired ordered categorical data. These methods have, so far, been applied to quality assessments of ordered categorical scales (32, 34), but could also be used in paired follow-up studies.

The present report is a part of the longitudinal population study of ageing and health among 70-year-olds in Göteborg, Sweden (22, 27, 30). The third cohort, born in 1911–1912, was added in order to analyse to what extent dysfunction caused by ageing and decline in health could be postponed or reduced by social, psychological and medical measures (13, 31). These studies include detailed somatic and psychological examination, measurement of physical performance, studies of home and social situations, as well as detailed assessment of the person's ability in performing daily life activities. The assessment used, the ADL Staircase, is a 10-level hierarchical scale of independence/dependence in daily life activities (27, 28). In an earlier study, it was shown that among participant survivors, the incidence of disability between 70 and 73 years of age was 8%, and between 73 and 76 years of age 26%. There were no major gender differences in overall dependence, even if the risk of becoming dependent with increasing age was somewhat greater in men than in women (27, 29). However, it was not possible to distinguish any systematic change in ADL for a group from individual changes.

The aim was to describe the application of a non-parametric method proposed by Svensson (32) to a study of changes in ADL measured by the ADL Staircase (27–29) and to demonstrate step by step the ability of the statistical method to separate and measure the level of change for the group and for the individuals. Measures of change for the subgroups, men and women, are also given.

Table I. *Definitions of personal (P-) and instrumental (I-) ADL according to a cumulative scale of conditional ADL steps (the ADL Staircase)*

Steps in I+P – ADL	Definitions
Step 0	Independent in all activities
Step 1	Dependent in one activity
Step 2	Dependent in cleaning and one more activity
Step 3	Dependent in cleaning, shopping and one more activity
Step 4	Dependent in cleaning, shopping, transportation and one more activity
Step 5	Dependent in all I-ADL and one P-ADL
Step 6	Dependent in all I-ADL, bathing and one more P-ADL
Step 7	Dependent in all I-ADL, bathing, dressing and one more P-ADL
Step 8	Dependent in all I-ADL, bathing, dressing, toileting and one more P-ADL
Step 9	Dependent in all activities
"Others"	Dependent in 2 or more activities but not classifiable as above
If the item of continence is included, the definitions of the last 2 steps will be as follows:	
Step 9	Dependent in all I-ADL, bathing, dressing, going to the toilet, transfer and one more P-ADL
Step 10	Dependent in all activities

Step 0
Step 1 Cleaning
Step 2 Shopping
Step 3 Transportation
Step 4 Cooking
Step 5 Bathing
Step 6 Dressing
Step 7 Toileting
Step 8 Transfer
Step 9 Continence
Step 10 Feeding

MATERIALS AND METHODS

Study group and the ADL assessment

In 1981–1982, 806 70-year-olds were invited to participate in a combined medical and social intervention programme (13). The subjects have been examined at 70, 73 and 76 years of age. At the age of 70, the response rate was 77%. Between 70 and 76 years of age, 17% died and 17% dropped out for other reasons. Three hundred and eighty two subjects (209 women, 173 men) participated in all three examinations. This report is based on those subjects who were classified as belonging to ADL steps 0–9 according to the Staircase of ADL, 205 women and 166 men (subjects classified as "Others" excluded, n=11). The participants received a home visit at 70, 73 and 76 years of age from an occupational therapist, who interviewed the persons according to the ADL Staircase (27, 28). This instrument consists of four defined I-ADLs: cleaning, shopping, transportation and cooking, combined with six P-ADLs: bathing, dressing, going to the toilet, transfer, continence and feeding (16, 27). The ability in performing each activity is assessed by a three-point scale, independent, partly dependent, and dependent. Dependence means that another person is involved in the activity and gives personal assistance or directive assistance. People living together are assessed as independent if they perform the activity when alone, and as dependent if another person is involved in the activity. The ratings are then dichotomized into independence or dependence; partly dependent is assessed as dependent in shopping, transportation, cooking, going to the toilet, transfer, and continence, and as independent in cleaning, bathing, dressing, and feeding. The activities can be arranged into one conditional ordered scale of ADL steps from the most independent to the most dependent person in I-ADL and P-ADL. When

continence is included, there are 10 ADL steps; when it is excluded, there are 9. Persons who cannot be classified according to conditional ADL steps are called "Others" (Table I).

The response data from the ADL Staircase indicate a rank order but the absolute distance between adjacent ADL levels is unknown. The reliability and validity of the instrument have been studied and reported earlier (27–29).

Statistical methods

Svensson (32) has developed a family of non-parametric rank-invariant methods that are valid for all types of ordered data without assumptions of the distributions. In her approach, the systematic component of observed differences between paired ordered categorical assessments is separated from the random variability and measured.

In this report, two basic measures for systematic and individual changes are used. The overall systematic change in the ADL level for the group is evaluated by the analysis of the change in the distribution of individuals on the ADL levels between 70 and 76 years of age, denoted X and Y, respectively. This distribution is also called the marginal distribution (1, 32). A change in the marginal distribution means that there is a systematic change over time in the ADL levels for the group. This systematic change in marginal distributions between two occasions is illustrated by plotting the two sets of cumulative relative frequencies for the marginal distributions against each other yielding a so-called ROC (relative/receiver operating characteristic) curve (see Result, Fig. 1) (2, 32). This application of ROC curves, to show systematic change, differs from the ordinary approach used in signal detection studies (32). A systematic change towards a higher level of ADL dependence will result in an ROC curve that deviates below the diagonal of unchanged distributions. The greater the deviation, the stronger the systematic change between the two occasions. Accordingly, an improvement in ADL will give an ROC curve above the diagonal. Marginal homogeneity means that there is no group change in ADL levels between the two occasions and the ROC curve is the diagonal of identical coordinates.

A measure of a systematic change over time is theoretically

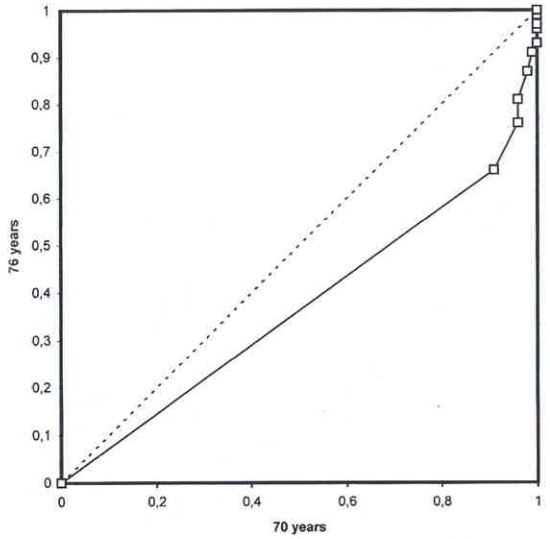

Fig. 1. The ROC curve for the systematic change in ADL levels between 70 and 76 years of age (n=371).

defined by the difference between two probabilities: the probability of the ADL assessment on the first occasion, here denoted X, to be distributed in lower categories than the ADL assessment on the second occasion, Y, and the probability of the ADL assessment on occasion Y to be distributed in lower categories than at X; in short, $P(X<Y)-P(Y<X)$. The empirical measure of the systematic shift in position on the ADL Staircase between the two occasions is called Relative Position (RP). Possible RP values are in the interval -1 to 1. A value of RP close to zero indicates unchanged ordered categorical distribution of ADL levels over time for the group. Increasing ADL level, which means a higher level of ADL dependence at the second measurement, implies a positive RP, and the corresponding ROC curve will deviate from the main diagonal in the lower-right direction.

This measure of systematic change over time, RP, is based on the occurrence of marginal heterogeneity and defines the level of change for the group. The pair of marginal distributions do not, however, show the individual changes over time. Therefore, the pattern of individual changes displayed by the joint distribution of the paired ordered categorical levels in a square (10×10) contingency table was studied [see Results and Figs. 2(a) and 4]. In the Svensson approach used here (32), the diagonal of unchanged categories is oriented from the lower-left to the upper-right corner of the square contingency table.

The observed individual pattern of change is compared with the so-called *rank-transformable pattern of change*, which is defined by the two sets of marginal distributions and illustrates the joint distribution of the systematic change for the group. Svensson has shown (32) that it is always possible to construct one rank-transformable pattern of change to each pair of marginal distributions. Characteristic of the rank-transformable pattern of change is the concentration of observations to a narrow band of cells that have the same ordering on the two occasions [see Results and Fig. 2(b)]. Note that this pattern of change is entirely defined by the pair of marginal distributions, which reflect the pattern of change for the group. The interpretation of the rank-transformable pattern of change is that there is a systematic change in ADL levels over time, but the rank order of the individuals is unchanged. The individuals may have changed their level of ADL dependence, but they have not changed their order in relation to the other individuals. However, in reality, a change in both level and order is more common, e.g. some individuals will show a more pronounced change than others in both directions, which means that the pattern of change will be dispersed from the rank-transformable pattern of change.

The observed pattern of change in ADL for individuals is compared with this rank-transformable pattern of change for the group. The dispersion of observations from the rank-transformable pattern of change can be explained by individual changes beyond the systematic group changes measured by RP. The empirical measure of this additional dispersion is called the *relative rank-variance*, RV. Possible values for RV are in the range from 0 to 1. The greater the individual changes from the systematic change for the group, the greater the RV. For the rank-transformable pattern of change, RV is zero.

When a study group is composed of independent subgroups, for example, defined by different diagnoses, gender or age, the contribution from each subgroup to the measures for the total group can be calculated. Previous studies (29) have shown that the change in ADL dependence measured by the ADL Staircase differs between men and women; therefore, the contribution to the measures of RP and RV from these subgroups was also calculated. The measures of systematic and individual changes for the subgroups, denoted A and B, were indexed, for example, RP_A, RV_A and RP_B, RV_B.

Table II. *The marginal distributions of the 371 individuals at 70 and 76 years of age on the ADL Staircase and of men (n=166) and women (n=205)*

Levels of ADL Staircase	0	1	2	3	4	5	6	7	8	9
X: 70 years of age:										
Category frequency										
men	157	5	0	1	2	1	0	0	0	0
women	181	12	2	7	1	1	1	0	0	0
Total	338	17	2	8	3	2	1	0	0	0
Cumulative frequency	338	355	357	365	368	370	371	371	371	371
Cumulative relative freq.	0.91	0.96	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00
Y: 76 years of age:										
Category frequency										
men	107	12	7	7	12	4	9	3	4	1
women	139	22	14	13	5	3	3	0	5	1
Total	246	34	21	20	17	7	12	3	9	2
Cumulative frequency	246	281	301	321	338	345	357	360	369	371
Cumulative relative freq.	0.66	0.76	0.81	0.87	0.91	0.93	0.96	0.97	0.99	1.00

The measures RP and RV for the total group are the weighted mean value of the values for the subgroups; $RP = (n_A RP_A + n_B RP_B)/(n_A + n_B)$, where n_A and n_B denote the number of observations for the subgroups.

The standard errors of the measures of group and individual changes over time were estimated by using the jackknife technique (20). The jackknife estimated standard error of a measure is based on the variance of all possible values of this measure having one observation deleted (32).

RESULT

This report demonstrates step by step how the method for paired ordered categorical data developed by Svensson may be applied to the ADL assessments of elderly people by means of the ADL Staircase.

Measuring group change in ADL between 70 and 76 years of age

Table II shows the distribution of ADL assessments on the ADL steps of the 371 individuals, 166 men and 205 women, at the age of 70 (occasion *X*) and 76 (occasion *Y*) years.

It is obvious that the two distributions on the ADL steps differ, which means that there is a systematic shift in the ADL level between 70 and 76 years of age. Therefore, the ROC curve is located to one side of the diagonal of agreement (Fig.1).

The measure of this systematic shift in ADL level is expressed by RP, and the calculation formula is based on category frequencies and cumulative frequencies, which means the number of observations which are less than or equal to a certain category. The following notations are used in the formula for RP. The number of ADL steps in the ADL Staircase is m=10, and the ordered categorical levels are indexed i, where i stands for 0–9. The numbers of observations at the ith category or level on occasion X and Y are denoted x_i and y_i, respectively. Then the total of all the category frequencies on occasion X equals the total number of observations, denoted n, and the same holds for the sum of y_i. Furthermore, let $C(X)_i$ and $C(Y)_i$ denote the ith category cumulative frequency of the ADL distributions on X and Y, respectively.

The formula of RP can then be written $RP = p_0 - p_1$, where

$$p_0 = \frac{y_1}{n} \cdot \frac{C(X)_0}{n} + \frac{y_2}{n} \cdot \frac{C(X)_1}{n} + \ldots\ldots + \frac{y_9}{n} \cdot \frac{C(X)_8}{n}$$

In short, this sum over the ADL levels is written

$$p_0 = \frac{1}{n^2} \sum_{i=1}^{9} [y_i \cdot C(X)_{i-1}].$$

Correspondingly, $$p_1 = \frac{1}{n^2} \sum_{i=1}^{9} [x_i \cdot C(Y)_{i-1}]$$

Referring to the frequencies and cumulative frequencies in Table II, the calculation of RP for the systematic change in ADL between 70 and 76 years of age for the study group is shown.

$$p_0 = \frac{1}{371^2}(34 \cdot 338 + 21 \cdot 355 + 20 \cdot 357 + 17 \cdot 365 + 7 \cdot 368 + 12 \cdot 370 + (3 + 9 + 2) \cdot 371)$$

$$p_0 = \frac{44502}{371^2} = 0.3233$$

$$p_1 = \frac{1}{371^2}(17{\cdot}246 + 2{\cdot}281 + 8{\cdot}301 + 3{\cdot}321 + 2{\cdot}338 + 1{\cdot}345 + 0)$$

$$p_1 = \frac{9136}{371^2} = 0.0664$$

$$RP = p_0 - p_1 = 0.257$$

The value of RP is positive (0.257), and the corresponding ROC curve deviates from the main diagonal in the lower-right direction (Fig. 1). The jackknife estimated standard error of RP is 0.024, which is 1/10th of the RP value. This confirms the certainty in the conclusion that there is a systematic increase in ADL dependence between the ages of 70 and 76 years.

The contributions from the subgroups of men and women to the total value of RP were also calculated. The ith category frequency for the subgroup A on the first occasion, X, is denoted $x_{i,A}$, and for the subgroup B, $x_{i,B}$. The total frequency of the ith category on occasion X is then $x_i = x_{i,A} + x_{i,B}$. Then the systematic part of the change in position between 70 years of age (X) and 76 years of age (Y) for the subgroup A relative to the cumulative frequency distribution of the total group is defined by $RP_A = p_{0,A} - p_{1,A}$, where

$$p_{0,A} = \frac{y_{1,A}}{n_A} \cdot \frac{C(X)_0}{n} + \frac{y_{2,A}}{n_A} \cdot \frac{C(X)_1}{n} + \ldots\ldots + \frac{y_{9,A}}{n_A} \cdot \frac{C(X)_8}{n}$$

Note that the category frequency of the subgroup, x_{iA}, is related to the cumulative frequencies of the total group. In short, the expressions of $p_{0,A}$ and $p_{1,A}$ are

$$p_{0,A} = \frac{1}{n_A \cdot n} \sum_{i=1}^{9} [y_{i,A} \cdot C(X)_{i-1}]$$

and

$$p_{1,A} = \frac{1}{n_A \cdot n} \sum_{i=1}^{9} [x_{i,A} \cdot C(Y)_{i-1}]$$

In the comparison between the change in ADL Staircase for men and women (Fig. 1), let A denote the subgroup of men. Then $p_{0,A}$ is calculated according to following:

$$p_{0,A} = \frac{1}{166{\cdot}371}(12{\cdot}338 + 7{\cdot}355 + 7{\cdot}357 + 12{\cdot}365 + 4{\cdot}368 + 9{\cdot}370 + (3 + 4 + 1){\cdot}371)$$

$$P_{0,A} = \frac{21190}{166{\cdot}371} = 0.3441$$

In the same way, it can be shown that $p_{1,A} = 0.0408$. The part of the systematic change in position on the ADL Staircase between 70 and 76 years of age accounted for by men is therefore $RP_A = p_{0,A} - p_{1,A} = 0.303$; $SE(RP_A) = 0.035$, and the corresponding contribution from women is found to be 0.219; $SE(RP_B) = 0.029$. This means that the change in ADL dependence between the age of 70 and 76 is more pronounced for men than for women.

Individual changes in ADL between 70 and 76 years of age

The systematic change between 70 and 76 years of age for the study group is defined by the two sets of marginal distributions (Table II). This pair of marginals is also used to construct the rank-transformable pattern of change for the group [Fig. 2(b)], in the square contingency table. The observed joint distribution of paired observations showing the pattern of change in ADL levels between the age of 70 and 76 for the 371 individuals is shown in Fig. 2(a).

It is obvious that the distribution of observations on the cells in Fig. 2(a) is dispersed from the rank-transformable pattern of change for the group in Fig. 2(b), but they have the same sets of marginal distributions. This additional dispersion is subject-related and is not explained by the systematic group-related change in ADL dependence. The measure of the dispersion from the rank-transformable pattern of change is RV.

For the calculation of RV we need some additional notations, as the observations are distributed in a 10×10 square table, where the cells are identified by a pair of indexes, i and j. The (ij)th cell frequency is denoted x_{ij}. The assessed ADL levels at 70 years of age are indexed i, where $i = 0, \ldots, 9$ and the ADL levels at 76 years of age are denoted j, where $j = 0, \ldots, 9$ and the cells of the square table are identified by the notation (i,j). Thus, an individual that changes from the ADL step 3 at the age of 70 years to the ADL step 6 at 76 years of age will appear as an observation in the (3,6)th cell of the square table.

The individual dispersion from the rank-transformable pattern of change is defined by the observations located in the upper-left and lower-right cells relative to an observation in the (ij)th cell (Fig. 3). Denote the upper-left and lower-right cell frequencies relative to the (ij)th cell x_{ij}^{ul} and x_{ij}^{lr}.

Consider, for example, the cell (3,6) [see Fig. 2(a)]. Individuals classified as belonging to ADL step 3 on the first occasion and to 6 on the second will appear as observations in this cell and the (3,6)th cell frequency,

ADL level at 70 years of age

ADL level at 76 yrs	0	1	2	3	4	5	6	7	8	9	tot
9	1	1									2
8	5	2		1	1						9
7	2				1						3
6	8			2	1	1					12
5	6					1					7
4	14	3									17
3	14	2	1	3							20
2	14	4	1	2							21
1	31	2					1				34
0	243	3									246
total	338	17	2	8	3	2	1	0	0	0	371

ADL level at 70 years of age

ADL level at 76 yrs	0	1	2	3	4	5	6	7	8	9	tot
9						1	1				2
8				5	3	1					9
7				3							3
6		10	2								12
5		7									7
4	17										17
3	20										20
2	21										21
1	34										34
0	246										246
total	338	17	2	8	3	2	1	0	0	0	

Fig. 2. (a) The frequency distribution of individual changes in ADL Staircase between the groups 70 and 76 years of age (n=371). (b) The rank-transformable pattern of change in ADL Staircase between the groups 70 and 76 years of age (n=371).

x_{36}, is 2. The upper-left (3,6)th cell frequency x_{36}^{ul} is 2+5+1+2+1=11, and the lower-right (3,6)th cell frequency, x_{36}^{lr} is 1+1=2.

The individual pattern of change is measured by the relative rank-variance, RV, and is defined by

$$RV = \frac{6}{n^3} \sum_{i=0}^{9} \sum_{j=0}^{9} x_{ij}(x_{ij}^{ul} - x_{ij}^{lr})^2,$$

where n is the number of observations (n=371).

The calculation of RV for the observed individual pattern of change in Fig. 2(a) is demonstrated. The summation over all cells (i,j), where i and j are the ADL steps from 0 to 9 equals

$$\begin{aligned} &31 \cdot 3^2 + 14 \cdot 6^2 + 14 \cdot 13^2 + 14 \cdot 19^2 + 6 \cdot 22^2 + 8 \cdot 23^2 \\ &\quad + 2 \cdot 27^2 + 5 \cdot 28^2 + 1 \cdot 32^2 + 3 \cdot 95^2 + 2 \cdot 64^2 \\ &\quad + 4(50-1)^2 + 2(36-4)^2 + 3(22-8)^2 \\ &\quad + 2(1-14)^2 + 1 \cdot 16^2 + 1(58-1)^2 + 1(42-4)^2 \\ &\quad + 2(59-1)^2 + 3(42-1)^2 + 2(11-2)^2 \\ &\quad + 1(2-5)^2 + 1(12-2)^2 + 1(10-3)^2 \\ &\quad + 1(2-3)^2 + 1(25-1)^2 + 1(14-1)^2 + 1 \cdot 91^2 \\ &\quad = 95653 \end{aligned}$$

and finally $RV = \frac{6}{371^3} \cdot 95653 = 0.0112$.

In this case, the value of RV is small, which means that there is a small amount of individual changes in ADL level beyond the systematic group change. Note that the 3 individuals with a change in ADL from 1 to 0 and from ADL level 6 to 1 [see the observations in the (1,0)th and the (6,1)th cells in Fig. 2(a)] contribute very much to the value of RV, as the terms in the summation are 3.95^{-2} + 1.91^2. These non-zero cells are much dispersed from the rank-transformable pattern of change, which means that those individuals have changed their ADL levels quite differently from the other. The value of RV is small, but is still three times the jackknife standard error of RV (0.0036), which means that there is a small, but confirmed, individual dispersion from the group changes.

Note that, for the rank-transformable pattern of change, the upper-left and lower-right region frequencies to all cells are zero [see Fig. 2(b)], which means that RV is 0.

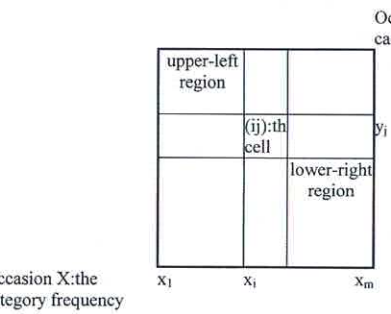

Fig. 3. The regions of the cells in an (m×m) contingency table that contribute to the measure of individual changes, RV. The upper-left region and lower-right region frequencies relative to the (ij)th cell are denoted x_{ij}^{ul} and x_{ij}^{lr}

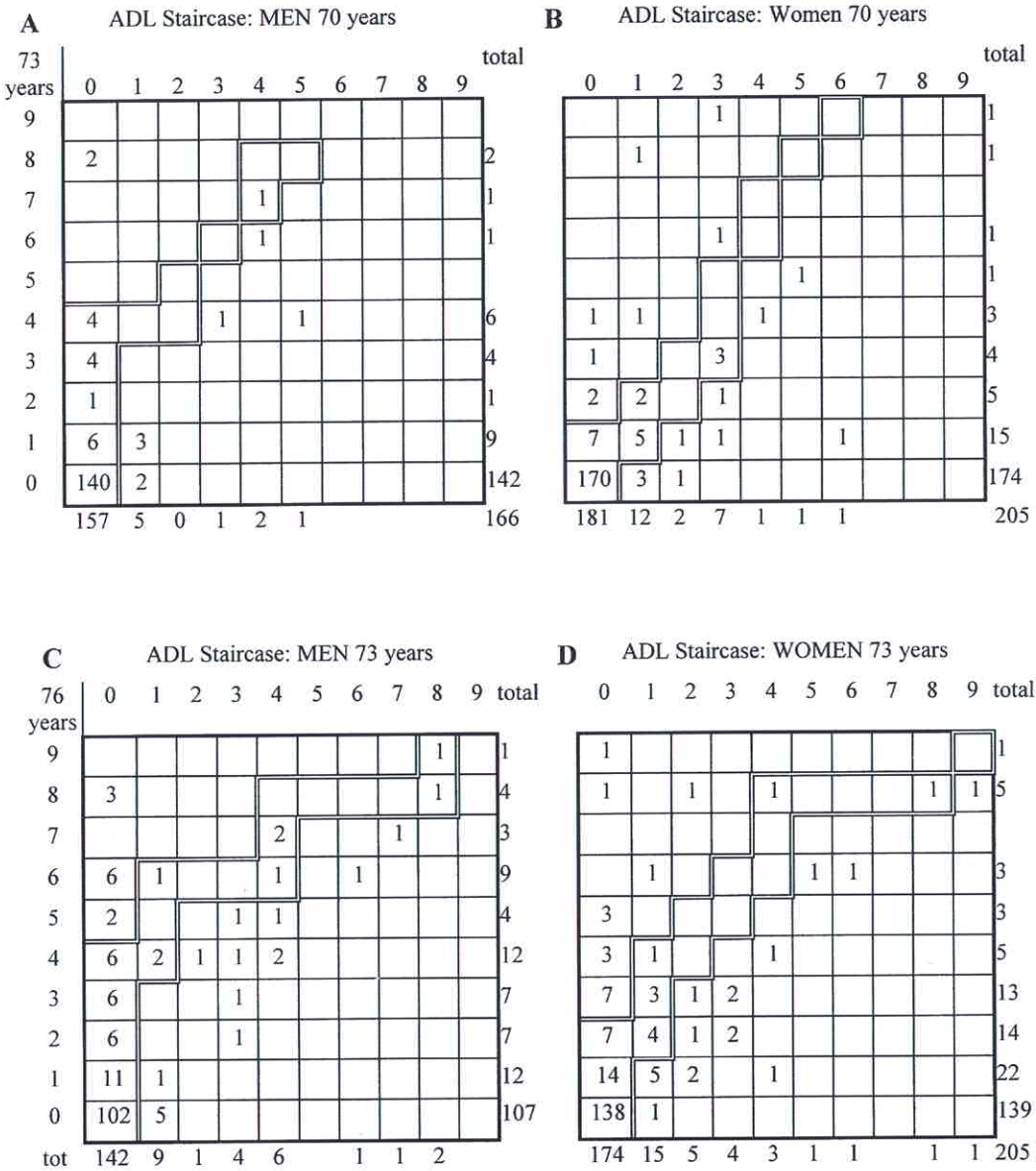

Fig. 4. The patterns of change in ADL Staircase for men (n=166) and women (n=205) between 70 and 73 years of age (a, b) and between 73 and 76 years of age (c, d). The cells of the corresponding rank-transformable patterns are delineated by double lines in the table.

Individual and group changes in ADL between 70, 73 and 76 years of age

In Figs. 4(a)–(d) are shown the patterns of change between 70 and 73 years of age and between 73 and 76 years of age for men and women with the rank-transformable patterns of change indicated in the background. The measures of individual (RV) and group changes (RP) are presented in Table III.

There is a small, but confirmed, individual dispersion from the group changes in ADL between 70 and 73 years of age, as RV is 0.002. The contributions from the subgroups of men and women to the total value of RV were also calculated. With the previous notations of A and B for the measure of individual changes in a subgroup, RV_A is defined by

$$RV_A = \frac{6}{n_A \cdot n^2} \sum_{i=0}^{9} \sum_{j=0}^{9} x_{ij,A} \left(x_{ij}^{ul} - x_{ij}^{lr} \right)^2$$

Table III. *The measures of change in ADL level measured by the ADL Staircase in the stepwise and baseline comparisons between ages 70, 73 and 76 for men (n=166) and women (n=205) and for the whole group (n=371); the jackknife standard errors for the measures are given in brackets*

	70–73 years of age	73–76 years of age	70–76 years of age
Systematic change in position for the group, RP (SE)			
Men	0.089 (0.024)	0.219 (0.034)	0.303 (0.035)
Women	0.038 (0.019)	0.180 (0.026)	0.219 (0.029)
Total group	0.061 (0.015)	0.197 (0.022)	0.257 (0.024)
Individual disperson from the group change, RV (SE)			
Men	0.0022 (0.00086)	0.0175 (0.0052)	0.0088 (0.0035)
Women	0.0020 (0.00078)	0.0142 (0.0042)	0.0132 (0.0042)
Total group	0.0021 (0.00085)	0.0157 (0.0044)	0.0112 (0.0036)

where $x_{ij,A}$ refers to the (ij)th cell frequency of group A. The total number of observations, n, is 371, n_A is the number of men, 166, and n_B is the number of women, 205. Note that the cell frequency of the subgroup is related to the upper-left and lower-right region frequencies of the total material.

The measures of individual changes, RV_A and RV_B, for men and women are similar (see Table III), as most of the individuals are independent in ADL, the ADL step 0, at both 70 and 73 years of age. However, the systematic change in ADL level for men is more obvious than for women, as RP for men is 0.09. It also appears from Fig. 4(a) that the main contribution to the RP for men is the systematic change from independence at 70 years of age to dependence in ADL (ADL steps 1–4). For women the systematic rank-transformable pattern of change is characterized by "one step at a time".

The patterns of change for men and women are more dispersed between 73 and 76 years of age, but the low proportion of observations implies that the RV values are still small. There are more individual variations in ADL changes with increasing age. However, the individual changes are still small compared to the systematic change in ADL for the subgroups of men and women, as the RP values are 0.22 and 0.18, respectively. The systematic change in ADL follows the same pattern as between 70 and 73 years, with a "one step at a time" change for women and with "many steps at a time" for men [see Figs 4(c, d) and Table III].

DISCUSSION

In rehabilitation medicine a great variety of instruments is used for measuring functional ability (7, 27, 32, 35). The quality of data is not often discussed, although the measurement level of data is the very first guide for choosing a correct statistical method for the analysis (3, 32). In clinical practice, results from scales play an important role for guidance and decision-making with regard to individual patients. Assessing ADL may have several purposes and it is obvious that a single score number or a scale label is too abstract for decision-making regarding individuals. One measurement instrument or rating scale can never be the only way to provide a qualified judgement of the status of a client or patient. Nevertheless, without reliable individual assessments, it is impossible to make general conclusions at a group level.

The Staircase of ADL is a hierarchical conditioned ordered scale for daily life activities. It must be emphasized that the symbols used for the ADL steps, from 0 to 9/10, only indicate a rank order and must not be taken as numbers in a mathematical sense.

Changes measured by the Staircase of ADL have previously been studied (29), and it was possible to demonstrate the proportions of abled/disabled elderly who changed status over time, the type of activities where new disability occurred, and the changes in ADL steps from one occasion to another by means of contingency tables. It was not possible to describe the changes at the group levels in other ways than by presenting frequencies, as the non-additivity of data means that changes must not be defined by differences in ADL steps.

The invariant properties of ordered categorical scales, such as the non-additivity of scale categories, are well recognized and documented (1, 3, 12, 14, 19, 25, 32, 38). This fact is not always taken into account, as there is a temptation to take advantage of the numerical labelling and treat ordered categorical data as if they were true

numbers in a mathematical sense. This often leads to an inappropriate choice of statistical methods that require quantitative data at least at interval measurement level (3, 7, 10, 19, 24). There is widespread misuse and confusion concerning the relevant treatment of data. It must be emphasized that, irrespective of labelling and of the number of possible values, ordered categorical recordings are always at the ordinal measurement level and should be treated by rank-invariant statistical methods. As arithmetics cannot be applied to ordered categorical data, there have been only a few invariant methods so far for the analysis of change, for example, the sign test and McNemar's test for dichotomous data. These methods do not, however, take account of the extent of the changes, which means loss of information. In the present study, we used the non-parametric rank-invariant method developed by Svensson (32) for the analysis of change in ADL.

The *ROC curve* is a suitable tool for illustrating the change in distribution of categories for a group and subgroups and provides information about both the extent and location of pronounced changes in categories. As most of the individuals in this study remained independent in ADL, the ROC curve will be even more useful to illustrate changes in groups in which disability is more frequent. The *rank-transformable pattern of change* illustrates the joint distribution of change that can be explained by a systematic change for the group. It was shown that men and women have different patterns of group changes in ADL. The change in ADL in women as a group can be characterized by ''one step at a time'', while men as a group climb ''many steps at a time''. This is also confirmed by the coefficient of systematic change, RP, in ADL for the group and the subgroups, especially between 73 and 76 years of age. The systematic change in ADL dependence is more pronounced for men as a group probably as a result of gender differences and underlying types of diseases and disorders (8, 26, 27, 29, 37). This might be contradictory to other studies reporting a higher prevalence of disability among women than men (9, 36). However, caution is necessary when comparing the prevalence of disability, as there are several different ways of measuring this variable, both concerning the type of activities involved and the dimensions of performance measured. That is, it depends how assessments are operationalized.

In future population studies the statistical method used here would offer an appropriate tool for the description and analysis of group changes, in addition to defining individual changes.The rank-transformable pattern of change describes the joint distribution of changes in categories over time for a group. In reality, there are always individual deviations from a common group change. This additional individual dispersion is measured by RV. In this study, the individual changes apart from the group changes between 70 and 73 years of age are negligible. Between 73 and 76 years of age the measures of RV indicate an increase in individual deviations from the group change, but the majority of individuals nevertheless follow the pattern of group changes in ADL.

As this statistical method identifies the pattern of true changes in a group, it is possible to make general conclusions and predictions at the group level, thereby facilitating the planning of interventions at the societal as well as the clinical level.

In this report, only some of the possible applications of the method for paired ordered categorical data are used. However, as the method has been developed for paired ordered categorical data irrespective of design, it is suitable not only for change but also for agreement assessments, for example, inter- and intra-rater reliability and inter-scale comparisons.

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