The Utility of Total Evaluation of Physical Fitness based on Fuzzy Principal Component Analysis for Individuals with Mental Retardation

ファジィ主成分分析を用いた知的障害者の体力の総合評価の有効性 (和文要旨)

知的障害者にとって，体力は社会に生活を営む上で重要である．体力は筋力や持久力等様々な要素で構成されている．そしてこれらの要素は，それぞれ別々の方法で独立に測定されている．社会生活を営む上で総合的な体力の評価は非常に重要であるが，人間の曖昧さを考慮した総合評価の方法は確立されていない．

そこで，知的障害者の体力の評価のためにファジィ主成分分析を提案し，その有効性を確かめた．被験者は20名の22歳から42歳の知的障害者(男性10名．女性10名)であった．6個の変数(閉眼片足立ち，タッピング，5分間のペダリング，握力(左右)，背筋力，立ち幅跳び)がテスト項目として採用された．

結果は以下のようであった．

1. 被験者の曖昧性を考慮した，ファジィ総合評価を行うことができた．
2. ファジィ総合評価の曖昧性は，被験者の可能性を示しているといえる．
3. 曖昧性を持ったデータに関してファジィ主成分分析が有効であることが示された．

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Abstract

The importance of physical fitness has been indicated in the institution for individuals with mental retardation. The improving of the physical fitness is needed for coming back to work and social life. The physical fitness consist of many factors. And these factors are measured by using independent method respectively. Although the total evaluation of physical fitness is very important to estimate the possibility of the working and sociallife, the method of total evaluation which can include the fuzziness of human beings has not been established. We propose the method of Fuzzy Principal Component Analysis for individuals with mental retardation, and confirm the effectiveness. The subjects were 20 individuals with mental retardation aged 22 to 45 years (10 Males with a mean of 31.0 ± 5.59 years, 10 Females with a mean of 34.2 ± 7.14 years). Six physical fitness measurements(Closed-eyes Foot Balance, Tapping(1 minutes), 5 minutes pedalling on the bicycle ergo meter, Grip strength (right and left), Back strength, Standing Long Jump) were used as the test items in this study. The following results were obtained:

1. We can obtain the total fuzzy score depend on the characteristics of subjects' fuzziness.
2. The total fuzzy score have explain the ability of subjects.
3. The fuzzy principal component analysis are useful for subjects whose data have fuzziness.

1. Introduction

The importance of physical fitness has been indicated in the institution for individuals with mental retardation[4)]. The improving of the physical fitness is needed for coming back to work and social life. The physical fitness consist of many factors[1)]. And these factors are measured by using independent method respectively[2)]. Although the total evaluation of physical fitness is very important to estimate the possibility of the working and social life, the method of total evaluation which can include the fuzziness of human beings has not been established. The method which treat the fuzziness were proposed L.A.Zadeh in 1996[9)]. The Fuzzy Principal Component Analysis is the extension of Principal Component Analysis for the

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data which include fuzziness[7]. The characteristics of subjects have fuzziness more than normal individuals[3]. So we propose the method of Fuzzy Principal Component Analysis for individuals with mental retardation, and confirm the effectiveness. And We make total score which can represent the ability of the subjects.

2. Method

2.1 Subjects

The subjects were 20 individuals with mental retardation aged 22 to 45 years(10 Males with a mean of 31.0 ± 5.59 years, 10 Females with a mean of 34.2 ± 7.14 years). The characteristics of subjects are shown in Table 1.

Table 1 The characteristics of subjects

	Male(average ± SD)	Female(average ± SD)
age	31.0 ± 5.59	34.9 ± 7.33
height(cm)	162.0 ± 6.88	150.4 ± 5.77
weight(kg)	55.7 ± 7.65	56.7 ± 5.39
I Q	30.1 ± 19.71	34.2 ± 14.53

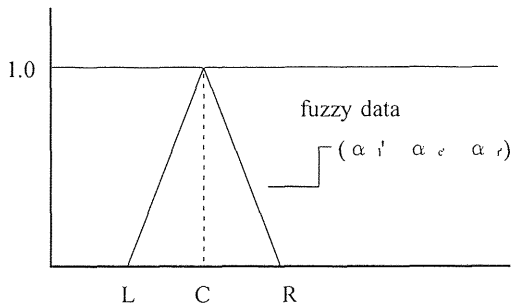

Figure 1 The Fuzzy data

2.2 Measure items

Six physical fitness measurements were used as the test items in this study. Physical fitness items are as follows:

1. Closed-eyes Foot Balance(hereafter cited as *CFB*)
2. Tapping (1 minutes)
3. 5 minutes pedalling on the bicycle ergo meter (hereafter cited as *Pedalling*)
4. Grip strength (right and left)
5. Back strength
6. Standing Long Jump (hereafter cited as *SLJ*)

These item were measured two times.

2.3 Analysis method

We employed Fuzzy Principal Component Analysis (hereafter cited as *FPCA*) instead of normal Principal Component Analysis (hereafter cited as *PCA*) because of the characteristic of subjects who were individuals with mental retardation. *FPCA* was used when the data was fuzzy one[7]. We made triangular fuzzy data from the two measurement of each items, and set the upper limit and the lower limit from the range of two measurement and made the center value of triangular fuzzy data from the average of two measurement (Figure 1). We process fuzzy principal component from these fuzzy data.

2.4 The Solution from *FPCA*

Here, we explain the concept of *FPCA* and the method of solution from FPCA. The data which we used have upper limit (x_r), center value (x_c), lower limit (x_l). The sample $\underset{\sim}{X}$ were n data characterized from p variables. These samples are shown:

$$\underset{\sim}{X} = \begin{bmatrix} \underset{\sim}{X}_{11} & \underset{\sim}{X}_{12} & \cdots & \underset{\sim}{X}_{1p} \\ \underset{\sim}{X}_{21} & \underset{\sim}{X}_{22} & \cdots & \underset{\sim}{X}_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ \underset{\sim}{X}_{n1} & \underset{\sim}{X}_{n2} & \cdots & \underset{\sim}{X}_{np} \end{bmatrix}$$

The average of date $\overline{\underset{\sim}{X}}$ are

$$\overline{\underset{\sim}{X}} = \frac{1}{n}\sum_{j=1}^{n} \underset{\sim}{X}_{ij}$$

And the fuzzy variance-covariance matrix are

$$\underset{\sim}{V}_{ij} = \frac{1}{n}\sum_{k}^{n}\sum_{l}^{n}(\underset{\sim}{X}_{ki} - \overline{\underset{\sim}{X}}_{i})(\underset{\sim}{X}_{lj} - \overline{\underset{\sim}{X}}_{j})$$

$$(i, j = 1, 2, \cdots, p)$$

We can solve these eigenvalue problem as a liner programming problem(LP problem)[7] :

$$max\, f_1 = \lambda$$
$$min\, f_2 = \overline{\lambda} - \underline{\lambda}$$

subject to

$$\underset{\sim}{V}\, l_i \subseteq \overline{\lambda} l_i$$
$$\underset{\sim}{V}\, l_i \supseteq \underline{\lambda} l_i$$
$$\underline{\lambda} \le \lambda \le \overline{\lambda}$$
$$(l_i, l_j) = \begin{cases} 1: & i = j \\ 0: & i \neq j \end{cases} \quad (i, j = 1, \cdots, p)$$

Here, λ are the center value of eigenvalue, $\overline{\lambda}$, $\underline{\lambda}$ are upper limit and lower limit of eigenvalue and l are eigenvector for λ, f is the subjective function.

3. Result

3.1 Eigenvalues and Total scores

The result (average and standard deviation) of each measurement are shown in Table 2.

The eigenvalues and the eigenvectors of the center value of fuzzy data from *FPCA* are shown in Table 3 and Table 4. The total score from these eigenvalues and eigenvectors are shown in Table 6.

Table 2 Average and Standard deviation

items	Male(average ± SD)	Female(average ± SD)
CBF(sec)	35.7±93.11	5.9±12.01
Tapping(time/min)	216.7±38.16	216.5±28.74
Pedalling(km)	1.65± 0.79	1.20± 0.56
Grip Strength(R)(kg)	19.2± 7.26	16.4± 4.16
Grip Strength(L)(kg)	17.7± 8.05	15.4± 4.92
Back Strength(kg)	39.5±22.45	29.9±18.71
SLJ(cm)	103.6±62.70	60.6±35.00

Table 3 The eigenvalue and eigenvector of center value of fuzzy data (Male)

items	eigenvalue :3.62	eigenvalue.1.27
	eigenvector:1	eigenvector:2
CBF	0.303	-0.533
Tapping	-0.137	-0.786
Pedalling	-0.355	0.198
Grip Strength(R)	-0.466	-0.100
Grip Strength(L)	-0.498	0.005
Back Strength	-0.367	-0.079
SLJ	-0.404	-0.230

Table 4 The eigenvalue and eigenvector of center value of fuzzy data (Female)

items	eigenvalue :3.53	eigenvalue.1.87
	eigenvector:1	eigenvector:2
CBF	-0.279	-0.407
Tapping	-0.105	-0.598
Pedalling	-0.236	0.515
Grip Strength(R)	-0.459	0.274
Grip Strength(L)	-0.476	0.234
Back Strength	-0.448	0.259
SLJ	-0.465	-0.120

Table 5 The unrotated factor matrix of center value of fuzzy data

items	Male		Female	
	FPC[1]	SPC[2]	FPC[1]	SPC[2]
CBF	-0.577	0.600	0.525	0.556
Tapping	0.261	0.885	0.198	0.818
Pedalling	0.675	-0.223	0.443	0.704
Grip Strength(R)	0.887	0.011	0.863	-0.375
Grip Strength(L)	0.948	-0.006	0.895	-0.320
Back Strength	0.698	0.089	0.841	-0.355
SLJ	0.768	0.259	0.873	0.167

[1] First Principal Component
[2] Second Principal Component

3.2 The correlation between IQ and the range of total scores

The correlation between IQ and the range of total scores with distinction of sex are shown in Table 7. These ranges are calculated by subtracting the lower limit score from the upper limit score. The correlation coefficient between IQ and the range of total score with male is -0.58 at first principal component, 0.11 at second principal component, and the correlation coefficient with female is 0.03 at first principal component, -0.34 at second principal component.

4. Discussion

The unrotated factor score of the first principal component indicated large number for all items except for Closed-eye foot balance with male and indicated large positive number for all items with female. Thus the first principal component represented "Basic physical fitness" common to all valuables. And the sum of square of the first principal component was 3.62 with male, 3.53 with female, these proportion to desirable criteria were 51.7%, 50.4% respectively.

The unrotated factor score of the second principal component indicated positive number for tapping and closed-eyes foot balance, indicated negative number for grip strength and back strength. Thus the second principal component represented the factor which divide muscle strength and nervous system. And the sum of square of the second principal component was 1.27 with male,1.87 with female, these proportion to desirable criteria were 18.1%, 26.7% respectively. As the total proportion added the first principal component and the second principal component were 69.8% with male, 77.1% with female, then these percentage suggested that the two pdncipal component described 69.8% and 77.1% changes of seven items respectively. As we employed *FPCA*, the result included "range", then we got the result which was considered the fuzziness of original data. The relation between IQ and the range of total score have highly negative correlation coefficient with male at first principal component, but not significant.

Table 6 The total score

		FCP[1]			SCP[2]		
	ID	L	C	R	L	C	R
Male	1	-1.43	-1.47	-1.49	-0.50	0.20	0.60
	2	-0.22	-0.27	-0.32	0.95	0.38	-0.14
	3	-0.65	-0.68	-0.69	-1.58	-1.54	-1.35
	4	0.37	0.39	0.40	-0.18	-0.32	-0.60
	5	1.91	1.71	1.51	-1.60	-1.54	-1.33
	6	-0.82	-0.89	-0.93	0.36	0.53	0.71
	7	0.65	0.79	0.91	1.07	1.66	1.79
	8	0.95	1.08	1.20	0.99	0.92	0.89
	9	0.08	0.14	0.19	0.70	0.04	-0.31
	10	-0.84	-0.81	-0.78	-0.21	-0.34	-0.26
	ID	L	C	R	L	C	R
Female	1	0.72	0.91	1.11	-0.52	-0.63	-0.75
	2	-0.83	-1.07	-1.25	-0.22	-0.38	-0.55
	3	1.06	1.16	1.23	-0.48	-0.38	-0.23
	4	0.87	0.80	0.73	0.17	0.19	0.12
	5	-0.06	-0.21	-0.29	0.61	0.22	-0.50
	6	0.59	0.51	0.35	-1.13	-0.86	-0.54
	7	-0.85	-0.81	-0.75	0.88	0.77	0.79
	8	-1.15	-1.08	-1.06	1.45	1.69	1.80
	9	-1.49	-1.30	-1.10	-1.73	-1.70	-1.42
	10	1.14	1.11	1.04	0.96	1.08	1.28

Table 7 The correlation between IQ and the range of Total score

Correlation coefficient	Male IQ	Female IQ
FPC[1]	-0.58	0.34
SPC[2]	0.11	-0.34

5. Summary

The importance of physical fitness has been indicated in the institution for individuals with mental retardation. The improving of the physical fitness in needed for coming back to work and social life. The physical fitness consist of many factors. And these factors are measured by using independent method respectively. Although the total evaluation of physical fitness is very important to estimate the possibility

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