# Factorial Analysis of Body Elements in Rhythmic Gymnastics

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Abstract: The main goal of this research was to analyze body movements of rhythmic gymnastics techniques, groups A and B, to classify them into homogeneous groups, to determine similarities between the obtained groups. The sample of entities was comprised of 108 body movements (elements), pertaining to the difficulty groups A and B, that were described by 33 variables. Reliability of the measuring instrument was determined on the basis of obtained opinions, collected from eight experts in rhythmic gymnastics. Ten significant latent dimensions were obtained by factor analysis under the component model with the Guttman-Kaiser criterion. The latent dimensions were interpreted as: one-leg jumps, spine mobility, frontal flexibility, free leg movements, the help of the arm-work, body rotation, two-leg jumps, forward bend, other jumps and specific elements. It is feasible to state that the application of the sophisticated measuring instruments for the different anthropological factors and biomechanical parameters determination could have provided more information on the characteristics of and differences between the rhythmic gymnastics elements.

## 1 INTRODUCTION

As in every sport, sport employees in rhythmic gymnastics have attempted to determine and classify movement structures into logically encompassed units. Sokal and Sneath (1963, prema Ferligoj, 1989.) have tried to merge different viewpoints of grouping (sorting), and that attempt evolved into an independent discipline within multivariate analysis. A. Spiessa (1810.-1858.) is considered as a first systematizer of exercises on apparatus, with the system described in the book "Lehre der Turnkunst" (1840/41.), and exercising material divided into:1) freehand exercises: stances, walking, running, hops, jumps, rotations and exercises during rotations; 2) hanging exercises: by hands, by trunk, by legs, swinging, climbing and crawling; 3) exercises while holding position: while standing (balance), while kneeling, in sitting position, balances on the foot, holding position on hands, on head and combined exercises, 4) group exercises: freehand group exercises, group exercises in holding position, group exercises while hanging, group exercising in lying position.

With the development of specific types of dancing techniques, their classifications and instructions for proper execution have been implemented (credited dancers or coreographers that have developed their own techniques of modern dancing that are recognisable even today: F. del Sarte, E. J. Dalcroze, R. Laban, L. Fuller, R. Saint-Denis, M. Graham, J. Limon, M. Cuningham et al.) One of the most advanced and transparent classifications in development of rhythmic gymnastics was given by a great pedagogue in that area J. Kramaršek (1952, 1959, 1961, 1964), as well as Jastrjembskaia, N., Y. Titov (1998).

Elements without props, that is, elements performed exclusively with the body are an essential foundation for individual and group routines in rhythmic gymnastics except in youngest competitive categories, movements have to be executed in harmony with how one of the following props is handled: jump rope, hoop, ball, cones and ribbon. Elements from different groups of elements need to be represented equally when assembling individual and group. Elements performed with the body need to be chosen in regard to logical and specifical techniques, which are unique for every apparatus. In rhythmic gymnastics routines, elements performed with the body need to be executed together with handling of the apparatus, and their execution is one of the criteria when judging: a) degree of difficulty of the routine (selection of elements of A, B, C and D scores) total number of elements in a routine and their



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combinations), and b) degree of quality of a routine (manner of execution of elements in a routine, synchronicity with music, total number of performed errors…).

Determinants of competitive performance in rhythmic gymnastics were analyzed by Bobo-Arce, M., Méndez-Rial, B. (2013), groups routines of elite rhythmic gymnastics Ávila-Carvalho L, Palomero M, Da L, Lebre E. (2009), about the importance of the "technical evolution" aspect Buarque Maag. (2003), then feedback in rhythmic gymnastics as a process of correcting technical mistakes Cristina-Elena M. Sport & Society (2012) etc.

When executing elements, every gymnast has to abide by the rules of execution, on which the height of the score for technical value is dependant. Common parameters on which the height of the score relies are proper posture, movement amplitude, balance control, controlled execution of footsteps... Besides that, all elements executed with the body must be performed without breaks, with constant exchanges of contraction and relaxation, with a close connection between dynamics, amplitude and speed of execution, in harmony with the rhythm and tempo of music. At the same time, they need to be executed simultaneously with the whole body, including the head and hands, which means that there should be no isolated muscle groups.

For the purposes of this research, experts analized 108 elements which display a representative sample of entities. Goal of this research was to conduct an kinesiological analysis of elements of rhythmic gymnastics. Because of a quantitative objective analysis of technique elements, a new measuring instrument needs to be assembled, and measuring characteristics determined (reliability analysis and factor validity). Description of analysed entities will be executed with a mathemathical-statistical procedure. For the purpose of differentiating of hypothetical groups, descriptive biomechanical and functional characteristics (criteria on which the groups should significantly differ), have been set in advance.

# 2 METHODS

## 2.1 Sample of Entities

Sample of entities in this research consists of mandatory elements of techniques of body movements without apparatus in rhythmic gymnastics. The research was conducted on a sample that is comprised from 108 elements, from total of 132 elements of A and B score. Elements that form a sample of entities have been chosen from the official Code of Points (Rulebook of rhythmic gymnastics), published by International gymnastics federation (FIG), in the year 1997. Elements for which the experts of rhythmic gymnastics agreed that are the most used when assembling a free composition were chosen. During the evaluation of execution of technique of elements, it is important to be familliar with all existing groups of elements of body movement, which can be executed in different directions, in every axis, interconnected with footsteps or no, with one or both leg support, but, during the whole execution, they need to be connected with movement of arms.

With regard that elements which are sorted in the group of other elements, are those that are used when interconnecting basic elements, and in this research they are not included in the sample of entities. All analysed elements from basic groups are, according to the Rulebook, divided into four groups and contain the following characteristics( characteristics of elements are listed in the Code of Points, 1997): *JUMPS* (high takeoff and good height during flight, defined and fixed form during the flight, large amplitude during the flight phase), *BALANCE* (executed on tip of toes, held for atleast one second, defined and observable shape, satisfying amplitude in forming of balance), *PIROUETTES* (executed on tip of toes, held and defined shape during and when finishing rotations, large amplitude of movement), *FLEXIBILITY / WAVES (MOBILITY)*( executed on one or both feet. or other parts of the body, well defined and held form, large movement amplitude). Rhythmic gymnastics elements are natural forms of movement, as are their variations, and they are formed in a way to meet the term of aesthetically designed movements. Requirements during the execution of elements of rhythmic gymnastics are subordinated to anatomical constitution of the female body, as to incorporate an aesthetic component during their execution.

Every group of elements in rhythmic gymnastics has specific phases. First phase is the so called preparation phase, which can be achieved through a running start, lunge, descending into a squat, or from a static position. As many of the elements in a routine are executed after a formerly executed element, which can be different, way of preparation varies. Because of that, elements executed with the body are descriped without a preparation phase. That way, every element, regardless of which group it belongs and the most characteristic preparation phase, is described starting from the standing position and not from movement. In that way, the experts can more

easily determine the possibility of interconnection of elements in a routine. The goal of analysis was to describe specific movements of every element in isolation.

## 2.2 Sample of Variables

Sample of selected elements in this research is described with a set of characteristics, which are divided into following subgroups: 1) descriptive biomechanical characteristics: a) movement of center of gravity in space; b) movement characteristics (movement of individual segments of the body - topological characteristics), c) support surface during element execution, and 2) functional characteristics: valence of binding the elements together. Characteristics, evaluated with the stated description, were treated ad binary variables.

## 2.3 Experimental Procedure

Quantification of characteristics on the sample of entities was conducted by eight (8) experts in rhythmic gymnastics, with a passed judge exam and with an experience of atleast three competitions of federal importance as a judge. All judges that have evaluated characteristics of elements of rhythmic gymnastics, have graduated on Faculty of Kinesiology, or have passed the courses Rhythmic gymnastics and Biomechanics. Collection of data was done through a structured interview, in the presence of the supervisor of experimental procedure. Surveys have been handed to all the experts at once, with guidelines and clarifications on how to fill out the surveys. The experts had a task where they had to evaluate if they agree or not with every of 59 statements that describe an element. The investigators assessed the characteristics of the technical elements by looking at the drawings of the elements from Code of Points. The answers were transcribed into binary values, where 1 is agreeing with the statement, and 0 is disagreeing with the statement.

## 2.4 Data Analysis Methods

For the purpose of verification of the measuring instrument, the data were processed by the SPSS program package for Windows.

Data analysis was conducted in several phases, and the following statistical analysis have been performed:

1. Correspondence of agreement of judges-experts on the unique subject of measuring of every element was determined through the calculation of:
   - number of significant main components of correlation matrix of judges for all required specifics of analysed movement structures
   - Variance size of first main components of judge scores for all analysed elements
   - Ortogonal projection of judges on the first main subject of measurement for every observed characteristic of every individual element
   - Reliability of measurement (Cronbach's alpha) for all applied variables
2. Condensation of results from all eight experts was conducted, and further procuders were executed on the basis of variables formed in that way.
3. Following descriptive parameters were calculated for all variables: *MEAN* – average value of scores given by the experts, *SKEWNESS* – asymmetry of score distribution, *KURTOSIS* – sharpness of peak, *ST.DEV.* – standard deviation Factor analysis was conducted to analyse latent contents in the space of original variables. Number of significant factors was determined by the Guttman-Kaiser criteria. Final exploratory factor structure was achieved by a skewed oblimin rotation, and is displayed through matrixes of ortogonal and parallel projections (structure and assembly), as is displayed with a matrix of correlations between factors

# 3 RESULTS & DISCUSSION

## 3.1 Metrical Characteristics of Variables

Reliabilities of variables, an assumption for further analysis, were evaluated on the basis of Cronbach α coefficient (table 1.). Not all variables have achieved satisfying reliability coefficients (alpha values ranged from 0,37 as the lowest and 1,00 as the highest value), primarily because of an unsatisfying degree of agreement of experts about the real subject of measurement. Only variables with a satisfying reliability and where all experts participated in formation of the result have been taken into account for further analysis. From the total of 59 variables, 33 were selected for further analysis and are displayed in table 1.

Reliability coefficients in mentioned variables range from 0,73 as the lowest, to 0, 99 as the highest. Variables 5, 12, 13 and 14 (table 1.) have alpha values in the range of 0, 70 to 0,80. Although the coefficient

Table 1: Descriptive statistics; cronbach α; values of main components and factors after oblimin rotation.

| code | VARIABLE | description | AS | SD | $a^4$ | $a^3$ | Cron-bach α | λ* | PCT | Factor | λ | % of Var | Cum % | Commu-nality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **V4** | **ACTKRBOC** | center of gravity is moving non-lineary in lateral plane | 2.35 | 2.70 | -.26 | 1.04 | 0,9157 | 5,24 | 65,4 | 1 | 6.40 | 19.4 | 19.4 | 0.93 |
| **V5** | **ACTKRCEO** | center of gravity is moving non-lineary in frontal plane | .94 | 1.59 | 2.02 | 1.67 | 0,7928 | 3,31 | 41,4 | 2 | 4.47 | 13.5 | 32.9 | 0.74 |
| **V8** | **ACTVISE** | center of gravity is moving in two or more planes | .87 | 1.61 | 2.77 | 1.93 | 0,8169 | 3,74 | 46,7 | 3 | 3.46 | 10.5 | 43.4 | 0.86 |
| **V9** | **BTPRET** | trunk bends forward | .92 | 2.14 | 4.73 | 2.44 | 0,9405 | 5,75 | 71,9 | 4 | 2.66 | 8.0 | 51.5 | 0.93 |
| **V10** | **BTOTKL** | Trunk bends sideways | .53 | 1.78 | 11.55 | 3.53 | 0,9638 | 6,42 | 80.3 | 5 | 2.27 | 6.9 | 58.3 | 0.92 |
| **V11** | **BTZAKL** | Trunk bends backwards | 1.61 | 2.87 | .38 | 1.45 | 0,9628 | 6,36 | 79,4 | 6 | 2.19 | 6.6 | 65.0 | 0.94 |
| **V12** | **BTZASU** | Trunk rotation | 1.41 | 1.88 | 1.20 | 1.41 | 0,7885 | 3,94 | 49,2 | 7 | 1.84 | 5.6 | 70.5 | 0.87 |
| **V13** | **BTZSPR** | Trunk rotation while bending forward | .31 | .96 | 12.44 | 3.53 | 0,7807 | 3,67 | 45,9 | 8 | 1.79 | 5.4 | 75.9 | 0.71 |
| **V14** | **BTZSZK** | Trunk rotation while bending backwards | .31 | .91 | 11.32 | 3.35 | 0,7398 | 3,12 | 39,1 | 9 | 1.10 | 3.3 | 79.3 | 0.59 |
| **V15** | **BTNEKR** | Trunk remains in starting position | 3.95 | 3.35 | -1.79 | -.07 | 0,9447 | 5,81 | 72,6 | 10 | 1.05 | 3.2 | 82.5 | 0.91 |
| **V16** | **BSLNZAPR** | Movement of free leg: extended leg swing | 4.66 | 2.78 | -.97 | -.73 | 0,8908 | 4,68 | 58,5 | 11 | .96 | 2.9 | 85.4 | 0.83 |
| **V17** | **BSTNZAPR** | kretanje stojne (odrazne) noge: extended leg swing | 1.50 | 2.68 | 1.41 | 1.74 | 0,9525 | 6,32 | 79,0 | 12 | .79 | 2.4 | 87.8 | 0.80 |
| **V18** | **BSLNKRPR** | Movement of free leg: extended leg circling | 1.78 | 2.35 | -1.24 | .76 | 0,8831 | 4,44 | 55,5 | 13 | .73 | 2.2 | 90.0 | 0.79 |
| **V20** | **BSLNZAGR** | Movement of free leg: flexed leg swing | .94 | 1.91 | 2.20 | 1.88 | 0,8885 | 4,52 | 56,5 | 14 | .67 | 2.0 | 92.0 | 0.83 |
| **V21** | **BSTNZAGR** | kretanje stojne (odrazne) noge: flexed leg swing | .46 | 1.43 | 12.96 | 3.55 | 0,8698 | 4,05 | 57,9 | 15 | .55 | 1.7 | 93.7 | 0.65 |
| **V22** | **BSLNIGR** | Movement of free leg: flexed leg elevation | .75 | 1.82 | 5.04 | 2.48 | 0,9099 | 4,97 | 62,1 | 16 | .41 | 1.2 | 94.9 | 0.80 |
| **V30** | **B2RUSLN** | One hand supports free leg | .94 | 2.43 | 3.84 | 2.35 | 0,9810 | 7,09 | 88,6 | 17 | .36 | 1.1 | 96.0 | 0.80 |
| **V31** | **BRUNESLN** | Both hands support free leg | 6.30 | 2.59 | 1.44 | -1.72 | 0,9403 | 6,17 | 77,2 | 18 | .27 | .8 | 96.8 | 0.83 |
| **V32** | **BGLPRET** | Hands do not support free leg | .66 | 1.67 | 6.65 | 2.72 | 0,8957 | 4,67 | 58,4 | 19 | .22 | .7 | 97.5 | 0.97 |
| **V33** | **BGLZAKL** | Head bends forward | 1.65 | 2.79 | .05 | 1.34 | 0,9494 | 5,92 | 74,0 | 20 | .20 | .6 | 98.1 | 0.93 |
| **V34** | **BGLOTKL** | Head bends backwards | .41 | 1.48 | 14.97 | 3.95 | 0,9322 | 5,56 | 69,5 | 21 | .12 | .4 | 98.4 | 0.96 |
| **V35** | **BGLROTS** | Head bends sideways | 2.18 | 2.40 | -1.39 | .50 | 0,8583 | 4,21 | 52,6 | 22 | .10 | .3 | 98.8 | 0.91 |
| **V36** | **BGLMJES** | Head rotates sideways | 3.72 | 2.71 | -1.14 | .36 | 0,8553 | 4,06 | 50,8 | 23 | .09 | .3 | 99.0 | 0.86 |
| **V38** | **CPOCSTO2** | Head stays in starting position | 1.91 | 1.64 | .21 | .67 | 0,6165 | 6,16 | 77,0 | 24 | .08 | .2 | 99.3 | 0.84 |
| **V39** | **CPOCSTO1** | Element is performed on both feet fully and on both legs | .13 | .87 | 68.42 | 8.02 | 0,9470 | 6,67 | 83,4 | 25 | .06 | .2 | 99.4 | 0.59 |
| **V47** | **COP1KLEK** | Element is performed on the foot of one leg | .66 | 2.00 | 7.75 | 3.03 | 0,9698 | 6.96 | 87,0 | 26 | .05 | .1 | 99.6 | 0.43 |
| **V49** | **COPSUODR** | Element is performed in a one-leg kneeling position | .47 | 1.74 | 13.29 | 3.83 | 0,9731 | 7,46 | 93,2 | 27 | .03 | .1 | 99.7 | 0.65 |
| **V50** | **COP1ODR** | Element is performed with takeoff from both feet | .57 | 1.99 | 10.32 | 3.45 | 0,9881 | 7,86 | 98,2 | 28 | .03 | .1 | 99.8 | 0.97 |
| **V51** | **COPIZMOD** | Element is performed with a one-legged takeoff | 1.47 | 3.09 | .77 | 1.65 | 0,9974 | 7,36 | 92,0 | 29 | .03 | .1 | 99.8 | 0.97 |
| **V52** | **CSUNDOS** | Element is performed with multiple alternating takeoffs from foot to foot | .09 | .78 | 101.44 | 9.95 | 0,9698 | 7,49 | 93,6 | 30 | .02 | .1 | 99.9 | 0.57 |
| **V53** | **CJEDDOS** | Landing is on both feet | .50 | 1.88 | 12.16 | 3.69 | 0,9895 | 7,60 | 95,0 | 31 | .01 | .0 | 100 | 0.97 |
| **V55** | **CDOSZAM** | Landing is on one foot | 1.46 | 3.03 | .77 | 1.64 | 0,9925 | 6,31 | 78,9 | 32 | .01 | .0 | 100 | 0.98 |

*Number of significant main components (K=1), specific values of first main components (EIGENVALUE) and percentage of clarified common variance of (PCT) of every variable for eight judges; Eigenvalue - specific values and Pct of Var - percentage of explained variance; Communality - communality values of variables

is low, these variables were included as to have better coverage in the group of descriptive variables. Eight variables had satisfying reliability coefficients (alpha 0,80-0,90), and most of the variables were over the range of alpha of 0,90, and it can be concluded that the agreement of the experts around the real subject of measuring is satisfying and high, having in mind that rhythmic gymnastics is one of the sports with the most developed Rulebook and judging criteria because of the sensitivity of determining the score on competitions.

Selected variables are supoorted by size of acquired specific values of the first main components of matrix correlation of experts in all criteria variables (table 1.). Through the factorisation process, it was determined that every variable of 33 selected has a unique subject of measurement, which is also proven by the size of variance of first main components (K) for every expert in particular. Component values of every expert in forming of the first main component are located in the annex.

Specifical values of the first main components (EIGENVALUE) and percentages of common variance of measurement range from the lowest (40 - 60%), to highest (over 90%). With regard to current research (Zagorc, 1993., Trninić, 1995.), it can be concluded that there is similarity between results, and therefore, further statistical analysis have been conducted.

## 3.2 Factorial Analysis of Variables

Regardless of various procedures of factor analysis, every technique extracts a specific group of important,

Table 2: Matrix of model.

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 | Factor 8 | Factor 9 | Factor10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **V4** | .92818 | .11697 | -.02792 | -.03244 | -.04342 | .15139 | .09450 | .02504 | .03598 | -.04062 |
| **V5** | .44590 | .04817 | .40852 | -.14928 | -.02116 | -.28342 | .16226 | .23810 | -.03464 | .14002 |
| **V8** | .62143 | .03341 | .17243 | -.03651 | .00003 | -.42421 | .11827 | .17706 | .03007 | .17721 |
| **V9** | -.06026 | -.09567 | -.15287 | -.05305 | -.03606 | .14345 | .02256 | .99725 | -.06612 | -.08572 |
| **V10** | -.06998 | -.02709 | .97312 | .02560 | -.04861 | .07055 | -.05474 | -.05588 | .04281 | -.00118 |
| **V11** | -.00307 | .91905 | -.15387 | -.01664 | -.04244 | .19796 | .05180 | -.11767 | -.05831 | .10261 |
| **V12** | .30484 | -.04854 | .07528 | .12063 | .06775 | -.77662 | .09487 | .01351 | -.01885 | .16109 |
| **V13** | -.01035 | .16312 | .14647 | .17659 | .02762 | -.16004 | -.10543 | .63114 | .21641 | .11926 |
| **V14** | .12590 | .31535 | .11858 | .20700 | .06747 | -.34661 | .10379 | .06003 | .12650 | .38963 |
| **V15** | -.11816 | -.67369 | -.26344 | .03631 | .04546 | -.04693 | -.10590 | -.38556 | .15807 | -.00910 |
| **V16** | .23777 | -.09992 | -.10773 | -.82690 | -.01615 | .06282 | -.13255 | .02070 | .01631 | .16466 |
| **V17** | .80001 | -.05959 | -.07045 | -.13101 | -.04002 | .03794 | .12302 | -.01919 | .27313 | -.00182 |
| **V18** | -.09734 | -.03472 | -.23274 | -.37132 | .05634 | -.75440 | -.13282 | .00683 | -.11198 | -.15117 |
| **V20** | .12703 | -.05776 | -.07104 | .90062 | .00907 | .03393 | -.04629 | -.01467 | -.12223 | -.03374 |
| **V21** | .53936 | .07663 | -.09422 | .21417 | -.06461 | .06704 | .08127 | -.15489 | -.49129 | -.14833 |
| **V22** | -.08274 | -.07517 | -.03691 | .84618 | -.04515 | .09077 | -.09506 | .18094 | .04236 | .07451 |
| **V29** | -.06808 | -.02353 | .01414 | -.03387 | .86129 | -.00219 | -.04124 | -.08024 | .00063 | .02069 |
| **V30** | -.04836 | -.00693 | -.13312 | .06540 | .89663 | .01049 | -.02676 | .02097 | .01812 | .01544 |
| **V31** | -.04075 | -.04550 | -.00742 | .01571 | -.99410 | -.03096 | -.01469 | .01897 | -.00125 | .03647 |
| **V32** | -.08226 | -.02563 | -.06734 | .10537 | -.06151 | .09001 | -.06619 | .95916 | -.01438 | -.02745 |
| **V33** | .02202 | .93927 | -.13017 | .02233 | -.02300 | .15773 | .05976 | -.12390 | -.02802 | .07611 |
| **V34** | -.08760 | -.05668 | .97228 | .00788 | -.06680 | .07343 | -.04556 | -.11260 | -.00751 | -.03303 |
| **V35** | -.16834 | -.15900 | -.06212 | .05432 | -.10253 | -.91723 | -.07998 | -.14622 | -.02543 | -.10838 |
| **V36** | .02755 | -.70266 | -.17813 | .05933 | .13562 | .32288 | .00794 | -.23575 | .13160 | .14014 |
| **V38** | -.07351 | .47964 | .04276 | .02845 | -.02749 | .00872 | -.11204 | -.08673 | .30139 | -.51789 |
| **V39** | -.05583 | -.05433 | .34097 | -.21983 | .18668 | .21557 | -.06608 | .03934 | -.29268 | -.18000 |
| **V47** | -.20064 | .14601 | -.08841 | -.15122 | -.15964 | .23585 | -.16733 | -.14584 | -.02771 | .65528 |
| **V49** | -.09137 | .01550 | -.06167 | -.02439 | -.03068 | .06444 | .99207 | -.04665 | -.01677 | -.04806 |
| **V50** | .99086 | -.04107 | -.03660 | -.01570 | -.04185 | -.00730 | -.17490 | -.05411 | .02170 | -.00885 |
| **V51** | .18579 | -.11314 | -.01519 | -.05298 | -.02219 | .14335 | -.00035 | -.02997 | .69219 | -.12695 |
| **V52** | -.10645 | -.00698 | -.04624 | -.03013 | -.03376 | .03562 | .99846 | -.04515 | .01823 | -.02691 |
| **V53** | .99024 | -.03183 | -.04649 | -.00269 | -.04811 | -.00607 | -.15806 | -.07379 | -.04739 | -.01734 |
| **V55** | .94574 | .01800 | -.04043 | .00363 | -.03589 | -.01205 | -.00608 | -.06180 | .01670 | -.01556 |

factors. Because the procedure of factor analysis is applied on the matrix of intercorrelations of variables it is necessary that the values are not zero or close to zero. A procedure of factorisation under the component model of Gutman-Kaiser criteria was used in this research, which determines all main components with specific value equal or above 1,00 as significant. ten significant factors have been extracted in this research (table 1.). Without regard for existing and other criteria, the criteria G-K was chosen, because it excretes a larger number of significant factors, which is important in this example, as to get as much information as possible about latent space.

Total size of variance that exhausts ten acquired factors is 82,5%. On the basis of former studies (Zagorc, 1993., Trninić, 1995., Vuleta, 1997.), it can be said that latent space is described with a higher percentage of common vairability and co-variability of kept variables. First factor exhausts 19,4%, second 13,5%, third 10, 5%, fourth 8,0%, fifth 6,9%, sixth 6,6%, seventh 5,6%, eighth 5,4%, ninth 3,3% and tenth 3,2% of total variance (table 1.).

Values of communality of variables are displayed in table 1., which range from low (0,43), middle, and in most cases, largest (0,98) values, which displays that most of the variables carries a significant variance in the space of kept latent dimensions. Lowest communalities have been noticed in four variables, which descripe execution on elements on full feet V38 and V39, execution of movement structures with multiple alternatig takeoffs V51, or execution of backward bend with simultaneous trunk rotations. Movement structures that incorporate those

Table 3: Matrix of structure.

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 | Factor 8 | Factor 9 | Factor10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **V4** | .93320 | .18659 | -.00882 | -.00319 | -.20906 | .02220 | .26051 | .00050 | .06552 | .03621 |
| **V5** | .52923 | .16264 | .49828 | -.09098 | -.10352 | -.41701 | .26133 | .37186 | -.02988 | .20393 |
| **V8** | .71723 | .12063 | .25286 | .01610 | -.11940 | -.56146 | .25046 | .28914 | .05257 | .26142 |
| **V9** | -.09173 | -.02823 | .05961 | .06190 | -.03753 | .02600 | .01526 | .92188 | -.05496 | -.02718 |
| **V10** | -.07348 | .09803 | .94676 | -.00264 | -.01193 | .01605 | -.04905 | .16202 | .01321 | -.03475 |
| **V11** | .03871 | .91133 | -.07469 | .06717 | -.23186 | .24006 | .18715 | -.09347 | -.05211 | .13980 |
| **V12** | .42998 | -.01517 | .13094 | .14345 | .01512 | -.84246 | .17539 | .16220 | -.00230 | .22392 |
| **V13** | .01471 | .23740 | .31241 | .26413 | -.05467 | -.26889 | -.04520 | .73101 | .22868 | .17496 |
| **V14** | .23412 | .37922 | .18833 | .26932 | -.07969 | -.40709 | .21644 | .21865 | .13339 | .44156 |
| **V15** | -.16797 | -.77047 | -.44616 | -.08504 | .19900 | .02986 | -.24860 | -.49771 | .15722 | -.07780 |
| **V16** | .21066 | -.18627 | -.11300 | -.83980 | .02434 | .04409 | -.18690 | -.11683 | .02590 | .14745 |
| **V17** | .82614 | -.01146 | -.08382 | -.11524 | -.16437 | -.07208 | .22273 | -.05830 | .29795 | .06198 |
| **V18** | -.04227 | -.15978 | -.16870 | -.37876 | .14983 | -.70482 | -.18864 | -.00551 | -.09864 | -.13865 |
| **V20** | .10757 | .01531 | -.09404 | .88631 | -.05822 | .00799 | .06046 | .06405 | -.10486 | -.00718 |
| **V21** | .53028 | .11668 | -.10451 | .20902 | -.13013 | .03333 | .21631 | -.16709 | -.47034 | -.10574 |
| **V22** | -.09876 | .01357 | -.03186 | .85595 | -.10061 | .05792 | -.02385 | .26244 | .05901 | .09785 |
| **V29** | -.19997 | -.20798 | .00972 | -.12096 | .88311 | .00233 | -.12775 | -.11592 | -.06112 | -.08340 |
| **V30** | -.18483 | -.19589 | -.11359 | -.00674 | .89505 | .00597 | -.10147 | -.03825 | -.03916 | -.07630 |
| **V31** | .10646 | .14645 | -.02982 | .09532 | -.98347 | -.01228 | .05418 | .06077 | .06814 | .13653 |
| **V32** | -.10574 | .05780 | .14142 | .21722 | -.08472 | -.02895 | -.04538 | .94028 | .00242 | .03420 |
| **V33** | .06865 | .93471 | -.04694 | .10676 | -.22171 | .19535 | .20324 | -.08400 | -.02249 | .11730 |
| **V34** | -.09282 | .06376 | .93091 | -.02945 | -.01216 | .03215 | -.04889 | .09817 | -.03830 | -.07218 |
| **V35** | -.05439 | -.19952 | -.05140 | .03715 | -.01142 | -.86220 | -.10802 | -.04196 | -.00536 | -.08016 |
| **V36** | -.06005 | -.75071 | -.35496 | -.04628 | .23846 | .33844 | -.11199 | -.37164 | .11880 | .06638 |
| **V38** | -.08945 | .44046 | .08369 | .04181 | -.06669 | .06282 | -.09231 | -.06664 | .29982 | -.50546 |
| **V39** | -.14942 | -.08264 | .34609 | -.26156 | .26931 | .20914 | -.11480 | .03101 | -.32395 | -.23662 |
| **V47** | -.18487 | .13974 | -.14109 | -.14520 | -.19931 | .26917 | -.15553 | -.15816 | -.01263 | .62943 |
| **V49** | .06686 | .14829 | -.05413 | .07474 | -.09038 | .07062 | .97290 | -.04584 | -.06265 | -.00096 |
| **V50** | .96640 | -.01647 | -.05048 | -.03508 | -.16284 | -.13225 | -.01669 | -.07568 | .06735 | .05279 |
| **V51** | .17738 | -.10864 | -.06512 | -.06320 | -.05954 | .11638 | -.03225 | -.07134 | .69512 | -.11983 |
| **V52** | .05900 | .12884 | -.04075 | .06926 | -.09073 | .04037 | .97370 | -.03706 | -.02814 | .02019 |
| **V53** | .96690 | -.00607 | -.06140 | -.02228 | -.16699 | -.12604 | .00509 | -.09609 | -.00191 | .04468 |
| **V55** | .95209 | .06435 | -.04469 | .00578 | -.17518 | -.13195 | .15457 | -.07180 | .05338 | .05504 |

movement structures are obviously rare in rhythmic gymnastics and are not in common with other variables, which is probably the reasom of their low positioning in the space of latent dimensions.

With analysis of matrix of model (table 2.) and matrix of structure (table 3.), it can be concluded that both matrixes carry almost identical informations about isolated latent dimensions, that is, values of parallel and ortogonal projections on oblimin factors are of equable values. The reason for that is most probably in the relatively high independence of isolated factors.

Generally, first eight factors are formed with a larger number and higher values of projections of variables, while the last two are defined by a smaller number of variables and lower values.

*First latent dimension* was defined by the largest number of variables. For the biggest part, it consists of variables linked with descriptions of movement structures which are incorporated into most of the jumps:

- *V50* – execution of elements with one-leg takeoff,
- *V53* – one-leg landing,
- *V55* – landing on swing leg,
- *V4* – movement of center of gravity in lateral plane,
- *V17* – movement of standing leg by swing out,

and with following variables:

- *V8* – movement of center of gravity in two or more planes,
- *V21* – takeoff foot moving flexed in a swing,
- *V5* – movement of center of gravity in frontal plane.

By visual analysis of jumps, phases that the trunk and body segments go through are obvious. Most of the jumps consists of preparation, which is performed by swing of the leg, separation of other leg, with which the center of gravity starts moving in one of the planes (usually lateral), the flight phase itself, which takes place in a parabolic manner, and one-legged or two-legged landings. During the flight phase, exercisers can add another movement structures which define the type and difficulty of the jump. The first latent dimension encompasses most of movement structures specific for jumps, and it can be named *ONE-LEG JUMPS*.

*Second latent dimension* was defined by two positive and two negative projections. All four variables describe the position of trunk and head during the execution of element. Positively projected variables:

- *V33* – head bends backwards:
- *V11* – trunk bends backwards;

negatively projected variables:

- *V36* – head stays in place,
- *V15* – trunk remains in starting position.

Mentioned positions of trunk and head are present in a large number of elements of rhythmic gymnastics and can be found in all groups. It can be said that these variables divide elements into those that do not require mobility of the spine, and those that do. Flexibility is a motor ability which is positioned at the very top of specification equation of thythmic gymnastics. Although the elements for which flexibility is a primary requierment for their execution, are sorted in a group called *MOBILITY*, flexibility is present and necessary for execution of elements from the remaining three groups. However, when holding trunk and head in the starting position, as when performing bends, spine stabilisator muscles are activated, and in that way, it can be concluded that this latend dimension is of topological character and divides elements according to demands in mobility of the spine (trunk), and therefore can be named *SPINE MOBILITY*.

*Third latent dimension* was determined by high projections of two variables:

- *V10* – trunk bends sideways,
- *V34* – head bends sideways.

As in the second latent dimension, for execution of elements in which the trunk bends sideways, high flexibility of spine needs to be present. However, in the example of sideway bends, there is a high demand on flexibility of muscles of lateral sides of the trunk, most of the bends are executed with heads extended above head, where lateroflexors, rotators, retroflexors and adductors are in a stretched position. Usually, those types of movement are present in groups of elements from the group of balance and flexibility. According to the topologically specific factor, this group can be named *FRONTAL FLEXIBILITY*.

*Fourth latent dimension* was determined by one variable which is positively situated:

- *V20* – free leg movement, flexed swing;

and with two negatively situated:

- *V22* – free leg is lifted while flexed,
- *V16* – free leg movement, extended swing.

It can be concluded that the positively situated variable carries information about elements from the group balance and pirouette, where the swing of flexed leg is the first phase in execution of the element. Two negatively situated variables describe the execution of element in a more complex way, from physiological and biomechanical viewpoint. It can be determined without a doubt that the force that muscle generates to overcome the distance that is covered by the longer lever is much larger than the force that needs to be generated to overcome the movement of the shorter lever. The same situation is when determining the force needed to execute a swing with flexed leg. and the same swing with extended leg. Another situation is observed in gradual lifting of flexed leg when compared with swing of flexed leg. When performing a swing with a flexed leg, starting force of inertia enables a large amplitude of movement, while, when gradually lifting a flexed leg, the same work needs to be generated during the whole movement, and executing that kind movement is much harder for the exerciser. It can be said that this latent dimension discriminates some of the balance elements and pirouettes from easier to harder. It can be called *FREE LEG MOVEMENT*

*Fifth latent dimension* was determined by three variables of high parallel and ortogonal projections. Two are with positive projections:

- *V30* – describes execution of elements where both hands support the free leg,
- *V29* – describes execution of elements where one hand supports free;

and one negatively projected variable:

- *V31* – execution of elements without the arm support for the free leg.

Elements described in this way belong to the groups flexibility, balance and pirouettes, where one leg is in a forward, backward or upside position. As described before, in one case the element is executed with the help of one or both hands, while in the other case, there is no support with arms during the execution of these demanding elements. As with the fourth latent dimension, there is a differentiation between less and more demanding elements. This factor could be named with a title that comes out of the very definition of the variable, *HELP OF HANDS.*

*Sixth latent dimension* is formed from negatively positioned variables with same characteristics:

- *V35* – head rotation,
- *V12* – trunk rotation,
- *V18* – circling with extended leg.

Common elements in rhythmic gymnastics are those where the body and segments of the body change their position. When executing such elements (jumps with roration, flexibility and pirouettes) the head leads the movement, and if the focus of the subject are jumps or pirouettes, the leg follows the movement of the body. From the anatomical perspective, elements in this group are executed with the help of rotator muscles of the body. In simple terms, this latent dimension can be named *BODY ROTATIONS.*

*Seventh latent dimension* is clearly defined with two variables which describe starting and final phase of two-legged jumps:

- *V52* – landing is on both feet,
- *V49* – takeoff is from both feet.

Classification of elements from the group of jumps, on jumps that are executed with one-legged takeoff and two-legged takeoff was given by Jastrembskaia and Titov (1998.). Frequently, it can be the same jump during flight phase, however, there are differences in learning methodics. In methodic learning in rhythmic gymnastics, there is no difference when learning jumps based on the type of landing. From this example, it is obvious that jumps can be classified based on this characteristic. Seventh latent dimension can be named *TWO-LEGGED JUMPS.*

*Eighth latent dimension* is characterised with variables that are defined by movement of the body in lateral plane:

- *V9* – forward body bend,
- *V32* – forward head bend,
- *V13* – trunk rotation with forward bend.

First two variables are highly projected in both matrixes, while the third one has somewhat lower parallel and ortogonal. This latent dimension encompasses descriptions of elements of techniques which execution carries a description of trunk and head rotation, primarily while bending forward, and backwards. That type of movement of trunk and head can easily be observed in all four grops of elements of technique. Movements where the trunk bends forward can be a basic position in execution of elements, but can also just be a phase through which the body goes during execution. Regardless of the main phase of elements which encompass this characteristic, this factor clearly "recognizes" and

Table 4: Matrix of correlation of isolated factors.

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 | Factor 8 | Factor 9 | Factor10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **F1** | 1.00000 | | | | | | | | | |
| **F2** | .05461 | 1.00000 | | | | | | | | |
| **F3** | .00841 | .13212 | 1.00000 | | | | | | | |
| **F4** | .00537 | .09675 | -.01602 | 1.00000 | | | | | | |
| **F5** | -.14611 | -.19406 | .02153 | -.08207 | 1.00000 | | | | | |
| **F6** | -.14102 | .01950 | -.07470 | -.02134 | -.01805 | 1.00000 | | | | |
| **F7** | .16782 | .14888 | .02069 | .10419 | -.07811 | -.02245 | 1.00000 | | | |
| **F8** | -.00496 | .08784 | .23233 | .12348 | -.03907 | -.14303 | .02811 | 1.00000 | | |
| **F9** | .03509 | .00507 | -.03205 | .01184 | -.06917 | -.01795 | -.04465 | .01161 | 1.00000 | |
| **F10** | .07267 | .05079 | -.02319 | .02939 | -.10314 | -.05440 | .05647 | .06957 | .01183 | 1.00000 |

isolates from other positions. This segment of movement is a natural motion, and does not require special involvement of flexor and rotator muscles of the body. Eighth latent dimension can be named *FORWARD BODY BEND.*

*Ninth latent dimension* carries information about a small group of elements and it is described with only two variables with medium and low parallel and ortogonal projections. It is positively determined:

- *V51* – execution of elements with multiple alternating takeoffs from foot to foot;
- *V21* – movement of takeoff leg is performed by swing of flexed leg.

It is clear that this dimension describes specific jumps, which are, although low in number, significant for description of the space of movement structures in rhythmic gymnastics in general. Ninth latent dimension can be named *OTHER JUMPS.*

*Tenth latent dimension* is determined by the rest of low value variables. Two are positioned on the positive end of factors:

- *V47* – execution of elements in one-legged kneeling position
- *V14* – Trunk rotation with backward bend;

while the third is positioned on the negative side:

- *V38* - execution of elements on full feet with both legs.

Factor is determined with very rare movement structures which are encompassed in elements balance and flexibility. While observing the function of dominant muscle groups, when executing all three movement structures, trunk, front and back upper-leg muscles are activated. What separates variable 38 is the support surface of the exerciser. Only one element from the flexibility group is executed with both legs on full feet. This latent dimension can be called *SPECIFIC ELEMENTS.*

It can be concluded that all chosen variables have contributed to formation of described latent dimension, with projection of lesser or greater significance, and that they have been chosen well for this purpose.

From the matrix of correlation of isolated factors (table 4.), it can be concluded that excreted factors are in a negative, null, or very weak correlation. However, the largest correlation value was achieved by factor 3, named *FRONTAL FLEXIBILITY*, and factor 8, named *FORWARD BODY BEND* (0,23). According to anatomical and visual inspection, those two factors are the most similar, and also specific enough on their own. It cannot be disputed that every one of this factors carries specific information in regard to describing movement structures in rhythmic gymnastics.

# 4 CONCLUSION

It was concluded that the groups differed according to the movements of the body and extremities through various planes, further, according to the recruitment of muscle groups, to the type of the support surface, and according to the types of take-off from the surface. Ten significant latent dimensions were obtained by factor analysis under the component model with the Guttman-Kaiser criterion. The latent dimensions were interpreted as: one-leg jumps, spine mobility, frontal flexibility, free leg movements, the help of the arm-work, body rotation, two-leg jumps, forward bend, other jumps and specific elements.

The results suggest that the determination of homogeneous groups in rhythmic gymnastics is a very demanding task, which can not be accomplished on the basis of the parameters obtained in the research. Nevertheless, this research revealed that

there were several equally ranking criteria according to which the rhythmic gymnastics technique elements could be grouped. It is feasible to state that the application of the sophisticated measuring instruments for different anthropological factors and biomechanical parameters determination could have provided more information on the characteristics of, and, differences between elements in rhythmic gymnastics. If the former had been conducted, the results could have been quite different and the model would have, probably, been more in accordance. This research is the first attempt on grouping of elements at the initial experimental level, which should facilitate further research on the observed issue.

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