Monten. J. Sports Sci. Med. 2 (2013) 1: 11–16
Original scientific paper
UDC 796.012

Metric Characteristics of One Battery of Motoric Measuring Instruments

Damjan Jakšić, Radenko Matić and Milan Cvetković
University of Novi Sad, Faculty of Sport and Physical Education, Novi Sad, Serbia

A B S T R A C T

The paper at hand presents the results of research, which is carried out on 161 male students of Faculty of Sport and Physical Education, University of Novi Sad, Serbia. System of 11 composite measuring instruments was applied on them and each of tests had three replications. Analysis of metric characteristics was done on two ways: in real and in Guttman's image space. Finally, it could be concluded that battery of motor measure instruments is absolutely appropriate for this sample of participants and also that it will be very useful to check all these outcomes with some of advanced statistical techniques in further investigations.

Key words: *composite measure instruments, metric characteristics, 20-year-old students.*

Introduction

During the motoric skills testing also very complex human characteristics are assessed. The mentioned testing is based on certain manifestations, because the motor skills by definition are of latent character and cannot be directly measured. All tests represent indirect estimates, and it is therefore necessary to check specific motor skill with the help of several motor tests which must meet certain metric properties[1].

Although kinesiometric problems are unjustly neglected recently despite the importance they have in practice, testing of metric characteristics of measuring instruments became very rare. Their testing is very important, if not even necessary prior to entering the high-quality research process. Every sample of respondents bears its own specificities. If we only note that none of motor skills is clearly isolated, and that probably we will never find such measuring instrument which could separate (partialize) "other" characteristics and skills that are not necessary when testing the same, all of that leads us to the conclusion that metric properties of tests are specific, and it is necessary to constantly control them. In this way, the current state is observed during the research process; it is corrected and directs further research[2].

Reliability is commonly cited as one of the two basic measurement properties of the test (the other is validity, of course)[3]. Although, when discussing this issue, it is much more correct to say that primarily it is about the reliability of the test score, and only indirectly about the reliability of the measuring instrument[4,5]. This terminological distinction is important, but meaningfully and practically does not significantly change the basic settings of the research work.

The validity of the measuring instruments by its significance represents more important metric characteristic than reliability. Very often, when observing the structure of motoric space, we can note that although the test hypothetically covers a certain motor skill, after operationalization, it actually better explains some other motor skill. In these cases it is possible that the test is invalid, and it is necessary to replace it with more valid test. However, it is not fair to prejudge the conclusions, because there is no invalidity always. There may be other reasons for it, such as imbalance of the system variables, and often there is a shortcoming of statistical procedure.

With this in mind, the aim of the research is to check the reliability of concrete motor measuring instruments, and to define the structure of the motor space over the applied battery of measuring instruments.

Materials and Methods

Motor tests were performed on male students of the Faculty of Sport and Physical Education (FSPE) from Novi Sad, with total of 161, mean age 20.15 (± 0.83) decimal years, clinically healthy and without apparent psycho-somatic aberrations.

The system of 11 composite measuring instruments was applied on them. Each of the tests contained three particles, or replications.

These were the following motor measuring instruments: (1) Flexibility with the bat, (2) Forward bend on the bench, (3) Rope, (4) Standing broad jump, (5) Agility with the bat, (6) Lying medicine ball throw, (7) Standing high jump (vertical jump), (8) Drumming with hands and feet, (9) Seated medicine ball throw, (10) Non-rhythmic drumming and (11) Standing triple broad jump.

All the methods of measurement and testing were performed according to the recommendations of Metikoš et al.[6].

"There is a well-established view that for the reliability evaluation it is not sufficient to apply only one indicator. There is plenty of reliability coefficients (dozens) and behind each of them there is an elaborated measuring model and elaborated assumptions. The necessity of using several different coefficients is manifested by the fact that all of these coefficients, when calculated, give different estimates of reliability for the same data."[3].

Reliability was tested using three different reliability coefficients as follows:

1. Spearman-Brown-Kuder-Richardson-Guttman-Cronbach's α reliability coefficient (hereinafter referred to as α), which is commonly used to calculate the reliability of measuring instruments,
2. Lord-Kaiser-Caffrey's β coefficient and

Received for publication February 20, 2013

3. Guttman-Nicewander's coefficient ρ.

Cronbach's α coefficient is based on the classical summation measurement model that takes into account all three particles, in quantitative terms. The next coefficient (β) represents the reliability of the first principal component, which means the priority of the calculation is the principal component and the projection of a single particle on it, and the last coefficient ρ is a coefficient that is based on Guttman's measurement model, thus transforming the variables in Guttman's image space, eliminating unique variance and calculation of the reliability of so-called pure variable, or test particle.

For calculation of the reliability of motoric measuring instruments a RTT11G program was used[7], which was written in Matrix pseudo-language so it could be performed in the standard SPSS environment. Definitions and formal mathematical presentation of these coefficients implemented in this program, can be found in Momirović's et al. study[8].

In addition to calculating the reliability, a structure of applied battery of tests was also determined. Thus, the obtained structure has led to information about the factor validity of the applied test battery stemmed from the findings. Structure of applied battery of tests was obtained using factor analysis, where the number of significant principal components is determined based on the Kaiser-Guttman's criteria, then the initial intercorrelation matrix was rotated into more favorable parsimonic promax solution.

It should also be noted how to select the most appropriate replication which is further factorized. At least four ways of taking adequate replication are methodologically different, so they as such, will be presented below by the quality. So, there is a possibility of one of the following four choices:

1. to take the best value out of three replications,
2. to take the arithmetic mean out of three replications,
3. to take a replication which saturates the first principal component the most,
4. to take the factor score obtained from the all three replications.

In this particular case, for further analysis of the data the value obtained by factoring replications and calculating factor scores was taken, and also all other values are mentioned in informative purposes and will be discussed later.

In addition, the factor scores were transformed into Guttman's image metrics[9]. In that way partial images of variables are obtained in order to theoretically eliminate the error variance.

Results and Discussion

In Table 1 we extracted the most important information for each motor test and its single replication.

TABLE 1
BASIC DESCRIPTIVE STATISTICS, CORRELATIONS AND CALCULATION OF THE FIRST PRINCIPAL COMPONENT OF EACH SEPARATE TEST

Variable	Item	Descriptive		Pearson[a(all)]			Hotteling		
		Mean	SD	1	2	3	H1	h^2	%
Flexibility with the bat (cm)	1	78.33	14.94	1.00			.97	.93	
	2	75.13	15.95	.93	1.00		**.99**	.97	95.02
	3	73.24	16.90	.90	.95	1.00	.97	.95	
Forward bend on the bench (cm)	1	48.18	8.55	1.00			.99	.97	
	2	50.40	8.43	.98	1.00		**1.00**	.99	98.18
	3	51.72	8.47	.96	.99	1.00	.99	.98	
Rope (cm)	1	184.74	11.46	1.00			.98	.97	
	2	186.14	11.21	.95	1.00		.99	.97	97.03
	3	186.51	11.30	.95	.96	1.00	**.99**	.97	
Standing broad jump (cm)	1	235.08	19.84	1.00			.94	.88	
	2	239.65	19.21	.85	1.00		**.96**	.93	91.06
	3	242.03	19.28	.84	.91	1.00	.96	.92	
Agility with the bat (0.01 s)	1	617.07	147.84	1.00			**.86**	.74	
	2	589.46	130.09	.58	1.00		.83	.68	70.36
	3	575.37	137.19	.58	.51	1.00	.83	.68	
Lying medicine ball throw (cm)	1	963.14	146.79	1.00			.93	.87	
	2	990.13	159.76	.83	1.00		**.96**	.92	90.23
	3	1001.19	151.88	.83	.90	1.00	.96	.92	
Standing high jump (cm)	1	287.36	11.79	1.00			.99	.97	
	2	288.32	11.73	.99	1.00		**.99**	.98	95.37
	3	288.02	13.62	.90	.90	1.00	.96	.91	
Drumming with hands and feet (freq.)	1	15.66	3.75	1.00			.93	.86	
	2	16.58	3.72	.85	1.00		**.97**	.93	88.66
	3	16.99	3.79	.77	.87	1.00	.94	.87	
Seated medicine ball throw (cm)	1	648.22	83.97	1.00			.95	.90	
	2	661.72	78.96	.91	1.00		**.96**	.92	87.81
	3	667.41	95.23	.76	.79	1.00	.90	.81	
Non-rhythmic drumming (freq.)	1	17.63	4.76	1.00			**.92**	.85	
	2	19.31	4.43	.76	1.00		.91	.83	83.59
	3	20.08	4.61	.77	.73	1.00	.91	.83	
Standing triple broad jump (cm)	1	658.38	59.05	1.00			.95	.91	
	2	669.99	56.60	.89	1.00		**.97**	.95	93.34
	3	675.78	56.31	.88	.93	1.00	.97	.94	

Legend: Mean – arithmetic mean; SD – standard deviation; Pearson – Pearson coefficient of correlation; [a] – statistical significance at the level of p=.00; H1 – the first principal component; h^2 – communalities; % - percentage of common variance.

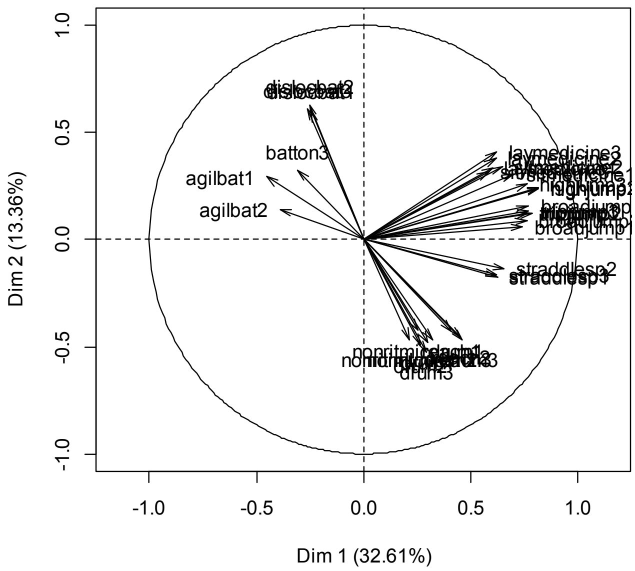

FIGURE 1
VARIABLES FACTOR MAP (PCA)

Table 1 helped to choose which of test replications gave the most information about particular variable which represents "something common". As we can see from above mentioned table, the biggest projections on belongs factor is just as follows: in test Flexibility with the bat – second replication; in test Forward bend on the bench – second replication; in test Rope – third replication; in test Standing broad jump – second replication; in test Agility with the bat – first replication; in test Lying medicine ball throw – second replication; in test Standing high jump – second replication; Drumming with hands and feet – second replication; Seated medicine ball throw – second replication; Non-rhythmic drumming – first replication and test Standing triple broad jump – second replication. All significant replications are bolded in Table 1 and also graphically presented in Figure 1.

Table 2 shows the values of the reliability coefficients of the motor measuring instruments, while Tables 3, 4 and 5 show the results obtained by factor analysis in real and image space. As a criterion for the formation of a matrix which is subsequently factorized, the best particles from each test are taken. In other words, the particle carrying the most information has been selected as the most suitable for further work.

TABLE 2
RELIABILITY OF MOTOR TESTS

Variable	*Measure of reliability under the classical summation model*	*Measure of reliability of the first principal component*	*Measure of reliability under Guttman's measuring model*
	α	***β***	***ρ***
Flexibility with the bat	.973	.973	.997
Forward bend on the bench	.990	.990	.999
Rope	.984	.984	.998
Standing broad jump	.950	.950	.988
Agility with the bat	.789	.789	.832
Lying medicine ball throw	.945	.945	.987
Standing high jump	.975	.975	.999
Drumming with hands and feet	.935	.936	.984
Seated medicine ball throw	.930	.930	.986
Non-rhythmic drumming	.901	.901	.951
Standing triple broad jump	.964	.964	.994

Legend: α – Spearman-Brown-Kuder-Richardson-Guttman-Cronbach's reliability coefficient; β – Lord-Kaiser-Caffrey's reliability coefficient; ρ – Guttman-Nicewander's reliability coefficient.

TABLE 3
PRINCIPAL COMPONENTS IN REAL AND IMAGE SPACE

Variable	Real space				Image space		
	H1	H2	H3	H4	H1	H2	H3
Flexibility with the bat	-.26	.54	.48	-.17	-.49	.71	.40
Forward bend on the bench	.44	-.36	-.40	.37	.71	-.37	-.21
Rope	.63	-.10	-.10	.52	.83	.03	-.01
Standing broad jump	.80	.11	-.16	-.41	.88	.15	-.12
Agility with the bat	-.48	.31	.41	.41	-.74	.32	.36
Lying medicine ball throw	.64	.39	.31	.28	.75	.44	.20
Standing high jump	.81	.27	.00	.06	.90	.29	-.03
Drumming with hands and feet	.32	-.62	.58	-.02	.41	-.41	.70
Seated medicine ball throw	.69	.34	.20	.13	.82	.44	.17
Non-rhythmic drumming	.30	-.60	.59	-.10	.43	-.56	.56
Standing triple broad jump	.80	.12	-.01	-.37	.89	.17	-.08
Variance [%]	35.63	14.83	12.81	9.23	54.09	15.78	11.14

Legend: H – principal components, Variance [%] – percent of common variability.

TABLE 4
PATTERN MATRIX IN THE REAL AND IMAGE SPACE

Variable	Real space				Image space		
	A1	A2	A3	A4	A1	A2	A3
Flexibility with the bat	.26	-.17	**-.74**	-.02	.30	**-1.04**	-.04
Forward bend on the bench	.11	.01	**.77**	-.03	.19	**.69**	.09
Rope	**.58**	-.18	**.59**	.03	**.65**	.25	.09
Standing broad jump	.26	**.80**	-.04	-.03	**.77**	.25	-.08
Agility with the bat	.29	**-.79**	-.26	-.01	-.23	**-.78**	.08
Lying medicine ball throw	**.90**	-.12	-.07	.03	**.98**	-.27	.06
Standing high jump	**.69**	.29	.07	-.07	**.92**	.07	-.05
Drumming with hands and feet	.02	-.02	.03	**.90**	.08	-.08	**.91**
Seated medicine ball throw	**.78**	.08	-.07	.00	**1.02**	-.23	.05
Non-rhythmic drumming	-.02	.04	-.03	**.90**	-.06	.15	**.86**
Standing triple broad jump	.34	**.71**	-.12	.06	**.81**	.21	-.04

Legend: A – pattern.

Bearing in mind the obtained results one can observe that the largest number of measuring instruments gave the best projection on the first principal component in their second particle. Such was the case with the test: Flexibility with the bat, Forward bend on the bench, Standing broad jump, Lying medicine ball throw, Standing high jump, Drumming with hands and feet, Seated medicine ball throw and Standing triple broad jump. Tests Non-rhythmical drumming and Agility with the bat had the best values on the first attempt, while the test Rope saturated the best its own main component at the third attempt. It is easy to conclude that the majority of motor test requires a test attempt. Although the specificum of the sample of respondents is that they have above-average motoric capabilities[10], that they probably had a lot of testing in their past, because they are generally more or less athletes, we can explicitly point to the necessity for a second attempt. Recalling of the movement structures necessary when performing test task can be seen as a necessity.

Tests Non-rhythmical drumming and Agility with the bat showed that the best value of the projection is on the first principal component during the first attempt. Hasty concluding could lead to the wrong track and say that it is enough to run these tests only once. However, the values of the percentage of common variance are clearly the lowest if we observe the full applied battery of tests. In other words, the differences are relatively high when repeating the tests, which later pointed to the unreliability of the test Agility with the bat. We could say, with a great degree of certainty, that in these tests processes of rapid acquisition of motor skills are very present, because by repetition in a short period of time we learn relatively complex movement structures that are always being performed in an identical manner. Also, the correlation values indicate that the highest value between the first and the third attempts. Therefore, it is recommended to perform the test three times, and if the examiner decides to use the real values (quantitative), he should use the third replication.

The test Rope, as it was expected, showed the best value for the third replication, since the level of engagement of muscle cells under the influence of elongation occurs after 10-12 seconds so the longer the retention the probability for a better result also increase.

Threshold value of the criteria for determining reliability is set at approximately 0.90[3], although for some authors closely related to our case study, this limit is somewhat more liberal for motor abilities assessment tests[8].

From the presented table it can be seen that only the Agility with the bat test did not show satisfactory reliability values. It is also obvious that none of the three criteria ($\alpha = 0.79$, $\beta = 0.79$ and $\rho = 0.83$) obtained by different measurement models did not reach an approximate theoretical value for the motor measuring instruments[8], and the reason for that is a big difference between the initial first attempt which can almost be taken as a probationary and the other two where the process of learning already gained momentum and provided for better values. But, if test has other metric characteristics on satisfactory level (i.e. validity, if has good discrimination, if it is economical etc.) it could be used in further research.

Below, we can see that in the real space we isolated four factors that can be meaningfully interpreted as: 1) explosive strength (35.63% of common variability), 2) explosive leg strength and agility (14.83% of common variability), 3) flexibility (12.81% of common variability) and 4) coordination* (9.23% of common variability). It is notable, too, that the measuring instrument Rope tends to equally saturate two latent dimensions. What the author could have concluded, on the basis of a previous research, is also confirmed here. In the paper by Cvetković et al.[11], it is found that the test Rope is not carefully selected. Although this work has confirmed that the test is reliable, the test didn't meet its basic purpose. Therefore, the validity of the measuring instrument is not at a satisfactory level. This problem was highlighted in the aforementioned study, where was, among other things, proved that this measuring instrument has very high correlation with variables of longitudinal dimensionality of the skeleton.

The importance of Guttman's image theory was observed by looking at the pattern matrix in image space. If we assume that the applied sample of the variables was drawn from a universe of variables, and this brought us to defining "pure" variables in which the measurement error was eliminated, we can observe that it is much more meaningful to define latent variables than in real space. Consequently, we can say that the first factor, explaining 54.10% of common variability, is interpreted as explosive strength factor, although another variable that constitutes this factor, Rope, was not interpreted because of the reasons mentioned in the preceding paragraph. Another factor has been interpreted as flexibility factor (explaining 15.78% of common variability), while the third factor – as a factor of coordination** (11.15% common variability).

In tables 5 and 6 results of correlations in real and Guttman's space are shown.

TABLE 5
FACTOR CORRELATION MATRICES IN REAL SPACE

Factor	1.	2.	3.	4.
1. Explosive strength	1.00			
2. Explosive leg strength and agility	.41	1.00		
3. Flexibility	.16	.27	1.00	
4. Coordination	.15	.15	.16	1.00

TABLE 6
FACTOR CORRELATION MATRICES IN IMAGE SPACE

Factor	1.	2.	3.
1. Explosive strength	1.00		
2. Flexibility	.35	1.00	
3. Coordination	.16	.15	1.00

Conclusion

In the end, it is necessary to emphasize that the calculation of the metrical characteristics of motoric measuring instruments represents the necessity in any research, because they do not have a permanent character and because they change from one to another type and sample of respondents as well as numerous other factors. In this paper, the authors intended to illustrate the possibility of adequate implementation of already standard motor tests, using some kinesiometric concepts to define the internal characteristics of composite measuring instruments. It is not difficult to conclude that almost all coefficients have a very high value, much higher than those that are common in this type of analysis. This situation may also indicate the different nature of particles in motor tests. Accordingly, it is probably necessary to analyze composite motoric measuring instruments on some other ways, since it was shown that the classical methods are too "soft" for kinesiometric problems, or at least only in so far as it deals with the problem of motor tests.

The authors recommend further research based on Guttman's test theory, and methods that have been discussed in the works of Zhu and his collaborators[12,13,14,15], dealing with similar problems, but using a relatively new so-called item response theory and Rasch's model, which are already used in kinesiometric research in the United States for some time now.

* Conclusion was taken conditionally because third test, which is necessary for defining any motor ability, was missing in this particular case.
** Ibidem.

R E F E R E N C E S

1. BALA G, AMBROŽIČ F, Internal metric characteristics of motor tests in physical education students. Acta Universitatis Carolinae – Kinanthropologica, 39(1) (2003) 5. – 2. JAKŠIĆ D, CVETKOVIĆ M, Reliability of tests for assessing explosive strength in physical education students: how reliable are they and how can the proper one be chosen? Kinesiologia Slovenica, 15(1) (2009) 49. – 3. FAJGELJ S, Psychometrics. (Centre for Applied Psychology, Belgrade, 2005). – 4. BRAUMGARTNER TA, Reliability and error of measurement. In T. Wood & W. Zhu (Eds) Measurement Theory and Practice in Kinesiology (Human Kinetics. Champaign, 2006). – 5. HAASE V, Reliability generalization: exploring variance in measurement error affecting score. Educational and Psychological Measurement, 58 (1998) 6. – 6. METIKOŠ D, PROT F, HOFMAN E, PINTAR Ž, OREB G, Measurement of Basic Motor Dimensions of Sportsmen (Faculty of Physical Education, Zagreb, 1989). – 7. MOMIROVIĆ K, RTT11G: Program for analyzing metric characteristics of composite measurement instruments consisting of a small number of replications of a same task. Technical Note (Institute for Criminological and Sociological Researches, Belgrade, 2001). – 8. MOMIROVIĆ K, WOLF B, POPOVIC DA, Introduction to measurement theory I. Internal metric properties of composite measuring instruments (University of Priština, Priština, 1999). – 9. GUTTMAN L, Image theory for the structure of quantitative variates. Psychometrica, 18 (1953) 123. – 10. METIKOŠ D, PROT F, HORVAT V, KULEŠ B, HOFMAN E, Basic motor skills of respondents of above-average motoric status. Kinesiology, 14(5) (1982) 21. – 11. CVETKOVIĆ M, JAKŠIĆ D, ORLIĆ D, Relations between anthropometric characteristics and flexibility in persons with above-average motor abilities. In M. Mikalački (Ed) Proceedings Book of 1st International Scientific Conference "Exercise and Quality of Life" (Faculty of Sport and Physical Education, Novi Sad, 2009). – 12. ZHU W, Constructing Test using Item Response Theory. In T. Wood & W. Zhu (Eds) Measurement theory and practice in kinesiology (Human Kinetics, Champaign, 2006a). – 13. ZHU W, Scaling, equating, and linking to make measures interpretable. In T. Wood & W. Zhu (Eds) Measurement theory and practice in kinesiology (Human Kinetics, Champaign, 2006b). – 14. ZHU W, COLE LE, Many faceted Rasch calibration of a gross motor instrument. Research Quarterly for Exercise and Sport, 67(1) (1996) 24. – 15. ZHU W, TIMM G, AINSWORTH B, Rasch calibration and optimal categorization of an instrument measuring women's exercise perseverance and barriers. Research Quarterly for Exercise and Sport, 72(2) (2001) 104. –

D. Jakšić
University of Novi Sad, Faculty of Sport and Physical Education, Novi Sad, Serbia
e-mail: jaksicd@uns.ac.rs

METRIJSKE KARAKTERISTIKE BATERIJE ZA MJERENJE MOTORIČKIH SPOSOBNOSTI

S A Ž E T A K

Ova studija ima za cilj da prikaže rezultate istraživanja koje je sprovedeno na uzorku 161 studenta muškog pola sa Fakulteta sporta i fizičkog vaspitanja na Univerzitetu u Novom Sadu. Sistem od 11 kompozitnih mjernih instrumenata je primenjen, a svaki od testova je imao tri ponavljanja. Analiza metrijskih karakteristika izvršena je na dva načina: u realnom i u Guttman-ovom prostoru. Na posletku je zaključeno da je baterija za mjerenje motoričkih sposobnosti apsolutno primjerena za upotrebu na ovom uzorku ispitanika, dok bi savjet za buduća istraživanja trebalo da skrenu pažnju da bi bilo veoma korisno da se ishodi ove studije provjere sa nekom od naprednijih statističkih procedura.

Ključne riječi: kompozitne mjere, mjerni instrumenti, metrijske karakteristike, 20-godišnji studenti.