INFLUENCE OF SOME MEASUREMENT PROCEDURES ON THE STRUCTURE OF FLEXIBILITY

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Abstract:

The main purpose of this study was to define flexibility space while using different measurement procedures and to assess its susceptibility to the influence of morphological characteristics. The data were collected using a sample of 236 male students of the University of Ljubljana who were all between 21 and 22 years of age. Flexibility was measured using fifteen tasks, all requiring wide amplitudes of movement in the area of the shoulder, trunk and hip joint. The amplitudes were measured with three different procedures, using linear measures, a gravity goniometer and a classical goniometer. The data on morphological characteristics were collected by using a battery of twenty-one measures. Most of the applied measures of flexibility showed a satisfactory degree of reliability (classical and contemporary coefficients of reliability). All factor structures (direct oblimin and KG criteria for factor extraction) obtained by means of different measurement procedures were defined by latent dimensions that are topologically oriented to joints and their wider areas, and accurately defined by the action and space characteristics of movements. The different measurement procedures used on the same tasks give the same form of flexibility. It was also found that almost all the measures of the three methods were influenced by morphology (regression analysis), although the structure of flexibility was not (congruence coefficients). On the basis of the collected data, it can be stated that the flexibility measurement procedure implying the use of a gravity goniometer is the most adequate way to collect the relevant data.

Key words: *male students, flexibility, morphological characteristics, structure, relations, measurement procedures*

EIFLUSS EINIGER MESSVERFAHREN AUF DIE FLEXIBILITÄTSSTRUKTUR

Zusammenfassung:

Das Hauptziel dieser Studie war, den Flexibilitätsraum mittels verschiedener Messverfahren zu bestimmen, sowie dessen Empfindlichkeit auf den Einfluß morphologischer Eigenschaften zu bewerten. Die Daten wurden auf einer Stichprobe von 236 Studenten der Universität Ljubljana, 21 und 22 Jahre alt, erworben.

Die Flexibilität wurde mittels 15 Aufgaben gemessen, die breite Bewegungsamplituden in der Schulter-, Trunk- und Hüftenzone forderten.

Drei verschiedene Messverfahren wurden zum Messen von Amplituden verwendet: das lineare Verfahren, das Gravitationsgoniometer und das klassische Goniometer. Die Daten über morphologische Eigenschaften wurden mittels einer Batterie von 21 Tests erworben. Die meisten angewendeten Messverfahren zur Bewertung der Flexibilität zeigten einen genügenden Grad der Zuverlässigkeit (klassische und zeitgemäße Zuverlässigkeitskoeffizient). Jede mittels verschiedenen Messverfahren erworbene Faktorenstruktur (direkte oblimin und KG-Kriterien zur Faktorenextraktion) wurde mit latenten Dimensionen erklärt, die topologisch an die Gelenke und die breitere Gelenkzone orientiert und durch die Aktions- und Raumeigenschaften der Bewegung genau bestimmt sind. Verschiedene Messverfahren, auf denselben Aufgaben angewendet, ergeben dieselbe Form der Flexibilität. Es wurde auch festgestellt, dass fast alle Verfahren innerhalb den drei Methoden durch Morphologie beeinflusst waren (Regressionsanalyse), während die Flexibilitätsstruktur es nicht war (Kongruenzkoeffiziente). Auf Grund erworbener Daten kann es behauptet werden, dass sich das Messverfahren, in dem Gravitationsgoniometer verwendet war, zum Erwerben der relevanten Daten am meisten eignet.

Schlüsselwörter: *Studenten, Flexibilität, morphologische Eigenschaften, Struktur, Beziehungen, Messverfahren*

Introduction

Flexibility is a dimension of one's motor abilities and it is defined as an ability to execute movements with the widest amplitude in one or more functionally connected joints. A survey of literature in the kinesiological and medical field, dealing with these issues, shows flexibility to be a significant factor of optimal physical fitness of an athlete doing some sport, as well as to be a significant factor in his/her everyday life (Borms, 1984). On the basis of these conclusions we can say that flexibility is one of the major factors which influence the quality of life. Because of the significance of this, we had to obtain all the relevant data, as it enables us to understand the general motor behaviour, and on this basis it also enabled the programming of the kinesiological transformational processes and the valorisation of the effects of these processes.

The problem of metrics in flexibility has been a subject of numerous studies in kinesiology, as well as in medicine (Šadura et al. 1974; Boone et al. 1978; Pistotnik, 1984; Agrež and Pistotnik, 1987). An overview of these studies enables us to conclude that (as flexibility indicators) only those motor tasks are used, which demand of the measures the widest possible amplitude of movement of those body segments in question. On this basis, various procedures have been developed, where the amplitude was measured with linear measures, or with angle degrees. However, the majority of relevant research is based on information obtained by linear procedures for measuring flexibility. Therefore, questions arise about the structure of flexibility, whereby any initial information about it would be obtained with the help of angular procedures. Differences may appear mainly due to the variable influence of body measurements on the chosen flexibility measurement procedure. For the linear procedure, mainly the influence of the longitudinal body measures on the results was determined (Pistotnik, 1989), whereas we do not have any credible data about its influence on the angular measures.

The basic aim of the current research was to determine the structure of flexibility according to the application of various groups of indicators, and to ascertain the congruence of the defined spaces prior to and after the partialisation of the morphological body characteristics of the subjects.

Methods

The sample, 236 male persons, was chosen from the University of Ljubljana's student population, aged 21 and 22 years. Such an age assures the measuring at a stable physically mature state of development, since at the age of approximately 21 years physical development is complete, whereas the deterioration processes have not yet begun. All the chosen subjects were active in a regular physical education programme.

A 15-measure test battery for determining flexibility was chosen, in which each movement task was simultaneously measured by three different procedures. We used the linear measurement of the distance between a fixed point in space and a point on the movable segment at maximum amplitude, as well as the measurement of the angle between the starting position and the final position of the movable segment with gravity (Leighton, 1955) (Photo 1) and the classical two-prong goniometer (Heck et al., 1965) (Photo 2). As the 15 flexibility tasks were performed separately in the shoulder area, the trunk, and the hip joint, 45 measures of flexibility were obtained in this way (description of the measures in Pistotnik, 1991). The abbreviations of the tests mean - e.g. MFGS BSP: M motor behaviour, F flexibility, G gravity goniometer (C classical goniometer), S shoulder (T trunk, H hip joint), BSP (or other codes) the description of movement.

Photo 1: Gravity goniometer.

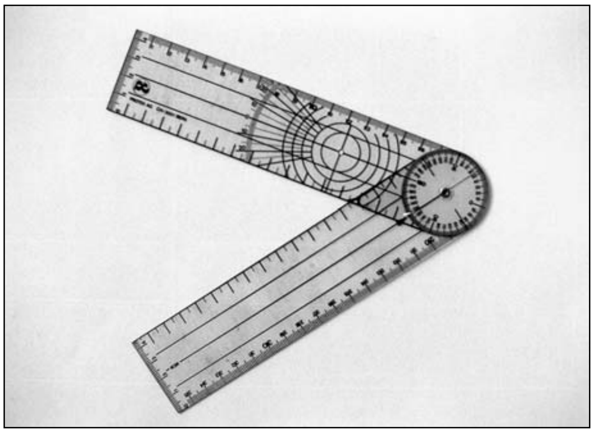

Photo 2: Classical two-prong goniometer.

	Measurement procedure		
Motion (movement) task	**linear**	**gravity**	**classical**
1. arms held backwards from sideways position, prone	MFS BSP	MFGS BSP	MFCS BSP
2. arms held backwards from upwards position, prone	MFS BUP	MFGS BUP	MFCS BUP
3. arms held upwards inward from sideways position, standing	MFS USS	MFGS USS	MFCS USS
4. arms held backwards from downward position, prone	MFS BDP	MFGS BDP	MFCS BDP
5. arms held forwards inward, prone over the box	MFS FIP	MFGS FIP	MFCS FIP
6. trunk-bending to the right, standing	MFT RBS	MFGT RBS	MFCT RBS
7. trunk-bending forwards on the bench	MFT BFB	MFGT BFB	MFCT BFB
8. trunk-bending forwards beside the wall bars	MFT BFW	MFGT BFW	MFCT BFW
9. trunk-bending forwards in forward split	MFT BFS	MFGT BFS	MFCT BFS
10. arch, kneeling	MFT ARK	MFGT ARK	MFCT ARK
11. leg held forwards, lying on the back	MFH HFL	MFGH HFL	MFCH HFL
12. leg held backwards, standing	MFH HBS	MFGH HBS	MFCH HBS
13. leg held sideways, lying on the side	MFH HSL	MFGH HSL	MFCH HSL
14. leg held forwards inward, standing	MFH FIS	MFGH FIS	MFCH FIS
15. forward straddle	MFH FS	MFGH FS	MFCH FS

We tried to include all the measurements of the most significant body segments contained in the execution of movement tasks of flexibility in the battery for determining the morphological characteristics of the subjects' bodies. The battery of 21 body measures from the International biological program are consistent with the latent morphological dimensions of previous research (Stojanović, 1975).

Measurements of individual groups of subjects were performed in two sessions. In the first session every subject was measured with a battery of anthropometric indicators. After completing the first session, a general warm-up with a complex of gymnastic exercises followed. From this we tried to reduce the possibility of the local warm-up influence on the test's results. In the second session, following a warm-up, we measured flexibility. The subjects were barefoot, in shorts and T-shirts, and of their own choice went from one measurement place to the next. At each measurement position their flexibility was measured simultaneously for each movement task by all three measurement procedures.

The data obtained from the flexibility and the morphological characteristics of the body were processed by standard descriptive statistics. Using classical and contemporary procedures (Spearman-Brown RTT, Guttman-Nicewander LMBD6, Cronbach-Kaiser-Caffrey ALPHA, Kaiser-Rice MSA) contained in the RTT 7G programme (Alvey et al., 1980), we defined the basic characteristics of the measures used. The latent structure of the researched spaces was determined by oblimin rotation, and on the basis of the Kaiser-Guttman criterion KG (Norusis, 1988). On the basis of body measures the flexibility-test results were evaluated by means of regression analysis and for each variable the part of variability which may be predicted by the morphological characteristics of the body was defined. The same procedures of factor analysis as on the original results were also executed on the partialised results. On the basis of Tucker's congruence coefficients (Tucker, 1951) we established the consistency of the obtained factor results, prior to the partialisation and after it.

Results and discussion

The applied flexibility variables showed good metric characteristics. This is evident in certain statistical indicators, reliability coefficients (Table 1) and the comparison of factors. Linear measures showed the best metric characteristics; they were followed by measures obtained by the gravity goniometer, then by measures obtained by a classical goniometer, of which some are at the very limit of appropriate reliability *(leg held forwards inward, standing* - MFCH FIS).

For the majority of measures it can be said that there are no significant differences between arithmetic averages of items, which shows a certain stability of measuring. The noted gradual but moderate increase of results toward the third item can be attributed to the local warm-up, which, however, in this case, is not substantial enough for measurement instability. Sensitivity of the majority of flexibility measures is satisfactory, only the tests *leg held forwards inward, standing* (MFH FIS) and *leg held backwards, standing* (MFH HBS) diverge slightly. This is reflected in somewhat poorer coefficients of reliability. The validity of the chosen flexibility variables was defined by the comparison between the factor solutions of measurement procedures which were consistent. Due to such good results, all the applied measures were included in further analysis.

Factor analysis of the spaces defined by the manifest variables, obtained by individual flexibility

Table 1 : Reliability estimates

TEST		RTT	LMBD6	ALPHA	MSA
MFS	BSP	.972	.966	.972	.674
	BUP	.985	.983	.985	.661
	USS	.983	.979	.983	.693
	BDP	.981	.977	.981	.695
	FIP	.978	.976	.978	.652
MFT	RBS	.974	.969	.974	.668
	BFB	.990	.988	.990	.696
	BFW	.978	.978	.978	.588
	BFS	.985	.981	.985	.709
	ARK	.981	.974	.981	.706
MFH	HFL	.979	.973	.979	.704
	HBS	.960	.949	.960	.683
	HSL	.980	.976	.980	.686
	FIS	.956	.945	.956	.678
	FS	.986	.981	.986	.718
MFGS	BSP	.974	.970	.974	.692
	BUP	.992	.991	.992	.674
	USS	.962	.954	.962	.662
	BDP	.981	.975	.981	.709
	FIP	.964	.960	.964	.642
MFGT	RBS	.971	.964	.971	.689
	BFB	.983	.982	.983	.657
	BFW	.981	.981	.981	.629
	BFS	.985	.980	.985	.705
	ARK	.984	.980	.984	.687
MFGH	HFL	.955	.943	.955	.672
	HBS	.934	.922	.934	.646
	HSL	.967	.961	.967	.682
	FIS	.942	.921	.942	.679
	FS	.975	.967	.975	.710
MFCS	BSP	.979	.974	.979	.694
	BUP	.981	.976	.981	.688
	USS	.968	.959	.968	.694
	BDP	.967	.954	.967	.698
	FIP	.965	.958	.965	.665
MFGT	RBS	.958	.946	.958	.681
	BFB	.981	.976	.981	.690
	BFW	.967	.966	.968	.647
	BFS	.969	.958	.969	.706
	ARK	.984	.979	.984	.711
MFCH	HFL	.937	.919	.937	.662
	HBS	.878	.850	.878	.600
	HSL	.955	.944	.955	.668
	FIS	.929	.904	.930	.673
	FS	.981	.975	.981	.714

measurement procedures, showed a very similar structure. It was possible to define the factors topologically (in relation to the joints) and on the basis of action (in accordance with the type of basic movement) and space criteria (in relation to the basic planes of movement). Although we isolated 5 factors by the analysis of linear variables and by the gravity goniometer variables, and 6 factors by the analysis of a classical goniometer variables, the differences between the results were not great and could be attributed mainly to somewhat poorer measurement characteristics of the measurements made by the classical goniometer. Namely, in all three defined spaces of trunk flexibility in flexion, flexibility of the arms in retroflexion, trunk flexibility in the sagittal plane, i. e. flexibility of the body in hyperextension, as well as arm flexibility in the shoulder area occurred. The factors also defined as the flexibility of extremities in adduction are very similar to each other (Table 2).

The common factor analysis of all the 45 flexibility measures produced 13 factors, which is only 2 factors less than the number of the applied flexibility tasks. The same movement tasks used in all three measurement procedures defined in principle the independent factors. The differences appeared in only two factors, defined by two very similar movement tasks. The second factor was defined by two unrestrained forward bends, and the 5th factor by two tests of arms held backwards. Thus, the consistence of angle measurement procedures and their factor structure with the reference system, represented by linear measures, was confirmed. The factor analysis of the second degree, performed on 13 factors obtained by means of the first degree factor analysis, only confirmed the conclusion about the structure of flexibility, obtained on the basis of the analysis of information collected by individual measurement procedures.

The results of various flexibility measurement procedures are influenced by all the morphological body characteristics of the subjects, but with a different intensity and structure regarding different flexibility measures. Linear measures are characteristically more under the influence of anthropometric variables, mostly the longitudinal skeletal measures, which mainly favour the motor manifestation of flexibility. The conclusions reached are consistent with the majority of previous research (Kos, 1965; Harris, 1969; Pistotnik, 1989). This research established a significant influence of voluminosity and subcutaneous fat tissue in the results of the linear measures, which is even more distinct in the flexibility measures of the hip joint. Body mass and voluminosity especially manifest a negative influence on the results, except in the cases when muscle mass is directly included in the execution of the movement with a wide

Table 2: Factor structure of individual flexibility measurement procedures

FA	LINEAR MF....	GRAVITY MFG....	CLASSICAL MFC....
1	TBFB, TBFS, HHFL, (HFS) .880 .780 .704 (.545) flexibility of the body in flexion	TBFB, TBFS, HHFL, (HFS) .839 .715 .684 (.568) flexibility of the body in flexion	SUSS, SFIP, (SBUP) .774 .708 (.515) arm flexibility in shoulder
2	HHBS, SFIP, (HHSL) .749 .739 (.538) flexibility of extremities in adduction	TRBS, SUSS, (SBUP) .649 .616 (.569) arm flexibility in shoulder	TBFB, HHFL, TBFS .800 .768 .719 flexibility of the body in flexion
3	TRBS, SBUP, (SUSS) -.754 -.634 (-.495) arm flexibility in shoulder	TBFW, HFIS, (HHSL) .679 .636 (.590) trunk flexibility in the sagittal plane	TARK, HFIS .859 .610 body flexibility in hyperextension
4	TBFW, HFIS, (TARK) .796 . 671 (.462) . trunk flexibility in the sagittal plane	HHBS, SFIP 693 .690 flexibility of extremities in adduction	HHBS, (TRBS), (HHSL) .778 (.420) (-.489) leg flexibility in adduction
5	SBDP, SBSP -.782 -.740 arm flexibility in retroflexion	SBDP, SBSP -.821 -.709 arm flexibility in retroflexion	TBFW (HFS) .720 (-.483) trunk flexibility in flexion
6			SBDP, SBSP .788 .658 arm flexibility in retroflexion

FA – factor, LINEAR measures, GRAVITY goniometer, CLASSICAL goniometer,
MF..., MFG..., MFC... – the first part of the test's name, SBDP – the second part of the test's name,
880 – the highest scores of variables in factors

amplitude, representing an active extension force. The subcutaneous fat also presents a negative factor in attaining maximum movement amplitudes, as it can physical hinder the execution of a movement in the flexion of body segments. On the other hand, it may have a positive influence in the body parts that are being stretched, also on the size of the movement amplitude, since a proportionally greater quantity of fat tissue, which supersedes muscle tissue, offers less resistance to the stretching force than a corresponding quantity of muscle would.

Body measures have significantly less influence on the results of the angle flexibility measures. It can be stated that the longitudinal skeletal measures do not influence the results, this being expected as the technique of measuring in itself excludes this influence. Voluminosity, with body mass and subcutaneous fat, shows a similar influence on the results of angle measures, as described for linear measures. Although certain differences between the influence of body measures on the individual flexibility measures obtained by the gravity goniometer and the measures obtained by the classical goniometer do exist, we can nonetheless assert that the influence of body measures on the applied angle measures of flexibility are very similar.

Out of 45 applied measurements of flexibility, we found that body proportions did not influence the results only in 16 cases, that is, 7 measures obtained by the gravity goniometer, 7 measures obtained by the classical goniometer and only 2 linear measures.

The factor structures of flexibility, after the partialisation of body measures are, in individual measurement procedures, very similar to those we defined by the data in the complete space of flexibility measures. In this way, the linear measurement variables and the gravity goniometer variables define the same number of factors as prior to the partialisation (five), which are by their content very similar. In the flexibility space defined by the variables where the classical goniometer was used, we isolated one factor more than in the complete space of all measures (seven). This can be attributed especially to the poorer metric characteristics of the variable *leg held forwards inward*, *standing,* which (with its unsystematic influence) somewhat ruins the balance between the isolated factors. In spite of such a structure, the factor-congruency coefficients (prior to partialisation and after) show satisfyingly high values in all the three flexibility measurement procedures. On the basis of the presented results, we can conclude that the body characteristics of the subjects do not significantly influence the structure of flexibility.

Conclusion

The research presented here shows that previous research studies on flexibility structure were actually, as all of the three latent structures, defined on the basis of varying measurement procedures, and they are consistent with this research. The space of flexibility is determined by the dimensions which are topologically oriented towards the joints and joint components of the body, and defined by the action and the area characteristics of the movements. Flexibility is an ability with a relatively simple structure. This structure is unoccupied by the influence of the body characteristics of the subjects. Flexibility is also characterised by good and reliable measurement procedures and of which we would especially recommend the measurement by a gravity goniometer, because it has good metric characteristics and the body measures have the least influence on the results of the three presented procedures.

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UTJECAJ NEKIH MJERNIH POSTUPAKA NA STRUKTURU FLEKSIBILNOSTI

Sažetak

Glavni je cilj ovoga istraživanja bio definirati prostor fleksibilnosti primjenom raznih mjernih postupaka i procijeniti osjetljivost strukture fleksibilnosti na utjecaj morfoloških obilježja. Dostupna kineziološka i medicinska literatura, koja se bavi tim problemom, tvrdi da je fleksibilnost važan faktor optimalnog tjelesnog fitnesa (sportske pripremljenosti) svakog sportaša, a isto je tako i važan faktor u svakodnevnom životu. Problem mjerenja fleksibilnosti predmetom je brojnih kinezioloških i medicinskih studija. Na temelju toga razvijeni su mnogobrojni mjerni postupci gdje je amplituda pokreta mjerena ili linearnim mjerilom ili kutnim stupnjevima. Ipak, većina relevantnih istraživanja temelji se na informacijama dobivenima postupcima linearnog mjerenja fleksibilnosti. Stoga se postavlja pitanje kakva je struktura fleksibilnosti ako su ulazne informacije dobivene postupkom mjerenja kutnih stupnjeva.

Uzorak ispitanika činilo je 236 studenata Sveučilišta u Ljubljani, u dobi od 21 ili 22 godine. Za mjerenje fleksibilnosti ispitanici su morali izvesti 15 zadataka koji su svi zahtijevali veliku amplitudu pokreta ramenog pojasa, trupa i kuka. Amplitude pokreta mjerene su trima postupcima: linearno, gravitacijskim goniometrom i klasičnim goniometrom. Podaci o morfološkim obilježjima dobiveni su sklopom od 21 mjere. Obje skupine podataka (o fleksibilnosti i o morfologiji) obrađene su standardnim deskriptivnim statističkim postupcima. Klasičnim i suvremenim postupcima, koji su obuhvaćeni programom RTT7G, utvrđene su osnovne karakteristike uporabljenih mjernih instrumenata. Latentna struktura istraženog prostora utvrđena je oblimin rotacijom pod Guttman-Kaiserovim kriterijem. Rezultati testova fleksibilnosti vrednovani su regresijskom analizom na temelju antropometrijskih mjera. Za svaku varijablu definiran je udio varijabiliteta koji se može predvidjeti iz morfoloških obilježja. Isti postupci faktorske analize, koji su se koristili na sirovim podacima, primijenjeni su na parcijalizirane rezultate. Na temelju Tuckerovih koeficijenata slaganja ustanovljena je konzistentnost rezultata prije i nakon parcijalizacije.

Većina primijenjenih testova fleksibilnosti pokazala je zadovoljavajuću pouzdanost. Linearne mjere pokazale su najbolje metrijske karakteristike, a zatim slijede testovi mjereni gravitacijskim goniometrom. Sve faktorske strukture dobivene različitim mjernim postupcima bile su definirane latentnim dimenzijama topološki vezanima za zglobove i područja oko njih i točno su bile određene akcijom i prostornim karakteristikama pokreta. Različiti mjerni postupci, primijenjeni na istim zadacima, dali su isti oblik fleksibilnosti (5 faktora dobivenih linearnim mjerenjem i gravitacijskim goniometrom te 6 faktora dobivenih mjerenjem klasičnim goniometrom). Također se pokazalo da je morfologija utjecala na sve mjere svih triju metoda, ali nije utjecala na dobivene strukture fleksibilnosti. Tjelesne mjere značajno su slabje utjecale na rezultate dobivene mjerenjem kutnih stupnjeva. Od ukupno 45 mjerenja fleksibilnosti, tjelesne proporcije nisu utjecale na rezultate u samo 16 slučajeva: u 7 mjera dobivenih gravitacijskim goniometrom, 7 mjera dobivenih klasičnim goniometro te samo u 2 linearne mjere.

Na temelju prikupljenih podataka može se tvrditi da je mjerni postupak u kojemu se fleksibilnost mjeri gravitacijskim goniometrom najpogodniji za prikupljanje relevantnih podataka.

Ključne riječi: *studenti, fleksibilnost, morfološke karakteristike, struktura, relacije, postupci mjerenja*

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