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The influence of professional sport on flexibility in adulthood

Einfluss von Leistungssport auf die Beweglichkeit in späteren Lebensjahren

Summary

- **The functional efficiency** of the physical motor system constitutes one of the basic factors creating welfare which according to WHO is synonymous to health. 171 men aged 30-60 were tested.
- **The current and past levels of physical activity** were determined in the research. Measurements of the range of the torso's three-plane mobility. An impact of a systematic physical activity on the level of the functional efficiency of the physical motor system, including suppleness, was established.
- **The results of the research** allowed the authors to conclude that doing sports professionally in youth brings about a generally higher level of flexibility in adulthood, even with a lack of physical activity, which seems to indicate the existence of the „translocation effect".

Zusammenfassung

- **Die funktionelle Leistungsfähigkeit** des menschlichen Bewegungsapparates ist ein wichtiger Faktor für das körperliche Wohlbefinden, das laut der WHO unabdingbar zum Gesundheitsbegriff dazugehört.
- **Untersucht** wurden 171 freiwillige männliche Probanden im Alter von 30 bis 60 Jahren, dabei wurden das aktuelle und zurückliegende physische Aktivitätsniveau erhoben sowie motorische Tests zur Überprüfung der Rumpfbeweglichkeit in drei Ebenen durchgeführt.
- **Insgesamt konnte der Einfluss** regelmäßiger körperlicher Aktivität auf die motorische Leistungsfähigkeit, einschließlich der Beweglichkeit, festgestellt werden. Zudem kann man schlussfolgern, dass sportliche Betätigung in der Jugend im Allgemeinen einen höheren Grad der Beweglichkeit in späteren Lebensjahren zufolge hat, auch unter Berücksichtigung eines aktuellen Mangels an physischer Aktivität, was wiederum auf einen möglichen „Übertragungseffekt" hinweist.

KEY WORDS:
Flexibility, physical activity, translocation effect

SCHLÜSSELWÖRTER:
Beweglichkeit, körperliche Aktivität, Übertragungseffekt

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Introduction

The functional capacity of the musculoskeletal system is one of the main determinants of well-being in humans, which – according to the WHO definition – is thought to be synonymous with health (1, 2).

In the present world, economically developed societies are characterised by sedentary lifestyle. Insufficient physical activity has a particularly adverse influence on the functional capacity of the spine, or – to be more precise, taking into account the biomechanical complexity of the human locomotor system – on the movement functionality of the trunk (3). One of the major determinants of this functionality is flexibility, defined as the ability to perform movements within the optimal (the greatest possible) range of motion (1, 4).

The level of flexibility is determined by a number of factors, which include: sex, age, ambient temperature, time of the day, certain individual anatomic variations, efficiency of the processes involved in controlling and regulating human movement, and the individual's maximum rate of energy metabolism.

As a structural and morphological parameter, flexibility is readily susceptible to stimulation by physical activity (5, 6). The level and nature of this stimulation shows within-individual variation and its maximum level varies at different periods of life. Exploratory aspects and the related potential preventive directives raise questions about the existence and extent of the relationships between physical workload and range of motion (level of flexibility). It seems that the otherwise valuable analyses at the biomedical level may at times be unable to fully explain the complexity of these relationships. The large number of factors that shape human movement (genetics, lifestyle and the incompletely understood interrelationships between them) pose and will continue to pose new challenges to researchers. This suggests the need for performing analyses of a global nature, ones that would take into account the ›

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relationships between both standard (i.e. typical of the population in question) and increased levels of physical activity and the investigated motor effects. The above is also true for the motor potential for performing movements over an optimal range or over the greatest possible range (flexibility). As well as being dependent on the types and strengths of the stimuli, the impact of physical activity is strongly determined by its timing and duration. And this has prompted us to conduct the study reported here.

Aim

The principal aim of the study was to assess the relationship between an increased level of physical activity (compared to the mean level of physical activity in the general population), at present and in the past, and the level of trunk flexibility in middle-aged men (men between 30 and 60 years of age). The study also aimed to investigate whether the study subjects' morphological structure can be a significant factor determining the results of flexibility tests, as this might affect the principal aim of the study.

Material and methods

A total of 171 male volunteers between 30 and 60 years of age (mean age = 41.6 years; SD = 8.05 years) inhabiting several large cities of the Upper Silesian agglomeration were included in the study. Purposive sampling was used. In addition to satisfying the age criterion, the subjects had to be in relatively good health that would allow them to undergo movement function tests, i.e. they had to have adequate cardiovascular and respiratory function and they could not have any musculoskeletal functional limitations arising from any somatic conditions, physical injuries or contusions. The study consisted of the following stages:

Interviews with the subjects: Collection of data on the current level of sporting physical activity and on the athletic history.

Anthropometric measurements: In search for potential relationships between the subjects' morphological structure and the motor outcomes (the level of active flexibility). The following measurements were performed for this purpose: height, weight, upper limb length (from the acromion process of the scapula to tip of the middle finger), lower limb length (from the greater trochanter of the femur to the floor), and trunk length (from the symphysis pubis to the jugular notch of the sternum). Waist circumference and hip circumference were also measured. The measurements were taken using a non-stretch anthropometric measuring tape to an accuracy of 0.5 cm. Weight was measured with electronic scales to an accuracy of 0.1 kg.

The measured values were used to calculate the values of parameters that we believed might significantly affect the level of flexibility. These parameters included:

a) Waist-to-hip ratio (WHR)

b) Upper limb length to stature ratio = (averaged upper limb length / stature) * 100

c) Lower limb length to stature ratio = (averaged lower limb length / stature) * 100

d) Intermembral index = (averaged upper limb length / averaged lower limb length) * 100

e) Trunk length to stature ratio = (trunk length / stature) * 100

Completion of movement testing by the subjects (after a standard warm-up of several minutes' duration) which included tests assessing flexibility of the trunk in three planes:

In the sagittal plane: The fingertip-to-floor test and the sit and reach test. In both tests, the standard requirements included: knees fully extended, feet together, measurement taken with the flexometer, a measuring tool especially designed for this purpose. The foot plane was used as the reference point for the measurements. Reaches short of this point were recorded as positive values and reaches beyond this point as minus values. The measurements were taken to an accuracy of 0.5 cm (3, 6, 7, 8).

In the frontal plane: Lateral flexion of the trunk — the difference in the distance between the tip of the middle finger and the floor in the standing position and with the trunk laterally flexed — to the left (L) and to the right (R). The measurements were taken to an accuracy of 0.5 cm (9). Throughout the test the subjects were required to stand with feet shoulder width apart and touching the floor throughout the movement.

In the transverse plane: Trunk rotation with the trunk bend forward at the right angle. Starting position: standing with feet apart. The feet had to be as wide apart as possible to ensure that no hip rotation or knee flexion occurred. The measurements were taken with a Saunders inclinometer that was applied to a gymnastic baton held by the subject with both hands behind his back, close to both of his shoulder blades. The measurements were taken in degrees to an accuracy of 1° (6). In each subject the measurements were taken for both sides.

All the measurements were taken after the subject had maintained the target position for 2–3 seconds. Each subject completed each test in three runs with the tests in the frontal and transverse planes being completed in three runs per side. The mean of the three measured values, rounded to the nearest whole number, for each of the tests was included in the statistical calculations.

In order to maintain standard conditions the same equipment and the same procedures were used for each test in each subject, and the testing was conducted in the same building at a temperature of 20–22°C, in the afternoon.

Subscribing to the view that non-occupational physical activity is the type of physical activity that has the greatest impact on health and fitness level, including the level of flexibility, we adopted the following differentiating criteria (1, 2, 3, 10):

Physically active subjects were defined as those who regularly engaged in sporting physical activity of any type at least once a week for one hour.

Former athletes were defined as those who had trained and competed for a period of at least five years in any discipline and at any professional level.

Statistical analysis

The nature of the distribution of the study variables and the homogeneity of their variances were assessed with the Shapiro-Wilk test and the Levene test, respectively. The variables found to meet the criteria for the normal distribution and homogeneity of variance were tested with univariate analysis of variance with physical activity level being the independent variable and anthropometric parameters and flexibility tests being the dependent variable. If a significant main effect was identified, the Tukey post-hoc test for unequal sample sizes was used. The results were expressed as means with standard deviations (SD) and the minimum and maximum values. P values were provided for between-group differences, and for flexibility-related variables, the mean difference and the respective 95% confidence intervals (95% CI) were additionally provided. The relationships between the morphological parameters and the flexibility tests were assessed with the Pearson linear correlation. A significance level of $p<0.05$ was adopted throughout.

Table 1

Average and standard deviation (Standardabweichungen (SD)) of age and anthropometric parameter. 1=physically active person & former sportsman; 2=physically inactive person & former sportsman; 3=physically active person & no sportsman; 4=physically inactive person & no sportsman; 1=significance level of one-factor variance analysis. *=statistic significance; WHR=waist-to-hip ratio; ALI=index of arm´s length; BLI=index of leg´s length; IMI=index of intermembral; SKI=index of Skelisch.

PARAMETER	GROUP 1 N=48	GROUP 2 N=27	GROUP 3 N=52	GROUP 4 N=44	PH-VALUE 1
Age [years]	40,3 (7,1)	42,9 (7,1)	40,5 (8,5)	44,4 (8,1)	0,06
Size [cm]	177,7 (7,5)	174,9 (7,3)	175,7 (6,7)	174,3 (7,1)	0,14
Weight [kg]	84,1 (13,7)	85,4 (15,5)	79,6 (12,9)	79,6 (13,1)	0,13
WHR	0,89 (0,05)	0,95 (0,07)	0,91 (0,06)	0,95 (0,07)	<0,001*
ALI	45,1 (1,65)	45,2 (1,56)	45,2 (1,19)	45,6 (1,87)	0,32
BLI	50,5 (1,39)	50,3 (1,64)	50,4 (1,32)	50,2 (1,83)	0,83
IMI	89,2 (3,71)	89,9 (3,74)	89,8 (2,52)	91,0 (5,3)	0,18
SKI	60,0 (3,4)	62,4 (9,02)	58,5 (3,82)	58,8 (4,2)	<0,001*

Table 2

Average and standard deviation (Standardabweichungen (SD)) of motoric tests. 1=physically active person & former sportsman; 2=physically inactive person & former sportsman; 3=physically active person & no sportsman; 4=physically inactive person & no sportsman; 1=significance level of one-factor variance analysis. *=statistic significance.

TEST	GROUP 1 N=48	GROUP 2 N=27	GROUP 3 N=52	GROUP 4 N=44	P-VALUE 1
Distance of fingers to ground	5,71 (7,1)	5,62 (7,7)	3,71 (7,6)	0,73 (9,1)	0,01*
Sedentary crook of trunk forward	8,0 (8,1)	8,3 (7,7)	7,20 (7,2)	4,0 (9,2)	0,06
Sideways crook of trunk left	29,8 (6,5)	27,6 (4,2)	30,2 (8,3)	25,4 (6,0)	<0,01*
Sideways crook of trunk right	30,3 (6,8)	28,4 (4,8)	29,8 (8,4)	25,2 (5,7)	<0,01*
Rotation of trunk left	70,3 (8,9)	68,5 (12,5)	71,3 (12,4)	63,3 (11,4)	<0,01*
Rotation of trunk right	70,2 (9,9)	72,8 (14,3)	1,6 (13,5)	64,7 (12,7)	0,02*

Results

Subjects

After assigning the subjects to the study groups according to the physical activity status we did not reveal any statistically significant differences in age, height, body mass, upper limb length to stature ratio, lower limb length to stature ratio, or intermembral index. The post-hoc analysis revealed a significant difference in WHR between the group of physically active former athletes and the group of physically inactive former athletes (p=0.01) and between the group of physically active former athletes and the physically inactive group (p<0.001) Differences in trunk length were observed between the group of physically inactive former athletes and the group of physically active athletes (p=0.02) and between the group of physically inactive former athletes and the physically inactive group (p=0.04). A complete list of the mean values in each of the study groups is provided in Table 1.

Flexibility

Based on the results provided in Table 2, the analysis of the main effect showed statistically significant differences in all of the tests with the exception of the sit and reach test. A detailed post-hoc analysis revealed that the result of the fingertip-to-floor test in the group of physically active former athletes was, on average, 4.96 cm higher (95% CI: 0.58–9.38; p=0.01) than that in the physically inactive group. In the group of physically active former athletes, the mean result in the left lateral flexion of the trunk was 4.33 cm higher (95% CI: 0.58–8.07; p=0.01) and the mean result in the right lateral flexion of the trunk was 5.08 cm higher (95% CI: 1.27–8.89; p=0.02) than that in the physically inactive group. In the group of physically active non-athletes, the mean result in the left lateral flexion of the trunk was 4.77 cm higher (95% CI: 1.09-8.44; p=0.004) and the mean result in the right lateral flexion of the trunk was 4.61 cm higher (95% CI: 0.87–8.35; p=0.007) than that in the physically inactive group. The range of left rotation in the group of physically active former athletes was, on average, 7.01° higher (95% CI: 0.72-13.29; p=0.01) than that in the physically inactive group. The range of right rotation and the range of left rotation in the group of physically active non-athletes were significantly higher by 6.89° (95% CI: 0.04-13.75; p=0.04) and by 8,00° (95% CI: 1.83-14.2; p=0.004), respectively, than those in the physically inactive group. The mean values of all the analysed variables are provided in Table 2.

Relationship between the morphological parameters and flexibility

The analysis of correlation between the selected anthropometric parameters and flexibility in all the study groups combined revealed that the variable exerting the greatest impact on flexibility was WHR (Table 3).

Discussion

Our study has been inspired by the postulated significance of the the motor potential as the basis for motor independence. One of the essential elements of this potential is flexibility, defined as the available range of motion in a joint or group of joints. Flexibility is not a global parameter and may considerably vary from joint to joint (5). Hence the objection that its assessment with the use of movement function tests is an excessive generalisation (11, 12).

Table 3

Average and standard deviation (Standardabweichungen (SD)) of motoric tests. 1=physically active person & former sportsman; 2=physically inactive person & former sportsman; 3=physically active person & no sportsman; 4=physically inactive person & no sportsman; 1=significance level of one-factor variance analysis. *=statistic significance; WHR=waist-to-hip ratio; ALI=index of arm´s length; BLI=index of leg´s length; IMI=index of intermembral; SKI=index of Skelisch.

	DISTANCE OF FINGERS TO GROUND	SEDENTARY CROOK OF TRUNK FORWARD	SIDEWAYS CROOK OF TRUNK LEFT	SIDEWAYS CROOK OF TRUNK RIGHT	ROTATION OF TRUNK LEFT	ROTATION OF TRUNK RIGHT
Körpergröße	0,05	-0,01	0,09	0,12	-0,05	-0,04
Körpergewicht	-0,04	-0,06	0,16*	0,14	-0,06	-0,07
WHR	-0,29*	-0,25*	-0,04	-0,09	-0,24*	-0,25*
ALI	-0,06	0	-0,1	-0,12	-0,14	-0,15
BLI	0,02	-0,02	-0,02	0	-0,03	-0,03
IMI	-0,07	0,01	-0,07	-0,1	-0,09	-0,1
SKI	-0,15	-0,11	-0,06	-0,09	-0,02	-0,06

However, the range of motion measurements in specific joints (kinanthropometry), despite being very valuable from the scientific point of view, are mainly used in professional sport and in therapy. Prophylactic tests require measurements of a global nature that would be valid and reliable and at the same time not time-consuming. In this case, the heterotelic nature of the tests constitutes their advantage and because of that, in the batteries of tests evaluating fitness level, flexibility is most commonly assessed with the first two or with all of the three tests we used (7, 9). In light of the fact that trunk (spine) movements are of multiplanar nature, the uniplanarity of these tests seems to be their disadvantage (sagittal plane, possibly frontal plane) (13). Assessment of the range of motion in the transverse plane is associated with technical issues, particularly where population analyses need to be performed. The method of measuring flexibility in the transverse plane proposed in out paper is an attempt to address these needs. The performance of this test requires highly critical conditions, but in the functional aspect this test seems to be a good diagnostic tool. Also, movements of the trunk are an integral part of the wealth of human movement. The potential risks during this test may be minimised by selection criteria for this test.

The parameters of correlation between morphology and the analysed ranges of motion suggest no relationships between the parameters calculated from the linear measurements and flexibility (Table 3). A similar absence of relationship between the morphological parameters and flexibility measured in the fingertip-to-floor test has been observed by Kuszewski et al. (14) in a study of 284 adult women and men. Similar conclusions have been arrived at by Broer (15). It therefore seems that the objections raised by Borms regarding the potential influence of body proportions on the outcome of flexibility measurement are speculations that prove to be correct only in subjects with extremely non-standard morphological parameters (16).

The statistically significant negative correlations between WHR and the flexibility tests in the sagittal and transverse planes suggest that abdominal obesity (statistically significant differences between the physically active groups and the physically inactive groups) should be treated as one of the factors that directly limit flexibility (mechanical limitations). In addition, the increased lumbar lordosis as a consequence of abdominal obesity contributes to the shortening of the extensor muscles of the lumbar spine and the ischiocrural muscles, which results in decreased range of motion.

The correlations of WHR presented in this paper and the lack of relationship between the linear measurements and flexibility of the trunk highlight the significance of the behavioural factor (physical activity) in shaping flexibility. Specifying the commonly acceptable criterion dividing individuals into those physically active and those physically inactive can always give rise to controversy and inherently involves a certain level of arbitrariness. In our study, we adopted a minimal level of physical activity provided it was engaged into on a regular basis. As a result, physical activity in this dimension can be regarded as an element of lifestyle.

The adopted criteria of activity allow for a clear differentiation between the subjects. The subjects whose current and past physical activity did not exceed the average level were found to have the lowest mean values in all the flexibility tests (Table 2). These differences, when compared with physically active subjects, were statistically significant for each of the tests with the exception of the fingertip-to-floor test. Also, a higher level of physical activity in the past associated with participation in professional sporting activities (according to the adopted criterion) has been shown to strongly impact the current level of flexibility, as evidenced by the lack of statistically significant differences between the group of physically inactive former athletes and the group of physically active subjects irrespective of their athletic history. Furthermore, in the group of physically inactive former athletes, higher mean results were observed in each case, and for the fingertip-to-floor test and for forward flexion with right rotation, the differences were statistically significant in comparisons with subjects who had never been physically active. The lack of differences in the group of physically inactive subjects between those who were former athletes and those who had never engaged into any sporting activity may be explained as follows: with respect to the tests in the frontal plane by the minimal level of natural daily motor stimulation of movements in this plane of trunk movement, and with respect to the tests in the transverse plane, for the left side, by the predominance of right-handed subjects in the population. The results of flexibility assessment presented in this paper may suggest the existence of a carry-over effect: the physical activity (sport) in the past being "carried over" to the later decades of life.

Increased physical activity provides stimulation to the nervous system and leads to plastic changes through stretch reflexes, mutual inhibition and stretch reflexes (triggered by stretching of the muscles). As a result, the following system of interactions "neuromuscular spindles - Golgi bodies - joint mechanoreceptors" is elevated to a higher functional level. Based on the results of our study it may be concluded that the sensitivity to motor stimuli at young age (regular training is engaged into in the first few decades of ontogenic development) leaves a durable trace in the form of a generally higher level of flexibility compared with the population engaging in an average level of physical activity (17). The lack of motor stimulation later in life obviously leads to the natural decline of flexibility (as a result of decline of the muscle mass and force, dehydration of muscles and intervertebral discs, qualitative and quantitative changes in the connective tissue, etc.). However, a higher "baseline" level might lead to a certain delay in this decline. Obviously, it must be noted that engaging in competitive sport activity is associated with the risk of strain-related changes that may lead to various types of dysfunction in the musculoskeletal system that may be more or less permanent. This issue may , however, be addressed by appropriate selection, programming and execution of the training process and by ongoing medical care.

The issue of optimal ranges of motion may also be subject to discussion. Is a higher range of flexibility always a desirable value for physical health? After all, excessive range or motion, as well as pathologically limited range of motion, may increase the risk of injury (18, 19). It is justified to believe that in the era of predominantly sedentary lifestyle there is a higher risk of reduced rather than excessive flexibility. Our results lead us to believe that comprehensive stimulation with physical activity, also when it occurred in the first decades of life, increases the already mentioned motor potential in terms of flexibility, expanding in a way the limits of adaptation.

Conclusions

A systematic physical activity beneficially influences the level of the functional efficiency of the motor system, including flexibility.

Doing sports in youth brings about a generally higher level of suppleness in adulthood, even taking into account a lack of any physical activity, which can attest to the existence of the „transmission effect".

The body proportions considered in this study do not significantly influence the results of flexibility tests.

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