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The influence of static and progressive stretching exercises on the functional limitations of the musculoskeletal system

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Abstract
Introduction. **The main objective of the study was to assess the effectiveness of a warm-up programme that incorporated static and progressive stretching exercises in minimising the functional limitations of the locomotor system. Materials and Methods. The study consisted of 70 women and 18 men. The subjects performed Functional Movement Screen (FMS) and Core Muscle Strength and Stability Test (CMS&ST) twice. The first, it did not include warm up, which was in accordance with the authors' recommendations. Next, after a week, students were randomly divided into two groups and the tests were carried out again. Before the second examination Group I performed warm-up with static stretching exercises, while Group II did a warm-up consisting of progressive stretching exercises. The students participating in the study were also asked to fill a custom survey. The Mann-Whitney U test was used to evaluate the differences between the groups, and the Wilcoxon's test was used to evaluate the differences between the measurements, with minimal statistical significance set at $p \leq 0.05$. Results. The study showed that static and progressive stretching has a positive impact on minimising the functional limitations of the locomotor system measured with the Functional Movement Screen test. The differences between the first and the second measurement in the women's Group I and II, and the men's Group I and II were statistically significant. (Group I women – $p < 0.001$; Group II women – $p < 0.001$; Group I men – $p < 0.001$; Group II men – $p = 0.003$). Conclusions. Both static and progressive stretching may have a positive impact on minimising the functional limitations of the locomotor system. It is desirable to incorporate that kind of exercises into the supplementary training plan (warm-up/suplementary exercises).**

KEYWORDS: stretching, FMS, injury prevention, functional assessment.

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Introduction

Stretching is a simple, yet a very effective method of improving physical fitness that was developed by Sven A. Sölveborn. It allows to improve, in a safe way, one of the most important motor skills, i.e. flexibility, which is a feature of the locomotor system that enables to reach a high amplitude of exercises, in accordance with the physiological range of joint motion capacities [26, 30, 36]. Stretching exercises can have a variety of functions. In numerous disciplines, stretching is recommended also during the warm-up stage to improve the mobility of the musculoskeletal system. During a warm-up that prepares the body to undertake physical activeness, the body temperature rises. As a result, blood reaches the muscles faster and increases their excitability, which leads to a higher efficiency during physical effort. When the body is properly prepared and warmed-up, it is recommended to perform stretching exercises using proper techniques [13, 17, 30].

It is common to do stretching exercises after performing physical activity. On this stage, their aim is to calm the body and maintain the flexibility of the musculoskeletal system. Positive influence stretching exercises on supporting of post-exercise recovery was scientifically proven. It is important, especially in the case of athletes participated in competitions with high frequency. However one of the most important functions of stretching is minimizing the risk of body injuries [3, 7, 19, 21].

Currently, there are numerous methods of increasing the range of motion, originating from the methodology of sports training and rehabilitation. Each method has its benefits, but it should also be remembered that it carries potential risks for the locomotor system. Therefore, while implementing any of stretching techniques, it is important to adhere to an important rule, according to which flexibility can be increased in different forms of physical activeness, including strength exercises, general exercises and other forms of exercises, on the condition that the movement is performed to its full range. Otherwise, when muscles do not work to their full range, they show a tendency to get shorter, which creates an imbalance between agonist and antagonistic muscles [15, 18, 24, 25, 35].

The main objective of the study was to evaluate the effectiveness of a warm-up programme consisting of static and progressive stretching exercises in minimising the functional limitations of the musculoskeletal system.

Material and Methods

The study consisted of 70 women and 18 men, students of the Medical University of Warsaw (Table 1). The average participant was 22.77 years old ±1.95 (20-26 years old). To the research were qualified students without healthy contraindications for the physical exercises (injuries and diseases of musculoskeletal system).

The subjects performed Functional Movement Screen (FMS) and Core Muscle Strength and Stability Test (CMS&ST) twice. The first, it did not include warm up, which was in accordance with the authors' recommendations. Next, after a week, students was randomly divided into two groups and the tests was carried out again. Before the second examination Group I performed warm-up and static stretching exercises, while Group II did a warm-up consisting of progressive stretching exercises. The students participating in the study were also asked to fill a custom survey.

The Functional Movement Screen test (designed by Gray Cook and Lee Burton) was the main research tool [11, 12]. The test was designed for the purpose of an objective analysis of human movement patterns in relation to human functional capacity, and for the purpose of predicting and preventing injuries among athletes. The Functional Movement Screen consists of seven exercises testing the basic movement patters: 1. Deep squat, 2. Hurdle step, 3. In-line lunge, 4. Shoulder mobility, 5. ASLR – active straight leg raise, 6. Trunk stability push-up, 7. Trunk rotation stability. The FMS is conducted before exercises, prior to the warm-up. The assessment is made in two planes: saggital and coronal. The studied person does three repetitions of a specific test, and the person conducting the research assesses the best result. In case of doubts towards the correctness of the pattern, the score is lower. Each side is assessed separately. Performance of each of the seven exercises mentioned above is graded on a 4-grade scale, in line with the established criteria. Each movement pattern in graded from 0 to 3 points (3 points are awarded to a person who executed a movement pattern in the correct manner, 2 points are awarded to a person who executed a movement pattern with compensation, 1 point is awarded to a person who did not manage to execute a movement pattern, 0 points are given to persons who experience pain during executing a movement pattern or during a provocative test). A participant of the study can obtain 21 points in total [11, 12].

Core Muscle Strength and Stability Test (CMS&ST) was the second research tool. The objective behind using the test is monitoring the core stability of the examined person by the evaluation of his or her strength

Table 1. Characteristic of examined students

Gender	Group	Number of individuals	Age [years]	Body weight [kg]	Body height [cm]	BMI [kg/m²]
Women	I	34	21.47±2.13	56.97±13.68	169.15±6.09	19.96±4.71
	II	36	21.63±1.97	61.60±12.47	168.03±6.83	21.73±3.59
Men	I	9	21.22±1.39	81.88±12.05	181.00±3.39	24.95±3.22
	II	9	21.22±1.64	81.67±13.09	182.22±6.93	24.54±3.01

and endurance. The test consists of holding the posture while supporting the weight on the elbows, commonly known as a “plank”, for three minutes. During the test, the athlete lifts limbs from the ground according to the guidelines of the test assistant, which makes holding the posture harder by decreasing the contact of the body with supporting surface [28].

The data were analyzed using standard methods of statistical analysis and arithmetic means, including standard deviations. In order to establish the used statistical test at the beginning, the Kolmogorov-Smirnov test, it was examined whether the dependent variables had a normal distribution. All results indicated that the distribution of variables was not consistent with the normal distribution, therefore the following non-parametric tests were used. The significance of differences between the results of the first and second measurements were determined with the Wilcoxon signed-rank test. The significance of differences between the groups were determined with the U Mann-Whitney Test. The minimal level of significance was assumed at $p \leq 0.05$. The calculations were conducted using MS Excel and Statistica 10 software.

Results

The study showed that static and progressive stretching has a positive impact on minimising the functional limitations of the musculoskeletal system measured with the Functional Movement Screen test. The differences between the first and the second measurement in the women’s Group I and II, and the men’s Group I and II were statistically significant. (Group I women – $p < 0.001$; Group II women – $p < 0.001$; Group I men – $p < 0.001$; Group II men – $p = 0.003$) (Table 2 and 3).

In Group I, consisting of women that performed static stretching exercises before the second measurement, statistically significant alterations were observed in three tests: hurdle step, in-line lunge and active straight leg raise. The highest results (in both tests) were obtained in the case of straight leg raise, while the lowest results were obtained in the case of deep squat – the test assessing the bilateral, symmetrical and functional mobility of the hip, knee, and ankle joints.

In Group II, consisting of women that performed progressive stretching exercises before the second measurement, a statistically significant improvement was observed in six tests: hurdle step, in-line lunge, shoulder mobility, straight leg raise test, trunk stability push up and rotary stability. During the first measurement, 0 points were recorded in the shoulder mobility test. Whereas, in both tests 0 points were recorded twice in the push-up test.

In Group I, consisting of men that performed static stretching exercises a statistically significant difference

Table 2. FMS results performed by women

Group	Examination	Deep squat	Hurdle step	In-line lunge	Shoulder mobility	Active straight leg raise	Trunk stability push-up	Rotary stability	Sum
I	first	2.15±0.66	2.09±0.51	2.21±0.54	2.50±0.79	2.79±0.41	2.38±0.88	2.18±0.39	16.29±2.02
	second	2.21±0.64	2.50**±0.61	2.47**±0.56	2.59±0.66	2.91*±0.29	2.50±0.66	2.21±0.41	17.38***±1.74
II	first	2.25±0.55	2.17±0.56	2.44±0.51	2.33±0.89	2.69±0.52	2.19±0.89	2.17±0.38	16.25±1.63
	second	2.31±0.47	2.39**±0.55	2.64**±0.49	2.50*±0.77	2.89**±0.32	2.36*±0.72	2.25*±0.44	17.33***±1.67

*p < 0.05; **p < 0.01; ***p < 0.001 – difference between first and second measurement

Table 3. FMS results performed by men

Group	Examination	Deep squat	Hurdle step	In-line lunge	Shoulder mobility	Active straight leg raise	Trunk stability push-up	Rotary stability	Sum
I	first	2.00±0.71	2.00±0.00	2.11±0.33	2.11±0.61	1.89±0.61	2.89±0.33	1.78±0.44	14.78±1.72
	second	2.33*±0.71	2.22±0.43	2.56±0.53	2.33±0.71	2.11±0.33	2.89±0.33	2.00±0.50	16.44***±1.51
II	first	2.33±0.50	1.78±0.44	2.11±0.33	2.11±0.93	1.89±0.93	2.56±0.72	2.11±0.33	14.89±1.90
	second	2.56±0.53	2.11*±0.61	2.11±0.33	2.33±0.87	2.44**±0.73	3.00±0.00	2.11±0.33	17.11**±1.66

*p < 0.05; **p < 0.01; ***p < 0.001 – difference between first and second measurement was observed in deep squat. In others tests except push differences were close to significance.

In Group II, consisting of men that performed progressive stretching exercises a statistically significant differences were observed in hurdle step and push-up test. In the deep squat and push up tests differences were close to significance. In-line lunge and trunk rotation tests, the average results of the first and second attempts are similar.

An improvement in the results of the FMS test was observed in all groups. The results obtained in the women's Group I and II, and the men's Group I and II, indicate the effectiveness of both static and progressive stretching. The women's Group I and II obtained better results of the first and second measurement in the following tests: in-line lunge, shoulder rotational mobility and active straight leg raise (Table 2 and 3).

Considering the bilateral tests, significant differences were also observed between measurements first and second – especially in women (Table 4 and 5).

In the Core Muscle Strength & Stability Test (CMS&ST) no significant differences were observed. The Group I and II, six women reached the maximum time, while the same was observed in the case of seven men. The average time obtained by all participants in the first attempt was 123 seconds, while in the second attempt it amounted to 129 seconds (Table 6).

Table 6. CMS&ST results [s]

Gender	Group	Examination	
		first	second
Women	I	118.12±33.61	130.85±35.81
	II	119.96±39.17	125.06±36.23
Men	I	130.31±37.44	138.78±40.95
	II	113.68±38.28	122.67±42.72

Discussion

In the light of the growing popularity of physical activeness, it is very important to take care of safety when performing movements, and to introduce measures preventing bodily injuries. For this purpose, supplementary exercises, such as stretching, should be a part of trainings. Supplementary stretching exercises are

Table 4. FMS bilateral tasks results performed by women

Group	Examination	Hurdle step		In-line lunge		Shoulder mobility		Active straight leg raise		Rotary stability	
		left	right	left	right	left	right	left	right	left	right
I	first	2.38 ±0.55	2.23 ±0.55	2.50 ±0.56	2.38 ±0.61	2.53 ±0.75	2.73 ±0.57	2.88 ±0.33	2.82 ±0.39	2.29 ±0.46	2.26 ±0.45
	second	2.58** ±0.55	2.64*** ±0.54	2.67* ±0.47	2.59* ±0.56	2.71** ±0.59	2.76 ±0.49	2.94 ±0.24	2.94 ±0.24	2.44* ±0.51	2.41* ±0.50
II	first	2.38 ±0.64	2.39 ±0.49	2.61 ±0.49	2.63 ±0.49	2.44 ±0.73	2.58 ±0.84	2.83 ±0.45	2.75 ±0.50	2.28 ±0.45	2.25 ±0.43
	second	2.63*** ±0.54	2.63*** ±0.48	2.86** ±0.35	2.75 ±0.44	2.63** ±0.64	2.75* ±0.65	2.91 ±0.28	2.94** ±0.23	2.41* ±0.50	2.36* ±0.49

*p < 0.05; **p < 0.01; ***p < 0.001 – difference between first and second measurement

Table 5. FMS bilateral tasks results performed by men

Group	Examination	Hurdle step		In-line lunge		Shoulder mobility		Active straight leg raise		Rotary stability	
		left	right	left	right	left	right	left	right	left	right
I	first	2.33 ±0.50	2.33 ±0.50	2.44 ±0.53	2.67 ±0.50	2.22 ±0.67	2.67 ±0.50	1.89 ±0.60	2.22 ±0.44	2.22 ±0.67	2.00 ±0.71
	second	2.56 ±0.53	2.44 ±0.53	2.67 ±0.50	2.89 ±0.33	2.33 ±0.71	2.89 ±0.33	2.00 ±0.50	2.33 ±0.50	2.44 ±0.53	2.22 ±0.67
II	first	2.00 ±0.71	1.78 ±0.67	2.22 ±0.44	2.11 ±0.33	2.22 ±0.97	2.56 ±0.53	2.00 ±1.01	2.00 ±0.87	2.22 ±0.44	2.22 ±0.44
	second	2.33* ±0.71	2.33** ±0.71	2.44 ±0.53	2.11 ±0.33	2.33 ±0.86	2.67 ±0.71	2.33** ±0.86	2.33** ±0.71	2.33 ±0.50	2.33 ±0.50

*p < 0.05; **p < 0.01 – difference between first and second measurement an important element of trainings for both professional athletes and amateurs. According to the own research, static and progressive stretching incorporated in the warm-up stage contributes to minimising the functional limitations of the musculoskeletal system. The research allowed to observe a statistically significant improvement in performing movement patterns after introducing a set of stretching exercises in two variants: static and progressive [17, 30, 32].

Stretching techniques and their effectiveness are widely described in literature. However, the results of the studies are not unequivocal. Some researchers demonstrate a positive impact of stretching in bodily injuries prevention, thanks to increased flexibility of tendon and muscle fibres. Vasileiou et al. obtained a positive result in the study carried out using a static and dynamic stretching method. The implementation of both stretching methods in the warm-up stage in the case of a group of amateur football players allowed to observe a significant improvement in lower limb flexibility [34]. The majority of authors, however, cast doubts as to the use of stretching before physical activeness. Balle et al. [2] and Torres et al. [33] observed a major decrease of muscle strength directly after performing stretching exercises. In the case of sportspersons practicing disciplines that require explosive muscle involvement, stretching before a workout may lead to worse results. Due to ambiguous results of the available research, it is impossible to draw definitive conclusions regarding the link between stretching and sport injuries [2, 33].

Brown [9] and Mokha et al. [23] demonstrated that the persons who obtained a result below 14 points in FMS test are four times more likely to suffer injuries in comparison to those with the result above 14 points. The Functional Movement Screen test comprises of seven exercises that provide information on bodily structures. The studies show a significant dependency between the deep squat test and the total FMS result. According to Brown and Mokha et al., the persons who obtained a low score in the deep squat test were much more likely to achieve the FMS test result below 12 points. Therefore, the deep squat test may constitute a kind of control test, which would allow to shorten the research time by indicating the persons predisposed to obtain low total FMS result. In the case of such persons, further tests would be conducted aiming to determine the likelihood of occurrence of bodily injuries [9, 23].

The existing studies indicate that physical activeness, training experience, age and BMI have a significant impact on the FMS test result. The influence of these significant factors is stressed in the publications of Teyhen et al. [31], Adamczyk et al. [1], Lloyd et al. [20], Mitchell et al. [22], Portas et al. [27], Boguszewski et al. [5, 6], Kałużny et al. [16] and the own research does not show a significant correlation between the Functional Movement Screen and Core Muscle Strength and Stability tests results. This result, however, may be unreliable when being based on a one-time measurement. The impact of stability training on movement patters functionality was examined by Boguszewski et al. [6]. It was observed that women basketball players gained better FMS test results after an 8-week stability training programme. The core strength and stability was assessed with the Core Muscle Strength and Stability Test (CMS&ST). After a period of stability training, improved results were observed also during this test. Therefore, exercises improving core stability, strength and proprioception may be used to prevent functional limitations of locomotor system [6].

The FMS test is a frequently used research tool. It allows for a comprehensive examination of movement patterns and for identification of existing functional disorders in amateurs practicing sports and professional sportsmen of all disciplines. The wide use of FMS test proves its effectiveness. It allows to conduct a functional assessment of an athlete in an easy and reliable way, in order to identify the limitations of the locomotor system and to locate its weaknesses. Such a basic assessment allows for an adjustment and customisation of a training plan that would focus on the elimination of incorrect movement patterns, and, as a result, for an avoidance of bodily injuries [9, 14, 29].

The own research demonstrated a statistically significant improvement of the Functional Movement Screen test in both groups. The participants obtained results above 14 points, which did not place them at a greater risk of suffering bodily injuries. Similarly, in the deep squat test, described in the literature as a control test, the participants gained a high result, which meant that they are predisposed to a good overall performance in the FMS test [10]. Despite obtaining satisfactory results of the own studies, it is recommended to conduct further research that would cover a several-week programme consisting of stretching and core stability exercises.

There is a need to conduct more research using various methods that would enable to assess the influence of musculofascial auto-relaxation on the functional limitations of locomotor system. The authors of the existing research are not unanimous in respect to the influence of stretching on minimising the risk of bodily injuries, hence this subject requires further investigation. The disadvantage of the research is the subjective assessment by the physiotherapist. However each task of

FMS test is defined in detail. Physiotherapist can assess sportsmen in sagittal and frontal plane. Moreover test is used all over the world. There is a lot of literature about that [1, 5, 8, 10, 14, 16, 27, 29]. Researcher can compare own results with the results other authors. The direction of further research could be to assess the impact of other types of complementary and supplementary exercises to prevent injuries of musculoskeletal system. There is better to prevent injuries than to treat them.

Conclusions

1. Static and progressive stretching may have a positive impact on minimising the functional limitations of the locomotor system. It is desirable to introduce that kind of exercises into the supplementary training plan (warm-up/suplementary exercises).
2. The FMS test may serve as a diagnostic tool for bodily injuries prevention. It provides information on functional limitations of locomotor system and weaknesses in the biokinematic chain, which require correction and additional effort.
3. No significant statistical differences were observed between the group doing static stretching and the group doing progressive stretching in the warm-up stage. Both methods may have a positive impact on the functioning of the locomotor system.
4. Research on the use of stretching should be continued on more numerous and more varied groups, with the implementation of more advanced methods.

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