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Original Article

Improving upper body flexibility in students through various types of stretching during physical education lessons

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Abstract
This study, which was conducted on a university student population, followed the progress of upper body flexibility as a result of performing static (SS) and dynamic stretching (DS) during warm-up and cool down in physical education lessons. A group of 297 subjects (206 males and 91 females with an average age of 23.62 ± 4.3 years), who were students of the Dunărea de Jos – Galați University over the course of the academic year of 2018–2019, participated in the specific curricular physical education activities for 28 weeks with 1 module/2 h per week. The results recorded analyzed using the ANOVA procedure with repeated measurements confirmed only partially significant correlations in the investigated groups, especially for the tests including working positions and motions that are similar to the ones used frequently in joint mobilizations and muscle stretching during physical activities, an aspect reinforced by the high values of Partial eta squared/η^2_p. In many cases, the null hypothesis could not be rejected with only insignificant increases of the results, and the F values corresponded to a $P>0.05$ and η^2_p with values of <0.14, indicating low effects of stretching on the flexibility. The female subjects recorded statistically superior values compared to the male subjects in most tests, but the low frequency of the weekly physical activities was an impediment that limited significant improvements for the entire battery of tests. In conclusion, the authors recommend as solutions for optimizing the flexibility an increase in the number of physical education classes in the curricula of universities, but also making the younger generations aware of the need for exercise and stretching during leisure time activities as ways to ensure a state of wellbeing and to achieve good fitness.
Keywords: flexibility; dynamic and static stretching; range of motion; joint mobility; students; warm up; cool down

Introduction

Flexibility is a factor that influences one's health and physical fitness along with muscle strength and body stability; its optimal level of manifestation reduces the risk of injury, increases the motor performances during daily activities, leisure time activities, or sports/competitive activities. The limitation of flexibility can be prevented through physical activities that increase one's range of motion (ROM), creating an improved tolerance of the tissues to stretching, reducing joint and spine pain (Micheo, Baerga, & Miranda, 2012). The importance of flexibility in performing daily life activities, leisure time activities, and medical or athletic rehabilitation is supported by numerous studies (Alexe, 2010; Badau & Badau, 2018; Dobrescu, 2019; Enoiu, 2006; Gheorghiu, 2014; Iordan, Mocanu, & Mereuta, 2021). Flexibility is important in normalizing biomechanical functions in athletic activities, leisure time activities, and activities of daily living, its low values causing muscle injuries. Active children present higher values than the ones with a sedentary lifestyle, regularly performed stretching being effective in increasing their range of motion (Liyanage, Krasilshchiko, Hashim, & Matjawis, 2020; Souza, Pereira, & Gomes, 2017).

The frontal and sagittal spine ROM values and shoulder flexibility are positively correlated, but there are major variations according to sex, age, individual anthropometric sizes, occupation, sports, etc. (Battié, Bigos, Sheehy, & Wortley, 1987). Spine flexibility is important in many sports activities, some of them (women's gymnastics) demanding extreme amounts through hyperextension movements needed to perform technical procedures, especially in the lumbar area, where without these limitations, it negatively influences one's health (Sands et al., 2016). Spine flexibility directly influences the abdominal muscle performances (Gidaris, Hatzitaki, & Mandroukas, 2009), which specifies its role in performing trunk curl-ups from the supine position.

Flexibility exercises are suggested as a prevention or treatment for tendon–muscle problems, with low flexibility values able to foretell functional problems, such as arterial stiffness. In middle age groups (40–59 years old) and in people over 60, experts have observed increased joint stiffness in subjects with limited flexibility, which was not observed in young people (20–39 years old) (Yamamoto et al., 2009). Low trunk flexibility can generate problems also in the case of healthy adults, which is associated with high aortic stiffening (Gando et al., 2017). The sitting SS versions play a role in limiting the cardiovascular risk, reducing the heart

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rate and the central and peripheral blood pressure, which has beneficial effects on lumbar flexibility (Logan, Kim, Lee, Byon, & Yeo, 2018). The usefulness of DS in warm up, compared to SS is highlighted for various demands, physical activities and sports (sprints and agility, power, artistic gymnastics, football, etc.), according to (Dallas, Theodorou, & Paradisis, 2019; Ferrara, Forte, Senatore, & D'elia, 2019; Galazoulas, 2016, 2017; Kyranoudis et al., 2018). SS values under 60 sec. in warm up does not generate negative effects on the knee flexor and extensor muscles (Vieira et al., 2019).

An increasing number of studies have shown the effectiveness of muscle stretching as it is integrated in the Pilates and Hatha Yoga techniques. They identified the progress of spine flexibility in the thoracolumbar area in all anatomical planes, an improvement in joint ROM and in trunk and pelvis flexibility, reducing the risk of injury in elderly people and axial musculoskeletal injuries (Geremia, Iskiewicz, Marschner, Lehnen, & Lehnen, 2015; Grabara & Szopa, 2015; Oliveira, Oliveira, & Pires-Oliveira, 2016; Phrompaet, Paungmali, Pirunsan, & Sitilertpisan, 2011). The use of the Pilates Matwork technique does not have the same effect of significant improvement in 8–12-year-old children in regards to trunk flexibility and posterior chain as it has had in adults (Cibinello, de Jesus Neves, Carvalho, Valenciano, & Fujisawa, 2020). The effectiveness of DS vs. SS concerning improvement of flexibility is a much-debated subject in professional literature. SS and Proprioceptive Neuromuscular Facilitation (PNF) lead to enhanced flexibility and ROM values, but they induce a limitation of power and strength performances, while DS and its ballistic version leads to enhanced power and strength performances with the results differing according to the specificity of the sport (Lima, Ruas, Behm, & Brown, 2019). The use of maximal and submaximal intensity stretches and increased work volumes can cause drops in power in adult women (Nogueira et al., 2019). There are sources that do not indicate significant differences between the use of DS and SS in the case of female volleyball players, in regards to lower limbs power and the dominant oscillation of the arm (Nogueira et al., 2019). The favorable effects of DS and SS were highlighted by Çelik (2017), who noticed an improvement in shoulder flexibility in young female volleyball players after both types of stretching. However, he identified a decrease in the scapular abduction strength after the SS, while the DS generated an improvement in the shoulder internal rotation force. SS does not provide a good warm-up of neck and shoulder muscles, which are often neglected during warm-up because this part needs dynamic movements and an imitation of the technical skills that are specific to the sport: throws, launches using the dominant segment, or ambidextrous performances. DS is recommended and effective during warm-up, where its effects are manifested also with regards to balance and coordination; however, the movements must be performed with an individualized speed, range, and frequency, primarily exercising the muscles and joints involved in the work, whereas SS is recommended for cool down (Mann & Jones, 1999).

Material and Methods

The purpose of this study was to verify the effects of implementing various stretching combinations on upper body flexibility during university physical education lessons.

Research hypotheses:

H0: There are no significant differences between flexibility test performances during the three assessments in the investigated groups (m1=m2=m3).

H1: Implementation of this stretching program will generate statistically significant differences between the flexibility values on the sexes during the three assessment stages (m1≠ m2 ≠m3).

H2: The average results for the women will indicate superior and statistically significant performances compared to the men for the flexibility tests.

Participants

The research was conducted over the course of the academic year of 2018–2019 on a group of undergraduate students from the Dunărea de Jos University, Galați, who studied Medicine and A.C.I.E.E. (Automatic Control, Computer Science, Electrical and Electronic Engineering), during first- and second-year physical education classes. The studied group comprised 297 subjects (206 males and 91 females) with an average age of 23.62±4.3 years. The study eliminated subjects who have not participated in at least 90% of the physical education classes, and all the participants were declared medically apt for physical work, even if most of them were not involved in regular physical activities. The team that carried out the present study declares that the subjects who participated in the research were informed of the voluntary nature of participation in the research, understood the information received and requested for research. They understood that withdrawal from the research could be done at any time without any adverse consequences on the participant. The study observed the ethical standards of research, and the students gave their consent for participation in this study.

This article represents the equal contribution of all authors.

Procedure

The study was approved by the "Dunarea de Jos" University Galati Ethics Committee in accordance with the Ethical Standards of the Helsinki Declaration (ecbr5-03-2020). The tested group was informed regarding the contents of the activities, the battery of tests, and the goals of the study conducted over the entire academic year (28 weeks). The tests were performed in three stages: T1 - the start of the first semester/October, T2 - week 12/December before the winter holidays, and T3 - end of May/end of teaching activity before the summer holidays. The FPES Human Performance Research Center in Galați offered optimal conditions for this study regarding the material conditions and similar testing conditions for the three above-mentioned stages. This study aimed to assess the flexibility of all body segments, but the large volume of data was reduced to those only on upper body flexibility for this paper. In the study, we applied seven tests to evaluate the mobility of the spine in the frontal, antero-posterior, and scapulo-humeral joints.

Flexibility training

The stretching program was applied during the warm-up for 5 min, which was preceded by jogging/aerobic for 3 min, and it was structured based on versions of repetitive DS with gradually increasing speed and range up to slightly go past individual limitations but avoiding exaggerated demands that would lead to intense joint and muscle pains. The choice was correlated to the theme of the lesson: football, volleyball, track and field, power, coordination, speed, etc. SS exercises were primarily programmed during cool down with 5 min per lesson, variable durations of maintaining stretching positions of the muscles (10–30 s), and mobilization of the joints that are in demand primarily during the main part of the lesson. The exercises were based on simple and effective drills, which are well known or easy to learn, in various positions of standing, sitting, prone and supine, hanging, and using accessible materials/devices, such as resistance bands, mattresses, Swedish ladder, and exercise balls. Examples of drills used to improve flexibility that were adapted to the particularities of the studied groups included (Mocanu, 2017; Motus Personal Training & Physiotherapy, 2021; Physique Engineer, 2019) being in a hanging position with back against the Swedish ladder, lateral balancing of the body or back extension with the knees flexed at 90°, and soles on the floor; forward lunges with palms backwards on the Swedish ladder and back extension; cobra and cat Yoga positions; simultaneous or diagonal lifting of the arms and legs in prone position; pelvis lifting in supine position with feet on the exercise ball; arms lifting forwards or lateral upwards with palms grabbing the resistance band; lateral flexions of the trunk with arching freely or using objects; contralateral rotation of the trunk, throwing the ball at the wall; back extension in standing position facing the Swedish ladder by bending the trunk forwards and progressively lowering the palms from step to step; traction of the elbow bended backwards using the other arm; and trunk twisting and back extension in a standing position with palms grabbing the back of the pelvis. The suggested exercises demanded the main muscle groups contributing to the performance of upper body movements: trapezius, deltoid, erector spinae, latissimus dorsi, rhomboideus minor and major, supraspinatus, infraspinatus, teres minor and major, pectoralis, etc.

Results and Discussion

The statistical analysis was based on the ANOVA procedure with repeated measurements that were differentiated into the sexes, which identified the progress of the experiment over the course of the three assessment stages, and it comparatively analyzed the progress between the sexes. The statistical calculation was performed using SPSS, whereas the charts were made using Microsoft Excel (Dr. Todd Grande, 2016; Hair, 2009; Murariu, 2018; Murariu & Munteanu, 2018; Opariuc-Dan, 2011; Statistics & Theory, 2020). The sphericity test (Maucly's) was used as the main criterion of the ANOVA test by applying corrections of the degrees of freedom for subunitary values of ε and significance thresholds of $P<0.05$, meaning Greenhouse–Geisser for $\varepsilon<0.75$ and Huynh–Feldt for $\varepsilon>0.75$. The confidence interval was set at 95% ($P<0.05$). The Partial eta squared (η^2_p) was calculated to identify the practical effect of the proposed stretching program on the flexibility, avoiding the formulation of categorical conclusions, strictly based on the observed statistical differences. Table 1 presents the ANOVA results of the repeated measurements.

Table 1. *ANOVA results of repeated measurements*

Test	**group**	**Maucly's Test of Sphericity**		**df**	**Error df**	**F**	**Sig.**	**(η^2_p)**
		Sig.	**ε**					
R lat. trunk flexib.	M	0.458	1.000	2	410	138.469	0.000	0.403
	F	0.074	0.966	2	180	81.901	0.000	0.476
L lat. trunk flexib.	M	0.186	0.993	2	410	121.657	0.000	0.372
	F	0.617	1.000	2	180	66.883	0.000	0.426
Comb. spine-hip flexib	M	0.000	0.863	1.727	354.019	81.427	0.000	0.284
	F	0.002	0.899	1.799	161.869	91.425	0.000	0.504
Back muscle flexib.	M	0.000	0.757	1.515	310.545	2.349	0.111	0.011
	F	0.000	0.806	1.612	145.125	3.922	0.030	0.042
Shoulder flexib. / baton test	M	0.000	0.514	1.029	210.874	5.151	0.023	0.025
	F	0.210	0.988	2	180	57.778	0.000	0.391
Apley test - R	M	0.000	0.808	1.615	331.159	1.504	0.226	0.007
	F	0.000	0.500	1	90	1.000	0.320	0.011
Apley test - L	M	0.000	0.661	1.323	271.173	4.267	0.029	0.020
	F	0.000	0.500	1	90	2.022	0.158	0.022
Arm flexib. horizontal	M	0.000	0.804	1.607	329.536	5.399	0.009	0.026
	F	0.000	0.818	1.636	147.209	1.508	0.226	0.016
Arm flexib. vertical	M	0.000	0.757	1.506	308.758	2.349	0.111	0.011
	F	0.000	0.824	1.647	148.249	3.068	0.059	0.033

The sphericity conditions were met only for a few tests, and correction factors were applied for the rest of them. A significant improvement in the performances for both sexes was observed in the case of the right and left lateral trunk flexibility, and for the combined spine-hip flexibility test, in the latter case, the men showed a $F(1.727;354.019)=81.427$ with $P=0.000$, a value <0.05, and the women a $F(1.799;161.869)=91.425$ with $P=0.000$, a value <0.05. These significant values were reinforced by the size effect results, which were $\eta^2_p=0.284$ for men and 0.504 for women, with results that were >0.14, indicating a strong influence of the stretching program on the flexibility for the first three tests. This aspect was encountered in only one more case, the women's baton test, where $F(2;180)=57.778$ with $P=0.000$, a value <0.05, and a $\eta^2_p=0.391$, a value >0.14. This significant progress was not confirmed for the other tests with significant F values, but which were not supported by the strong effects of η^2_p; there are numerous cases in which F values indicate insignificant accumulations, and η^2_p values indicate low or null effects of the independent variable. For example, for the Apley left test, the men recorded a significant value for $F(1.323;271.173)=4.267$ with $P=0.029$, at value <0.05; however, $\eta^2_p=0.020$, which indicated a poor effect of the stretching program. In the same test, the women recorded an insignificant value for $F(1;90)=2.022$ with $P=0.158$, a value >0.05, and $\eta^2_p=0.022$ also indicated a weak effect.

In 11 out of the 18 results presented in Table 1, there are not strong or even medium values of Partial eta squared (η^2_p) but only weak values, which confirms that the effect produced by the independent variable does not have the positive result expected. Interestingly, this aspect was encountered in tests based on work positions and movements that are less used during warm-up and cool down, such as the supine position, arm crossed behind the trunk, blocking the trunk with arms stretched horizontally or vertically while sitting, and in tests in which the performed movements require a flexion of the trunk sagittally and frontally or arm rotation, with the result showing significant thresholds.

Table 2. *Results of the differences in pairs of tests*

Test	Group	T1-T2		T2-T3		T1-T3	
		Mean difference	**Sig.[a]**	**Mean difference**	**Sig.[a]**	**Mean difference**	**Sig.[a]**
R lat. trunk flexib.	M	-0.333	0.000	-0.218	0.000	-0.551	0.000
	F	-0.368	0.000	-0.363	0.000	-0.731	0.000
L lat. trunk flexib.	M	-0.318	0.000	-0.221	0.000	-0.539	0.000
	F	-0.319	0.000	-0.280	0.000	-0.599	0.000
Comb. spine-hip flexib.	M	0.597	0.000	0.177	0.011	0.774	0.000
	F	0.538	0.000	0.516	0.000	1.055	0.000
Back muscle flexib.	M	-0.024	0.955	-0.049	0.473	-0.073	0.250
	F	-0.110	0.475	-0.165	0.250	-0.275	0.074
Shoulder flexib. / baton test	M	0.413	0.000	0.850	0.258	1.262	0.030
	F	0.527	0.000	0.462	0.000	0.989	0.000
Apley test - R	M	-0.024	0.955	-0.024	0.955	-0.049	0.473
	F	-055	0.960	0.000	-	-0.055	0.960
Apley test - L	M	-0.024	0.955	-0.097	0.136	-0.121	0.075
	F	0.000	-	-0.110	0.475	-0.110	0.475
Arm flexib. horizontal	M	-0.097	0.136	-0.073	0.250	-0.170	0.024
	F	-0.055	0.960	-0.055	0.960	-0.110	0.475
Arm flexib. vertical	M	-0.049	0.473	-0.024	0.955	-0.073	0.250
	F	-0.110	0.475	-0.110	0.475	-0.220	0.135

a. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the 0.05 level.

Table 2 presents the significance differences between the pairs of tests: T1-initial, T2-intermediary, and T3-final. In the first three tests (R and L lateral flexibility, combined spine-hip flexibility) for both sexes and in the Baton test for women, significant differences were recorded for all pairs, which showed constant and uniform progress throughout the academic year, and all the significance thresholds of P were <0.05.

This was in contrast to the case of tests for back muscle flexibility, R and L Apley, vertical arm flexibility for both sexes, and horizontal arm flexibility for women, where there were not any significant increases in the performances during any pairs of tests, and the P values were >0.05, which supports the results shown in the first table. One interesting aspect was found in the Baton test performed on the men, where significant differences were recorded between T1 and T2/first semester; then, there was a plateau of the progress between T2 and T3/second semester; the accumulation in the first semester was the basis for the significant progress in the entire academic year/between T1 and T3 with $P=0.030$, a value <0.05. A different situation was recorded for the horizontal arm flexibility test on the men, where the progress was insignificant between semesters; however, the low correlations still generated a significant difference for the academic year with $P=0.024$, a value <0.05.

Table 3 and Figures 1–7 present the comparative progress and the significant differences of the results between sexes.

Table 3. *Overall results and differences between sexes*

Test	group	T1	T2	T3	Mean	Mean difference	Sig.[a]
R lat. trunk flexib.	M	22.4466	22.7791	22.9976	22.741	-0.394	0.451
	F	22.7692	23.1374	23.5000	23.136		
L lat. trunk flexib.	M	21.9563	22.2743	22.4951	22.242	-0.712	0.192
	F	22.6484	22.9670	23.2473	22.954		
Comb. spine-hip flexib	M	37.772	37.1748	36.9976	37.315	6.582	0.000
	F	31.264	30.7253	30.2088	30.733		
Back muscle flexib.	M	4.1748	4.1990	4.2476	4.207	-1.086	0.011
	F	5.1648	5.2747	5.4396	5.293		
Shoulder flexib. / baton test	M	96.2330	95.8204	94.9709	95.675	21.114	0.000
	F	75.0659	74.5385	74.0769	74.560		
Apley test - R	M	8.8107	8.8350	8.8592	8.835	-0.652	0.058
	F	9.4505	9.5055	9.5055	9.487		
Apley test - L	M	6.6262	6.6505	6.7476	6.675	-1.494	0.006
	F	8.1319	8.1319	8.2418	8.168		
Arm flexib. horizontal	M	6.4078	6.5049	6.5777	6.497	-2.075	0.000
	F	8.5165	8.5714	8.6264	8.571		
Arm flexib. vertical	M	1.9660	2.0146	2.0388	2.006	-1.840	0.000
	F	3.7363	3.8462	3.9560	3.846		

a. Adjustment for multiple comparisons: Bonferroni
*. The mean difference is significant at the 0.05 level.

We observed high values for women in regards to R and L lateral flexibility, but these were not also statistically significant with P=0.451, and 0.192, respectively, values >0.05; this was found only for the Apley test R, and in all the other cases, the women showed superior results.

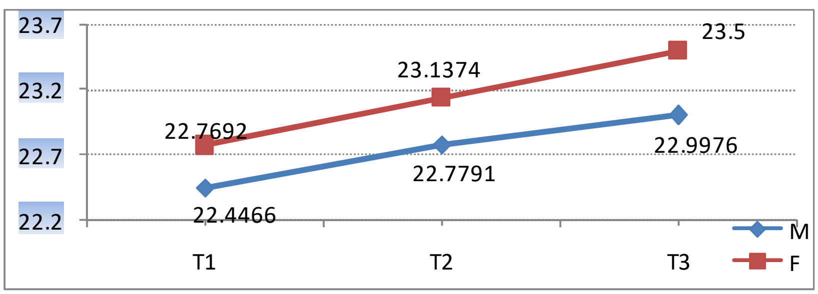

Figure 1. *Results for average right lateral flexibility*

Significant differences were observed for the combined spine–hip flexibility test, where the women recorded higher values than the men, corresponding to a P=0.000.

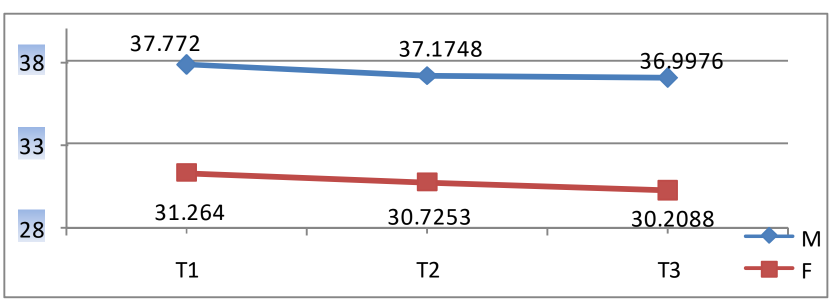

Figure 2. *Combined average results for spine–hip flexibility*

The women recorded statistically significant higher averages also for the Back muscle test, the men not being able to get their results closer. In total, 60 men showed 0 points during the final testing (29.12%), 117 showed an average score (56.79%), and only 29 showed a maximum score (14.07%). The women recorded better values in regards to the extreme values: 21 points (23.07%), for the minimum score, 41 for the medium score (45.05%), and 29 for the maximum score (31.86%).

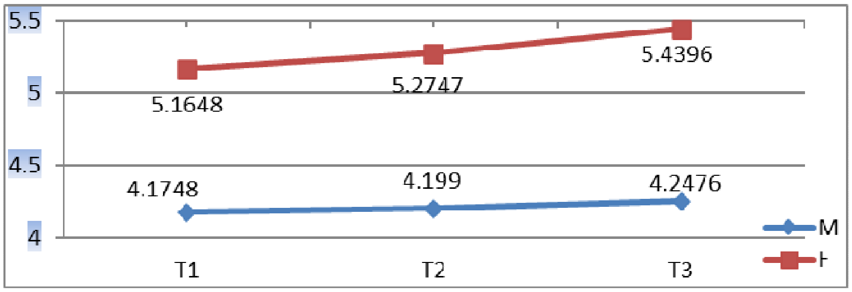

Figure 3. *Average results for back muscle flexibility*

The biggest differences between the results in the sexes were recorded for the Baton test, where these values could be explained through the anthropometric values (larger arm length and shoulder width in men) that led to high values for this test; the men were thus disadvantaged even at the same scapulohumeral joint angle.

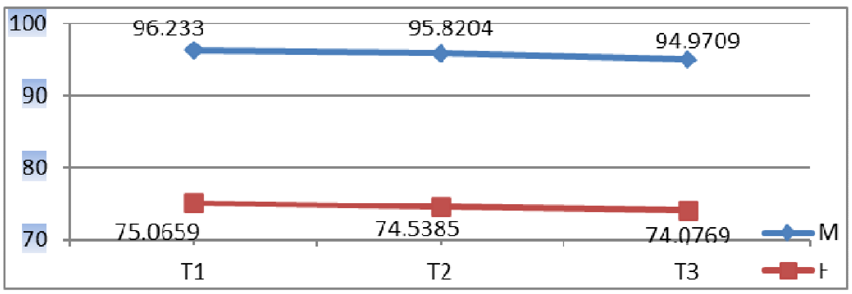

Figure 4. *Average results for Baton test flexibility*

The differences were insignificant for the Apley R test with P=0.58, a value >0.05, but they were significant for the Apley L/the non-dominant main segment with P=0.006, a value <0.05. In the latter case, the women recorded smaller null values and higher maximal values (in percentage) than the men did: 14 cases with a null score (15.38%) compared to 60 cases in the men (29.12%) and 73 cases with a maximum score (80.21%) compared to 132 in the men (64.07%). Figure 5 shows a stagnation of flexibility values in women over the course of the first semester, thus a lack of progress between T1 and T2, which showed the same value.

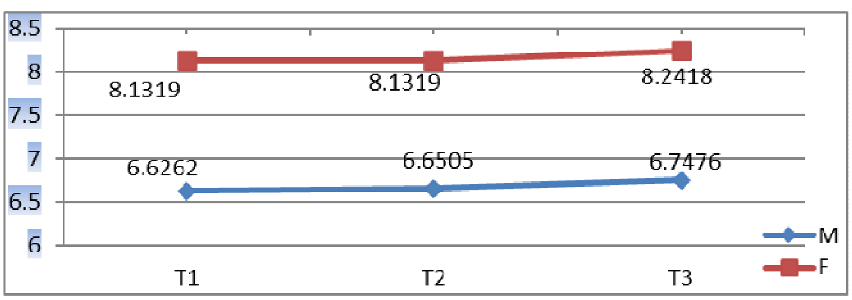

Figure 5. *Average flexibility results of the Left Apley Test*

The horizontal arm flexibility test also showed the women's superiority, even if none of the groups recorded statistically improved values because of the proposed stretching program. The maximum, medium, and null score values indicated this: 30 men (14.56%) recorded a null score, 81 (39.32%) showed a medium score, and 95 (46.11%) had a maximum score. Only one woman (1.09%) recorded a null score, 23 (25.27%) recorded a medium score, and 67 (73.62%) had a maximum score.

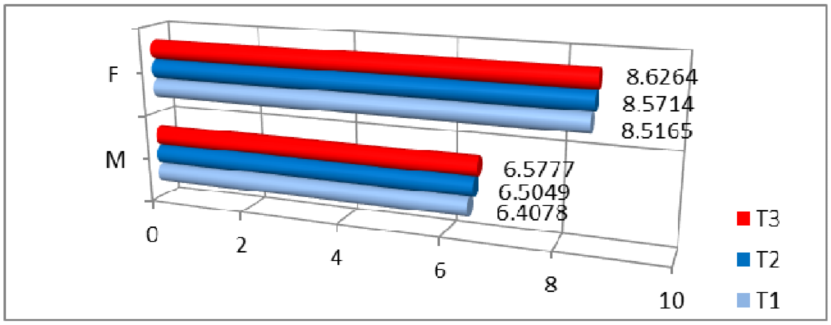

Figure 6. *Average horizontal arm flexibility results*

The test that the students perceived to be the most difficult was the flexibility test with arms raised vertically with the large number of null results confirming this. In many cases the students were unable to completely lift and extend their arms because the movement blocked the thorax and shoulders, presenting major difficulties for them to move their trunk away from the wall. Even if the women recorded superior average values, the number of cases with low scores indicates real performance issues: 38 women (41.75%) recorded a null score, 34 (37.5%) showed a medium score, and 19 (20.87%) had a maximum score. The men had a number of 139 cases (67.47%) with a null score with 50 (24.27%) with a medium score and only 17 (8.25%) with a maximum score.

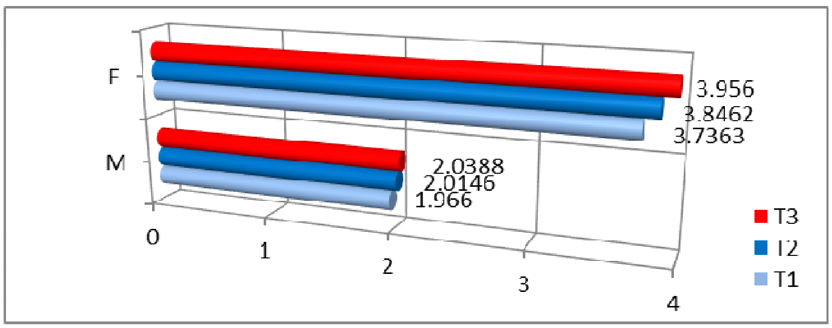

Figure 7. *Average vertical arm flexibility results*

Discussions

The results confirmed only for a few cases the first working hypothesis (referring to significant progress for each sex), and in most cases, the second hypothesis (regarding the significant superiority of the women during the flexibility assessment tests) was confirmed. The study was limited by a lack of laboratory tests based on latest generation devices, which would have allowed a higher measurement accuracy by using motion sensors, goniometers, electromyography/EMG, 3D cameras, etc., all of which could help provide a complete understanding of the movements performed by joints and muscles. Thus, the large number of tests covered all the upper body movements, and the results are a good indicator of the flexibility for the tested groups. The studies that focused on assessing flexibility for various categories of people, based on SS and/or DS programs have identified mostly favorable aspects regarding the range of motion progress, but they are based on a higher frequency of stimuli application, even with shorter time intervals in which the experiments were conducted. The beneficial effect of various types of stretching in elderly people, especially in the cervical and shoulder areas was proven by (Anacleto et al., 2019), who states that the use of Omega 3-based supplements does not generate extra benefits on the flexibility of the subjects.

Preoccupations for improving flexibility through extracurricular stretching programs (3 classes per week x 90 min.) are a real success in high school teenagers (15-16 years old), significant increases in upper body joint flexibility being recorded (Andriichuk, Hreida, Ulianytska, Zadvorniy, & Andriichuk, 2021).

An exercise program for stretching and strength that was applied on a group of 300 Brazilian pupils for 8 weeks 2 times per week had positive effects on the trunk mobility, shoulder posture, and reducing musculoskeletal pain. The spine mobility increased by 5° in the experimental group, whereas in the control group, there was a decrease by 1.8° (Batistão et al., 2019). SS exercises soften the spine concaveness in the thorax and cervical areas, reduce the scapular hunchback, and align the cervical and lumbar areas, according to a program for nurses aged 18–60 that lasted for 8 weeks that was 3 days/week with 40 min/session, and each static exercise was performed 4 × 30 s with a 30-s break (Filho, Gurgel, Silva, & Porto, 2017). Even if flexibility values are correlated to specific sports demands, (Singh, Singh, & Singh, 2011) do not identify significant differences between football students and badminton students. However, (Masliak, Krivoruchko, Bala, Horchaniuk, & Korchevska, 2019) highlight the beneficial effect of cheerleading exercises on the spine and shoulder bending movements, with strong effects in fifteen-year-olds. Strong effects on the spine flexibility/hyperextension and muscle strength were recorded in young jazz dancers, after 24 training sessions (Komeroski, Delabary, & Haas, 2016).

The effectiveness of Pilates has been highlighted (Alves de Araújo et al., 2012), and it improved the spine flexibility and posterior muscle chains and reduced the nonstructural scoliosis degree in a group of 31 Brazilian students. The combination of Pilates and the Schroth method (based on exercises of spine elongation and correction of trunk asymmetries), applied for 24 weeks daily with 1 h/session was favorable for chest expansion and trunk flexion for 69 young people with scoliosis who were between 10 and 17 years of age (Rrecaj-Malaj, Beqaj, Krasniqi, Qorolli, & Tufekcievski, 2020).

Other studies have mentioned the effectiveness of stretching in various professional categories (Amako, Oda, Masuoka, Yokoi, & Campisi, 2003). They confirmed the beneficial role played by SS in reducing pain and relaxing muscles, which reduced the incidence of injury and increased flexibility in a group of 383 young military men who were 19. The use of stretching during breaks by management and warehouse workers reduced upper body paresthesias, improved cervical and shoulder flexibility in the first category, while in the second category, there was an increase in the flexibility of the trunk and of the body areas that were affected by the work (Martins et al., 2015).

The use of contralateral trunk bending, contralateral trunk rotation, and the combination of these two is an optimal solution for the stretching of the latissimus dorsi, as stated in a study (Asayama et al., 2021) conducted on 14 young men with an average age of 25.3 years. Another study (Wakimoto et al., 2018) highlighted the effect of three versions of stretching on the trunk flexibility: using an unstable flexible chair, a stretching bench, and a stretch pad. The cumulated duration of the three stretches was for 6 min with recorded improvements in the neutral angles of the spine in the thorax and lumbar areas, an increase in the thoracolumbar extension, and horizontal flexion.

A study was conducted (Yang, Kim, Park, & Kim, 2015) on two groups including subjects with lumbar pain, who performed spine stabilization exercises and a combination of stabilization and mobilization exercises for 12 weeks; it showed that the combined version was more effective regarding significantly increasing the trunk flexor and extensor muscle strength and the thorax flexion; however, the lumbar flexion was insignificant. The usefulness of exercises in optimizing the shoulder flexibility was highlighted (Turgut & Baltaci, 2018) through the application of an active stretching/self-stretching program for 6 weeks on a group of 18 subjects with an average age of 34.8 years. It recorded a significant increase in shoulder flexibility, diminished scapulohumeral pain during exercise, but did not show a significant reduction in pain intensity during rest.

Conclusions

Because significant progress for both sexes was recorded only for some of tests, the null hypothesis could not be rejected in the other cases, and the low and very low values of η^2_p confirmed this. An increase of the weekly frequency of stretching is required; one single weekly session cannot generate significant accumulation on a long-term basis, and the statistical data confirmed only a stagnation or insignificant increases in the flexibility values for over 50% of the tests. The fact that the results significantly increased only for the tests that were based on performances, skills, and positions that are used frequently in daily life physical activities indicated a superior adaptation to those movements and represents a possible explanation for this observation. The female subjects recorded higher values than the male subjects (only in three cases were the differences insignificant), a result that was expected and observed since the initial testing; thus, the second hypothesis was validated in six out of the nine assessments.

Further studies on other groups (school children, various professions, athletes from various sports, the elderly, etc.) might show the progress of flexibility better because of stretching programs.

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