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Original scientific paper

BIOMECHANICAL STATUS AND STRUCTURE OF EXERCISES FOR FUNCTIONAL STAGE AND THE FIRST STAGE OF KYPHOSIS

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Abstract

The need for a scientific approach in the creation and the selection of complex exercises for functional and the first stage of kyphosis from different initial positions by use of props and equipment is essential and indispensable. The importance of this study is great, having in mind the fact that the rate of bodily deformities is quite high and tends to increase steadily. Starting from the need for a scientific approach in the creation and the selection of complex exercises for the functional and the first stage of kyphosis that are present among the school population is more than necessary. The importance of interdisciplinary character of biomechanics and its subject of interest and research in this study is presented through application of a qualitative biomechanical analysis which is conducted from several aspects of complex exercises for kyphosis, functional stage and first degree of deformity. Among other things, qualitative biomechanical analysis enables registration of changes that occur in the spine at different periods of growth and development of children. In particular, the pathological changes of the postural status that hinder the manifestation of motor skills and habits in the course of the physical and health education, as well as among those children who are actively engaged in sports. The research includes 12 exercises for strength of the postural muscles from different initial positions by use of props and equipment (functional stage and the first degree of kyphosis). The exercises are analyzed by the method of qualitative biomechanical analysis, algorithm ALPROBI and then processed by factorization of the matrix of inter-similarity by use of the method of the main components by the software package SPSS28 From the obtained results from this study it could be stated that the application of the exercises: Torso lifting from kneeling position with elbows bent at 90 degrees .908, Torso lifting from chest lying .952, Stretching the back muscles with hands on the bar.905. and their more frequent application throughout the training process both on daily and weekly basis would bring to more benefits and efficacy.

*Keywords:*biomechanical status,factoral structure,kyphosis,correction,spine

1. Introduction

Increased thoracic curvature of the spinal column is a postural disorder known as sagittal plane deformity. The normal thoracic kyphosis (TK) angle of the spine ranges from 20° to 40°, and TK angles of 45–50° are referred to as postural kyphosis, increased kyphosis or hyperkyphosis (Hertling, 2006, Yakut, 2018). In children, reduced physical activity, rapid growth and poor lifestyle habits lead to weakness of the trunk muscles and dysfunctional deformities of the spine during a growth spurt (Lizak, 2014). Increased thoracic kyphosis is a deformity that can occur as a result of spinal misalignment in all age groups (Bansal, 2014, Brzęk, 2017, Feng, 2018). Hyperkyphosis affects 32% of adults and 60% of the elderly population (Liu, 2016). Spinal deformities have been reported in 30% of school-age children (Kolarova, 2019). In a study, screening of adolescents revealed improper posture in 58.85% and spinal deformities in 23.67%

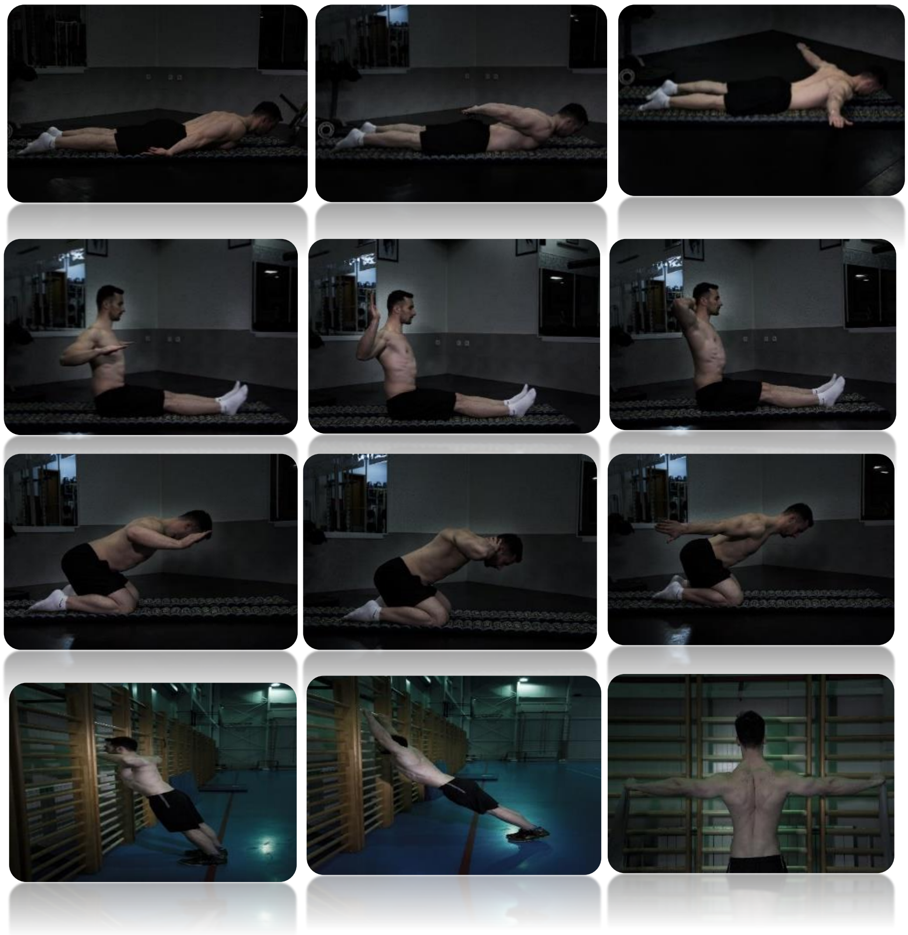
of children (Mitova, 2015). In children and adolescents, increased thoracic kyphosis (TK) may occur due to poor standing posture, sitting in front of a computer for long hours in an incorrect posture, and carrying heavy schoolbags (Brzęk, 2017, Kamaci,2015, Nikolova, 2003). Failure to correct spinal deformities in adolescence may cause static deformations in youth and adulthood (Kamaci, 2015, Tarasi, 2019). Thus, early diagnosis and correct assessment in adolescence may impede different effects of postural and spinal deformities (Tarasi, 2019). Additionally, with accelerated improvement of speed, coordination and movements, gains in muscular strength occur in adolescents aged 10 to 17 years (Mitova, 2015, Nikolova, 2003), and during this stage, suitable treatment, rehabilitation and active exercise programs can be recommended (Tarasi, 2019) The reported prevalence of poor posture in adolescents varies from 22 to 65% (Kolarova, 2019, Kratenová, 2007, Gh, 2012). In adolescents, improper posture and poor postural awareness may become habitual over time (Dolphens, 2016). Habitual incorrect posture has been shown to reduce the spine's ability to perceive, maintain, and reposition neutral postures (Edmondston, 2007). Poor postural awareness has been associated with habitual posture changes that place greater strain on supporting structures (Edmondston, 2007) It has been reported that unawareness of non-ideal postures while standing and sitting can have serious long-term effects (Bomen, 2022). Studies have shown that persistent incorrect posture in adolescence may lead to severe postural disorders in adulthood (Dolphens, 2016). Correspondingly, we think that it is important to correct improper posture and improve postural awareness in adolescence in order to avoid postural disorders in later life. There are a number of studies that applied training and exercise programs to correct postural disorders associated with increased TK (Tarasi, 2019, Katzman, 2016, Katzman, 2017). However, these studies mostly focused on correcting poor posture rather than improving postural awareness. We believe that it would be more effective to provide postural awareness training first and then apply training and exercises to correct improper posture. To our knowledge, no such training has been used in former studies involving individuals with TK. Therefore, in this study, a training program (PPT) was applied to improve postural awareness in adolescents with TK. In order an effective training to take place for prevention and correction of the poor kyphotic posture and the first stage kyphosis a certain selection of exercises is needed through qualitative biomechanical analysis of the selected exercises by the exercise therapist as well as determining of the factor structure of the exercises for kyphosis. In this study a selection of twelve exercises is made starting from different initial positions as well as props and equipment determining its homogeneity, their mutual connection in the complex as well as the factorization of the main components through which we would have clear picture to what extent that complex is going to be effective and beneficial.

2. Methods

Sample of entites

- Torso lifting from chest lying
- Torso lifting from chest lying with hands behind the back
- Torso lifting from chest lying with flying arms
- Stretching the back muscles from sedentary position at 90 degrees elbow bent.

- Bringing the scapula closer to the spine from sedentary position at 90 degrees elbow bent perpendicularly.
- Bringing the scapula closer to the spine from sedentary position with hands behind nape.
- Torso lifting from kneeling position with elbows bent at 90 degrees
- Torso lifting from kneeling position with hands behind nape
- Moving the arms backwards from kneeling position
- Push ups with hands on the bar
- Bringing the scapula closer to the spine by use of band stretched by the arms perpendicularly from frontal position to flying position.



Data processing

The basic motor stereotypes are analyzed by the method of qualitative biomechanical analysis, while the results will be given in an ordinary matrix that provides information about the basic biomechanical characteristics of each entity (exercise). (Tufekchiveski et al.,2012). The entity represents a vector, where the numeric value 1 indicates the possessiveness of a biomechanical characteristic, and 0 indicates the non-possessiveness of a biomechanical characteristic in that entity. The rows represent the vectors of the entities while the columns represent the vectors of the biomechanical variables. From the basic matrix, primarily, the coefficients of biomechanical similarity are determined among the analyzed entities. (Aliu,2021). Then full biomechanical similarity is determined i.e homogeneity as well as the force of the biomechanical similarity among the entities. This procedure is described in the ALPROBI Heraclitus algorithms and after wards the analysed latent biomechanical structure of the selected exercises will be processed through factorization of the matrix of the inter-similarity by use of the methods of application of the method of main components by use of software SPSS28.

3. Results and Discussions

Table1. Normed measures of biomechanical similarity(inter-similarity)coefficient of full biomechanical similarity and coefficients of biomechanical connetction force of a sample of complex exercises for kyphosis

	Cosine of Vectors of Values											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	1.000	.972	1.000	.476	.476	.594	.455	.455	.437	.280	.354	.340
2	.972	1.000	.972	.462	.462	.577	.442	.491	.424	.318	.393	.377
3	1.000	.972	1.000	.476	.476	.594	.455	.455	.437	.280	.354	.340
4	.476	.462	.476	1.000	1.000	.761	.654	.573	.628	.453	.491	.510
5	.476	.462	.476	1.000	1.000	.761	.654	.573	.628	.453	.491	.510
6	.594	.577	.594	.761	.761	1.000	.511	.511	.449	.432	.468	.490
7	.455	.442	.455	.654	.654	.511	1.000	.913	.917	.401	.435	.500
8	.455	.491	.455	.573	.573	.511	.913	1.000	.834	.482	.522	.584
9	.437	.424	.437	.628	.628	.449	.917	.834	1.000	.385	.459	.560
10	.280	.318	.280	.453	.453	.432	.401	.482	.385	1.000	.843	.731
11	.354	.393	.354	.491	.491	.468	.435	.522	.459	.843	1.000	.834
12	.340	.377	.340	.510	.510	.490	.500	.584	.560	.731	.834	1.000
CFBS	**.546**											

CBCF	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	.531	.536	0.531	.589	.589	.559	.576	.581	.560	.460	.513	.525
	8	7	8	1	1	6	4	3	5	12	11	10

From the analysis of the obtained results in the inter-similarity matrix from tab. 2, it can be determined that the greatest similarity is observed between the exercises Torso lifting from chest lying and Torso lifting from chest lying with flying arms. The largest similarity coefficients range from **.843** to **1**. The smallest similarity is present between exercises Pushups with hands on the bar.**354** andTorso lifting from chest lying with flying arms**.280** The smallest similarity coefficients range from **.280** to **.354**.The coefficient of full biomechanical similarity is CFBS= **.546** .According to the obtained results, the highest values of the CBCF coefficient of biomechanical connection force of one exercise with all other highest values were obtained in exercises Stretching the back muscles from sedentary position at 90 degrees elbow bent**.589**,Bringing the scapulas closer to the spine from sedentary position at 90 degrees elbow bent perpendicularly**.589**, and Torso lifting from kneeling position with hands behind nape **.581**.

Table 2. Communality

	Initial	Extraction
Torso lifting from chest lying	1.000	.982
Torso lifting from chest lying with hands behind the back	1.000	.958
Torso lifting from chest lying with flying arms	1.000	.982
Stretching the back muscles from sedentary position at 90 degrees elbow bent.	1.000	.745
Bringing the scapula closer to the spine from sedentary position at 90 degrees elbow bent perpendicularly	1.000	.745
Bringing the scapula closer to the spine from sedentary position with hands behind nape.	1.000	.626

Torso lifting from kneeling position with elbows bent at 90 degrees	1.000	.889
Torso lifting from kneeling position with hands behind nape	1.000	.779
Moving the arms backwards from kneeling position	1.000	.829
Push ups with hands on the bar	1.000	.863
Stretching the back muscles with hands on the bar	1.000	.918
Bringing the scapula closer to the spine by use of band stretched by the arms perpendicularly from frontal position to flying position.	1.000	.831

Table3. Size of the explained part of total variance and the coefficient of explained part of the total variance of a component

Component	Initial Eigenvalues			Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.031	58.593	58.593	7.031	58.593	58.593	4.040	33.666	33.666
2	1.842	15.353	73.946	1.842	15.353	73.946	3.327	27.721	61.387
3	1.275	10.622	84.568	1.275	10.622	84.568	2.782	23.181	84.568
4	.971	8.094	92.662						
5	.287	2.395	95.058						
6	.268	2.234	97.291						
7	.132	1.102	98.394						
8	.120	1.000	99.393						
9	.050	.419	99.812						
10	.023	.188	100.000						
11	-3.734E-17	-3.112E-16	100.000						
12	-5.286E-17	-4.405E-16	100.000						

Table 4. Projections of the exercises on a defined component (C)

	Component		
	1	2	3
Torso lifting from chest lying	.743	-.637	.153
Torso lifting from chest lying with hands behind the back	.748	-.600	.197
Torso lifting from chest lying with flying arms	.743	-.637	.153
Stretching the back muscles from sedentary position at 90 degrees elbow bent.	.825	.097	-.234
Bringing the scapula closer to the spine from sedentary position at 90 degrees elbow bent perpendicularly	.825	.097	-.234
Bringing the scapula closer to the spine from sedentary position with hands behind nape.	.783	-.115	-.001
Torso lifting from kneeling position with elbows bent at 90 degrees	.810	.169	-.452
Torso lifting from kneeling position with hands behind nape	.812	.194	-.288
Moving the arms backwards from kneeling position	.789	.196	-.410
Push ups with hands on the bar	.645	.443	.500
Stretching the back muscles with hands on the bar	.711	.404	.499
Bringing the scapula closer to the spine by use of band stretched by the arms perpendicularly from frontal position to flying position.	.729	.417	.354

Table 5. Rotated projections of the exercises on a defined component (C)

	Component		
	1	2	3
1	.247	.952	.121
2	.229	.936	.173
3	.247	.952	.121
4	.752	.310	.290
5	.752	.310	.290
6	.510	.516	.315
7	.908	.190	.170
8	.804	.212	.298
9	.871	.167	.204
10	.217	.118	.895
11	.253	.184	.905
12	.367	.148	.821

For establishing of different groups of elements with similar biomechanical structure a processing of factorization of the matrix of inter-similarity was applied by use of the method of main components. The results of this analysis are presented in the tables:3,4,5 According to the Kaiser-Guttman criterium for particular square root greater than one. There are three main components that are defined that explain the analysed space with total variance of the component that is 84,57% (table2).In the further procedure, the non-rotated matrix is rotated with Varimax solution (table 4).From the analysis of the table it could be stated that upon the first component the greatest projections have the exercises: Stretching the back muscles from sedentary position at 90 degrees elbow bent, Bringing the scapulas closer to the spine from sedentary position at 90 degrees elbow bent perpendicularly, Bringing the scapulas closer to the spine from sedentary position with hands behind nape, Torso lifting from kneeling position with elbows bent at 90 degrees, Torso lifting from kneeling position with hands behind nape, Moving the arms backwards from kneeling position.The greatest projections upon the second component have the exercises: Torso lifting from chest lying, Torso lifting from chest lying with hands behind the back, Torso lifting from chest lying with flying arms.While in the third component the greatest saturations have the exercises: Push ups with hands on the bar, Stretching the back muscles with hands on the bar, Bringing the scapulas closer to the spine by use of band stretched by the arms perpendicularly from frontal position to flying position.The greatest communality i.e degree of the explained part of the total variance of each of the exercises with the first main component is present in the exercise Torso lifting from kneeling position with elbows bent at 90 degrees .908.In the second main component the greatest saturations are present in the exercise Torso lifting from chest lying .952 and the exercise Torso lifting from chest lying with flying arms.952.In the third main component the exercise Stretching the back muscles with hands on the bar.905 has the greatest saturation.

4. Conclusion

From the received results of this study it could be concluded that the complex of the selected exercises presents great homogeneity that directs towards the fact that the researched exercises at the person with poor kyphotic posture and the first stage of kyphosis could be applied and a great effect would emerge after its appliance in certain time period. As far as the selected exercises are concerned the application of the factor structure of the main components the exercises: torso lifting from kneeling position with elbows bent at 90 degrees .908, torso lifting from chest lying .952, stretching the back muscles with hands on the bar.905 stand aside from the rest of the exercises as the most beneficial if applied more frequently on weekly basis and more frequently during a training in comparison with the other exercises from the complex. Through this study we had an idea of conveying more detailed analysis of exercises referring the above mentioned issue related to the spine and our recommendation would be that the selected exercises by the exercise therapist would be more beneficial if primarily they would be done and data processed as in this study so that the ones who would apply a certain complex of exercises by their own choice to the extent that the complex is homogeneous that would direct to its beneficial effect in short period of time. Moreover, the three above mentioned exercises that are result of the application of the factor structure direct towards more precise approach to the issue and its effective prevention and correction of the first stage kyphosis.

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