



## Effect of 4-Week Physical Program on Musculoskeletal System Changes in Adolescent Sport Class Students with Focus on Ice Hockey

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### Abstract

**Introduction:** The purpose of the study was to identify musculoskeletal system changes in adolescent extraleague ice hockey players. The 4-week physical program was realized within lessons of physical and sport education. **Methods:** The monitored group consisted of 11 adolescent sports grammar school students in Nitra, Slovakia (aged:  $17.27 \pm 0.5$ ; body height:  $175.96 \pm 1.2$  cm and body weight:  $77.23 \pm 3.5$  kg) who were the extraleague hockey players of HK Nitra. To monitor their musculoskeletal system, we used standardized methods for physical and medical practice, such as Klein and Thomas modified by Mayer. **Results:** The students' physical and sport education programs had positive changes on their musculoskeletal system, both in the muscle system ( $W_{\text{test}}=p<0.05$ ) and in the area of posture ( $W_{\text{test}}=p<0.05$ ). While comparing the level of the students' posture as the external manifestation of the functional muscle system, we stated that the difference, the improvement between the input (12.4) and the output (7.9) testing was significant with the value of  $p = 0.03$  ( $W_{\text{test}}=p<0.05$ ). By applying the 4-week physical program, the pain in the cervical and lumbar spine in students was also eliminated.

**Keywords:** ice hockey, musculoskeletal system, physical and sport education, physical program, pupil

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## INTRODUCTION

Participation in sports, such as ice hockey, especially at high volumes and intensities, brings certain risks, in the form of unilateral loading and overloading of the organism of sport class students and athletes [1]. The ice hockey particularly demands players to skate with alacrity and agility, as well as possess high physical strength, endurance, shooting skills, coordination and other general ice hockey skills throughout, constantly changing conditions of an ice hockey game. The sport performance in the ice hockey is a complex, dynamic system, in which each of the factors influence the outcome of a game. The players skate in heavy, specialized equipment (children's versions weigh approximately 10 kilograms), which increasing demands on both conditional and technical loads on their movement on the ice. Developing skills and improving abilities take place under conditions of great physical loads [2, 3]. The players are often in lowered positions and bending forward during play and practice. Thus, the trunk muscles (e.g., the trapezius and pectoral muscles) and lower limbs (i.e., the thigh muscles, knee flexors and calf muscles) are the most frequently involved in the whole skating movement [4]. Based on the known negative consequences of the unilateral physical burden, there is currently an effort to compensate the unilateral (training) burden. Unfortunately, within the teaching and training processes, there is no adequate time to compensate for the unilateral loading of the musculoskeletal system. In ice hockey, a muscle imbalance is a serious problem in relation to the musculoskeletal system. It generalizes and extends gradually into other areas of the body. It adversely affects the posture, movement stereotypes, muscle coordination, fatigue, increases vulnerability to injuries and limits the extension of the movement in the joints and their mobility [5].

The muscle imbalance is considered to be the most important cause of the chronic pain in the muscular system and spinal disorders. The inadequate primary prevention, thus leads to the occurrence of the vertebrogenic diseases in adulthood, which have far-reaching consequences for human health, as are evidenced by health insurance statistics.

The primary prevention, physical programs, health-oriented exercises contribute to improving the muscular system through the external body prism of the posture. Therefore, by adequate, selected health exercises, within the school physical and sport education, is possible to influence the quality of the muscular system and postural stability [6-12], promote its proper development, act preventively, thereby contributing to improving the health of the students and athletes [13-17].

The purpose of the study was to identify musculoskeletal system changes in adolescent sports grammar school students (extraleague ice hockey players). The 4-week physical program was realized within lessons of physical and sport education.

## MATERIAL AND METHODS

### *Participants*

The monitored group consisted of 11 adolescent sports grammar school students in Nitra, Slovakia (aged:  $17.27 \pm 0.5$  years; body height:  $175.96 \pm 1.2$  cm; body weight:  $77.23 \pm 3.5$  kg; BMI:  $25.22 \pm 1.9$ ). The listed students regularly played in the cadet and junior extraleague (aged:  $17.00 \pm 1.0$  years).

### *Measurement*

The research monitoring (input and output testing) was performed by applying the standardized methods for the physical and medical practice by physiotherapist with 12 years of experience. The static component of the posture was based on Klein and Thomas modified by Mayer [18]. The diagnosis of the muscular system with intention to hyperactive skeletal postural muscles and hypoactive antagonists with predominance of phase activity with the tendency to weaken was based on the functional diagnostics of the locomotor system according to Janikova [19], as well as the identification of the pain.

### Procedure

The creation of the physical program was based on initial testing of the musculoskeletal system of the probands. The realized experiment was pedagogical (school environment of the listed sports grammar school), terrain (lessons of physical and sport education) one-group (selected group of students with functional disorders of musculoskeletal system; willing to participate in research) and multifactorial (tested were areas of muscular system with intention to postural (m. trapezius - pars superior, m. levator scapulae, m. pectoralis major, m. quadratus lumborum, m. erector spinae, mm. adductores coxae, m. iliopsoas, m. rectus femoris, m. tensor fasciae latae, knee flexors, m. triceps surae) and phasic (deep neck flexors, lower fixators of scapula, m. abdominis, extensions of hip joint, abductors of hip joint) muscle groups; evaluated was posture and its individual segments: I. posture of head and neck, II. shape of trunk, III. shape of abdomen and angle of pelvis, IV. overall spinal curvature, V. posture of shoulders). The realization of experimental factor (physical program consisted of exercises with positometric and strengthening character), took place in the afternoon lessons' of the physical and sport education, in the period from 13.02.2017 to 10.05.2017. The frequency of the physical program was twice a week for 45 minutes.

### Data analysis

While processing the obtained qualitative and quantitative data of the musculoskeletal system, we performed percentage frequency analysis (%), multiplicity (n) arithmetic mean (M), standard deviation (SD), median (Mdn) and variation range ( $V_{R=\max-\min}$ ). The overall level of the musculoskeletal system was evaluated by the occurrence of the individual components, through the Wilcoxon's nonparametric test ( $W_{\text{test}}, p < 0.05$ ). The Cohen correlation analysis (r) was used to assess the degree of dependence between the muscle groups. We also used methods of logical analysis and synthesis, using inductive and deduction techniques, comparisons and generalizations. The data were further processed in MS Excel 2017.

## RESULTS

According to the objective, we present the results, as they need to be understood in the overall context as basic, in consideration of the upward trend in the functional and structural weaknesses of the musculoskeletal system in the sport classes students and schools.

From the input testing of the individual muscle groups (table 1), the knee flexors (m. biceps femoris, m. semitendinosus and m. semimembranosus) were the most shortened and problematic muscular group in the probands (90.9%; n=10). In 81.8% (n=9) of the probands, we diagnosed large shortening, where the extension of flexion in the hip joint was less than 80°. The flexion range was between 80°-90°, which was found in one (9.1%) proband and in one (9.1%) proband, we also found physiological value. In the second place we recorded m. iliopsoas with 90.9% (n=10) occurrence of the large or moderate shortening. The physiological value was found only in one (9.1%) proband. In the third place we recorded m. levator scapulae with the same 90.9% (n=10) occurrence of the large or moderate shortening. The large shortening was found in 36.4% of probands. By examining with the maneuver, we encountered hard resistance with positive palpation and found the angle of the scapula. The moderate shortening was observed in 54.5% of the probands. We also recorded the physiological length of the muscle in one (9.1%) proband. By applying the physical program, we recorded the greatest changes, in order of the following group of muscles: ( $W_{\text{test}}=-3.051, p < 0.05$ ), 2. m. pectoralis major ( $W_{\text{test}}=-2.236, p < 0.05$ ), 3. m. erector spinae ( $W_{\text{test}}=-2.236, p < 0.05$ ) and 4. m. iliopsoas ( $W_{\text{test}}=-3.162, p < 0.05$ ), as well as other muscle groups.

The input testing of the phasic muscle group revealed that even in one (9.1%) of the probands, we did not find a significantly weakened muscular group in individual evaluated areas. The percentage of moderate weakened muscle groups found in the initial testing is presented in table 2. In terms of moderate weaknesses, they were ranked in the following order: 1. lower fixators of scapula (81.8%), 2. - 3. deep neck flexors and brachial artery extensions (63.7%). The changes in attenuated muscle group levels, by applying the physical program, significantly ( $p < 0.05$ ) pointed to efficacy and improvement of the phasic muscle groups of the probands.

Table 1. Input and output testing of postural muscle system in probands (n=11)

| Postural muscle groups       | Testing           | Percentage [%]  |      |      |      | Order |
|------------------------------|-------------------|-----------------|------|------|------|-------|
|                              |                   | 0               | 1    | 2    | 1+2  |       |
| m. trapezius – pars superior | I <sub>1</sub>    | 9.1             | 63.7 | 27.3 | 90.9 | 4 - 5 |
|                              | O <sub>2</sub>    | 63.7            | 36.3 | 0    | 36.3 | 7 - 9 |
|                              | W <sub>test</sub> | -3.000 (p<0.05) |      |      |      |       |
| m. levator scapule           | I <sub>1</sub>    | 9.1             | 54.5 | 36.4 | 90.9 | 3     |
|                              | O <sub>2</sub>    | 54.5            | 45.5 | 0    | 45.5 | 5 - 6 |
|                              | W <sub>test</sub> | 3.000 (p<0.05)  |      |      |      |       |
| m. pectoralis major          | I <sub>1</sub>    | 36.4            | 18.2 | 54.5 | 72.7 | 8     |
|                              | O <sub>2</sub>    | 36.3            | 63.7 | 0    | 63.7 | 2     |
|                              | W <sub>test</sub> | -2.236 (p<0.05) |      |      |      |       |
| m. quadratus lumborum        | I <sub>1</sub>    | 9.1             | 63.7 | 27.3 | 90.9 | 4 - 5 |
|                              | O <sub>2</sub>    | 54.5            | 45.5 | 0    | 45.5 | 5 - 6 |
|                              | W <sub>test</sub> | -2.530 (p<0.05) |      |      |      |       |
| m. erector spinae            | I <sub>1</sub>    | 45.5            | 9.1  | 45.5 | 54.5 | 9     |
|                              | O <sub>2</sub>    | 45.5            | 54.5 | 0    | 54.5 | 3 - 4 |
|                              | W <sub>test</sub> | -2.236 (p<0.05) |      |      |      |       |
| mm. adductors coxae          | I <sub>1</sub>    | 72.7            | 18.2 | 9.1  | 27.3 | 11    |
|                              | O <sub>2</sub>    | 81.8            | 18.2 | 0    | 18.2 | 11    |
|                              | W <sub>test</sub> | -1.414 (p>0.05) |      |      |      |       |
| m. iliopsoas                 | I <sub>1</sub>    | 9.1             | 36.4 | 54.5 | 90.9 | 2     |
|                              | O <sub>2</sub>    | 45.5            | 54.5 | 0    | 54.5 | 3 - 4 |
|                              | W <sub>test</sub> | -3.162 (p<0.05) |      |      |      |       |
| m. rectus femoris            | I <sub>1</sub>    | 18.2            | 36.4 | 45.5 | 81.9 | 6     |
|                              | O <sub>2</sub>    | 63.7            | 36.3 | 0    | 36.3 | 7 - 9 |
|                              | W <sub>test</sub> | -2.887 (<0.05)  |      |      |      |       |
| m. tensor fasciae late       | I <sub>1</sub>    | 27.3            | 45.5 | 27.3 | 72.8 | 7     |
|                              | O <sub>2</sub>    | 63.7            | 36.3 | 0    | 36.3 | 7 - 9 |
|                              | W <sub>test</sub> | -2.887 (p<0.05) |      |      |      |       |
| knee flexors                 | I <sub>1</sub>    | 9.1             | 9.1  | 81.8 | 90.9 | 1     |
|                              | O <sub>2</sub>    | 27.3            | 72.7 | 0    | 72.3 | 1     |
|                              | W <sub>test</sub> | -3.051 (p<0.05) |      |      |      |       |
| m. triceps surae             | I <sub>1</sub>    | 63.7            | 18.2 | 18.2 | 36.4 | 10    |
|                              | O <sub>2</sub>    | 72.7            | 27.3 | 0    | 27.3 | 10    |
|                              | W <sub>test</sub> | -1.732 (p>0.05) |      |      |      |       |

0 - not shortened muscle; 1 - moderate shortened muscle; 2 - shortened muscle; I<sub>1</sub> - input testing; O<sub>2</sub> - output testing; W<sub>test</sub> - Wilcoxon nonparametric test; p - statistical significance at p<0.05

The presence of the functional disorders of the musculoskeletal system also revealed the pain in the probands. While testing the pain in the cervical spine with the functional state of the muscle groups involved in the upper crossed syndrome, we found that neither muscle group alone (p>0.05) was involved in the development of the pain in the cervical spine. While simultaneously shortening the muscle groups, such as m. trapezius pars descendens and m. levator scapulae, significantly (r=0.667) were involved in the development of the pain in the cervical spine. We showed that if one of the pairs of the muscles or sides showed pathological shortening and the other side or a pair of the muscles are slightly shortened, there was possibility of the pain in the cervical spine.

Table 2. Input and output testing of phasic muscle groups in probands (n=11)

| Phasic muscle groups      | Testing           | Percentage [%]  |      |   |      | Order |
|---------------------------|-------------------|-----------------|------|---|------|-------|
|                           |                   | 0               | 1    | 2 | 1+2  |       |
| deep neck flexors         | I <sub>1</sub>    | 36.4            | 63.7 | 0 | 63.7 | 2 - 3 |
|                           | O <sub>2</sub>    | 72.7            | 27.3 | 0 | 27.3 | 2 - 4 |
|                           | W <sub>test</sub> | -2.000 (p<0.05) |      |   |      |       |
| lower fixators of scapula | I <sub>1</sub>    | 18.2            | 81.8 | 0 | 81.8 | 1     |
|                           | O <sub>2</sub>    | 63.6            | 36.4 | 0 | 36.4 | 1     |
|                           | W <sub>test</sub> | -2.236 (p<0.05) |      |   |      |       |
| m. abdominis              | I <sub>1</sub>    | 45.5            | 54.5 | 0 | 54.5 | 4     |
|                           | O <sub>2</sub>    | 81.8            | 18.2 | 0 | 27.3 | 2 - 4 |
|                           | W <sub>test</sub> | -2.000 (p<0.05) |      |   |      |       |
| extensions of hip joint   | I <sub>1</sub>    | 36.4            | 63.7 | 0 | 63.7 | 2 - 3 |
|                           | O <sub>2</sub>    | 72.7            | 27.3 | 0 | 27.3 | 2 - 4 |
|                           | W <sub>test</sub> | -2.000 (p<0.05) |      |   |      |       |
| abductors of hip joint    | I <sub>1</sub>    | 81.8            | 18.2 | 0 | 18.2 | 5     |
|                           | O <sub>2</sub>    | 90.9            | 9.1  | 0 | 9.1  | 5     |
|                           | W <sub>test</sub> | -1.000 (p>0.05) |      |   |      |       |

0 - not shortened muscle; 1 - moderate shortened muscle; 2 - shortened muscle; I<sub>1</sub> - input testing; O<sub>2</sub> - output testing; W<sub>test</sub> - Wilcoxon nonparametric test; p - statistical significance at p<0.05

Table 3. Testing posture in students within individual segments (n=11)

| Areas of posture /Points | I    |      | II   |      | III  |      | IV   |      | V    |      |
|--------------------------|------|------|------|------|------|------|------|------|------|------|
|                          | I1   | O2   |
| Point [%]                | 0    | 54.5 | 0    | 36.4 | 0    | 36.4 | 0    | 27.3 | 0    | 63.6 |
| Point [%]                | 54.5 | 45.5 | 72.7 | 63.6 | 36.4 | 63.6 | 45.5 | 72.7 | 54.5 | 36.4 |
| Point [%]                | 45.5 | 0    | 27.3 | 0    | 63.6 | 0    | 54.5 | 0    | 45.5 | 0    |
| Point [%]                | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |

I - posture of head and neck; II - shape of trunk; III - shape of abdomen and angle of pelvis; IV - overall spinal curvature; V - posture of shoulders

Table 4. Statistical evaluation of changes in posture within students (n=11)

| Factors/ Multiplicity (n=11)                | 1              | 2  | 3  | 4  | 5  | 6              | 7  | 8  | 9  | 10 | 11 |
|---|----------------|----|----|----|----|----------------|----|----|----|----|----|
| Input (I <sub>1</sub> )                     | 12             | 13 | 14 | 10 | 14 | 12             | 10 | 14 | 15 | 11 | 11 |
| Output (O <sub>2</sub> )                    | 6              | 9  | 8  | 6  | 9  | 7              | 8  | 9  | 10 | 7  | 8  |
| Testing (I <sub>1</sub> )/(O <sub>2</sub> ) | I <sub>1</sub> |    |    |    |    | O <sub>2</sub> |    |    |    |    |    |
| Arithmetic mean (M)                         | 12.4           |    |    |    |    | 7.9            |    |    |    |    |    |
| Standard deviation (SD)                     | 1.75           |    |    |    |    | 1.30           |    |    |    |    |    |
| Median (Mdn)                                | 12             |    |    |    |    | 8              |    |    |    |    |    |
| Min   | 10             |    |    |    |    | 6              |    |    |    |    |    |
| Max   | 15             |    |    |    |    | 10             |    |    |    |    |    |
| Variation range (V <sub>R=max-min</sub> )   | 5              |    |    |    |    | 4              |    |    |    |    |    |
| Wilcoxon test (W <sub>test</sub> )          | -2.956         |    |    |    |    |                |    |    |    |    |    |
| p   | p=0.03         |    |    |    |    |                |    |    |    |    |    |

I<sub>1</sub> - input; O<sub>2</sub> - output; W<sub>test</sub> - Wilcoxon nonparametric test; p - statistical significance at p<0.05

In the lumbar spine, we also observed the relationship between the pain in the listed area and the functional state of the muscle groups involved in the development of the lower crossed syndrome. By Cohen's test, we found significantly ( $r=0.696$ ,  $p<0.05$ ) that hip flexors were involved in the pain in the dorsal part of the spine.

At the same time, we found that the stereotype of the forward head posture significantly contributed to the development of the functional disorders of the m. trapezius pars descendens ( $r= 0.687$ ,  $p<0.05$ ) and m. levator scapulae ( $r=0.683$ ,  $p<0.05$ ). The abdominal area significantly ( $r=0.536$ ,  $p<0.05$ ) effected the functional state of the m. erector spinae.

By the external manifestation of the functional changes in the area of the posture, we found the following (table 3). In the input testing, the most problematic was the III. area - The shape of the abdomen with the angle of the pelvis of 36.4% ( $n=4$ ) of the probands. There was also the presence of slight prominent abdomen, up to 63.6% ( $n=7$ ) of the probands. The positive changes in the output testing of the probands were attributed to the sufficient working out of the mm. abdominis, flexion of the hip joint and paravertebral muscles. The second most problematic area was the IV. area, where was found the overall curvature of the spine. In this area, 45.5% of the probands ( $n=5$ ) were found with the signs of reduced or enlarged curvature and 54.5% of the probands ( $n=6$ ) showed diminished or enlarged spine curvature. Interestingly was to found that in the overall view from behind, all of them were diagnosed with the pathological lateral deflection of the spine, where almost in all cases were single-bowed "C" scoliosis in the direction of holding a hockey stick. Deviating from the standard posture was the third most problematic area - V., in which we evaluated the posture of shoulders in the frontal plane. The results showed that 54.5% of the probands ( $n=6$ ) were found in the input testing with the slightly scapula. In 45.5% of the probands ( $n=5$ ), we determined the difference in the height of the shoulders and the scapula.

While comparing the posture and individual segments of the monitored group ( $n=11$ ), we can state the overall improvement by the realization of the physical program. The difference between input (12.4) and output (7.9) scores were statistically significant with  $p=0.03$  ( $W_{\text{test}}=-2.956$ ,  $p<0.05$ ) (table 4), indicating the effectiveness of the physical program.

## DISCUSSION

Several authors [20-24] have shown in their research that correctly chosen and targeted physical programs and exercises with the compensatory and medical nature, can positively affect the individual components of the musculoskeletal system. At the same time, the authors have agreed with statement that the disorders should be given increased attention from childhood.

Nelson and Bandy [25] focused on increasing hamstring flexibility by the static stretching and eccentric exercises. The object of observation was 69 probands in the average age of 16.45 years who were divided into two groups. The statistically significant improvement in the range of movement was found in range from 12.05° to 12.79° in the groups.

Marshall et al., [26] realized research to monitor the effect of the static stretching to the tolerance, strength, extensibility and passivity of the hamstrings. The experimental group consisted of probands aged 22.7±3.8 years old who performed 4 stretching exercises for 4 weeks (3 times, 30 seconds on both sides). It was focused on the area of hips and hamstrings. The results confirmed the statistically significant beneficial effect on the passive stiffness and extensibility of the tested muscles. As the increase in stretch tolerance was not statistically confirmed, the changes in the range of the movement attributed mainly to the changes in mechanical components of the muscular function.

Lindergren and Twomey [27] looked at the painful conditions of the dorsal part of the spine of elite ice hockey players due to muscle imbalance and improper posture who also had similar results to our research. Up to 25 of the 32 respondents of the survey reported lumbar spine pain, while 10 respondents reported these pains as moderate to severe. The authors labeled hyperlordotic body posture, shortened erectors of the spine with the flexors of the hip joint and the weakened abdomen muscles.

Ultimately, the physiological response of the organism is the essential limiting muscle balance. Elliott [28] emphasized the importance of maintaining static and dynamic balance in the athletes with various postural defects, such as muscle weakness of the axial system and muscle imbalance. At the

same time, he recommended that the physical program should include exercises that contribute to the correct posture and exercises to develop equilibrium skills on unstable pads. The means of developing muscle balance is also the isometric strengthening of postural muscles, the development of vestibular analyzer training, complex exercises of balance and also balance exercises [29].

## CONCLUSION

The study results showed the positive changes in the muscular system of the probands, which was also manifested in the posture after 12 weeks of exercise. At the same time, the musculoskeletal system was enhanced by the physical program and the pain in the cervical and lumbar spine of the proband was stabilized.

Based on the results of the study, we recommend the widening of the knowledge about the use of targeted exercises with the health aspect in the form of the physical programs, within the physical and sport education in sports schools.

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