Investigation of the effectiveness of a complex injury prevention programme among young swimmers

M. CHRENKÓ1*, Á. A. MAYER1, G. SZENDRŐ2 and A. VÁRNAGY3

1 Department of Physiotherapy, Faculty of Health Sciences, Semmelweis University, Budapest, Hungary
2 Fonyódi Health Institute, Fonyód, Hungary
3 Department of Orthopaedics, Faculty of Medicine, Semmelweis University, Budapest, Hungary

ABSTRACT

Purpose: The training load required at elite level can lead to shoulder pain even among the youngest swimmers, thus, besides modern water training plans and swimming technique development, the planning of dryland training with a preventive approach is of the utmost importance. The aim of the present study was to map kinetic patterns and sports injury risk factors among young competitive swimmers (between 9 and 12 years of age) and to investigate the effectiveness of a complex injury prevention programme on dry land.

Materials and methods: A total of 37 swimmers (19 girls and 18 boys, aged 10.8 ± 1 yrs) participated in the research. We performed a physical examination using the PostureScreen11.1 application, a digital goniometer, a manual dynamometer, and functional and diagnostic orthopaedic tests. The swimmers were divided into a trained group and a control group. A three-month complex injury prevention programme was developed for the trained group. We analysed our data using Statistica for Windows.

Results: We found that 19% of the swimmers had experienced shoulder pain since starting swimming. We also found several postural faults, a reduction in the rotational arc of motion in the shoulder joint, rotational muscle imbalance, serratus anterior weakness, and scapular dyskinesia. Following the programme, swimmers in the trained group showed significant improvement in the rotational arc of the shoulder joint, internal rotational range of motion, rotational muscle strength, and upper limb stability. Progress was also made in many other areas, although these results were not significant.

Conclusions: As shoulder pain and its risk factors can be observed even among the youngest competitors, a dryland training plan tailored to this group can reduce the occurrence of sports injuries.

KEYWORDS

prevention, swimmers, shoulder pain, dryland training

INTRODUCTION

Competitive swimmers participate in both water and dryland training to improve performance, since it is difficult to achieve the skills, speed, and muscle strength required for swimming by means of water training only [1]. Swimmers use their upper limbs to provide around 90% of their forward propulsion, which means that, during a stroke, the shoulder muscles are required to work extremely hard, resulting in muscle imbalance between the internal and external rotators in the shoulder [2].

Borsa et al. recommend the use of prevention programmes made up of land-based activities, which can reduce the risk factors for injuries and pain. In the context of elite sports, they also highlight the importance of developing optimised training programmes that correspond to the characteristics of the respective sport [3]. Although aquatic preparation is clearly one of the sports coach’s main tasks, the involvement of coaches in dryland training is
not self-evident. In Hungary, as elsewhere, clubs and coaches have recently started to request the help of medical professionals, and this trend is gaining ground.

Johnson et al. point out that injury prevention programmes for swimmers must be safe for the athletes, and that, besides being considered safe by the specialist, the selected exercises must also be effective. In each case, proper execution is essential [4].

A comprehensive stretching, strengthening, and endurance training programme can generally be said to be an essential part of the everyday life of elite swimmers [5]. Many other researchers suggest the addition of prevention programmes based on dryland training activities, which can contribute to reducing risk factors for injuries and pain [3]. Besides appropriate stretching, core exercises that strengthen the rotator cuff muscles, stabilise the scapula, and improve the stability of the lumbar spine are essential for competitive swimmers. Sufficient strength in the rotator cuff muscles, and especially the external rotators, is extremely important for preventing shoulder injuries among swimmers. Swimmers are prone to rotator cuff muscle imbalance caused by strong internal rotator muscles and overstretched, relatively weak external rotators [4].

In 2015, Manske et al. reported that, during their research, they found no studies addressing dryland training for swimmers with an average age of 14 years, thus our present research fills an existing gap [6]. The specific goal of our study was to map kinetic patterns and sports injury risk factors among young competitive swimmers (aged 9–12 years), and to examine the effectiveness of a complex injury prevention programme on dry land.

MATERIALS AND METHODS

A total of 37 young swimmers (average age 10.8 ± 1.0 yrs) participated in the research. They were divided into a “control” group (n = 16, 10.5 ± 0.97 yrs) and a “trained” group (n = 21, 11.0 ± 1.0 yrs). Swimmers from one club were placed in the control group, while swimmers from a different club formed the trained group. Members of the control group completed the questionnaire survey and physical examination, but did not participate in the prevention programme. The training load of the two groups was similar: the prevention programme did not add to the training load of the trained group. The dryland prevention programme for the trained group took place over three months, for one hour three times a week. It was followed by an assessment of programme effectiveness. During the two measurements, the same physiotherapist was present with both groups, on both occasions.

EXAMINATION PROCEDURES

Questionnaire survey

We used a questionnaire to collect data on the athletes’ anthropometric characteristics (body weight, height, dominant limb), swimming history, current training load, and past and present complaints, injuries, and pain. A visual analogue scale (VAS) was used to measure the level of pain, and the level of current shoulder pain was recorded at rest, during exercise, and after exercise. Pain evaluation was carried out in accordance with the Swimmer’s Functional Pain Scale (SFPS) [7]. Following the three-month training, the participants completed the same questionnaire as earlier, this time with the addition of questions on their opinion of the effects of the training programme.

Physical examination

The swimmers were tested in the Duna Arena swimming pool on both occasions. To evaluate posture, the Posture-Screen11.1 application was used with an iPad. We performed the posture analysis from the front, right side, back, and left side in a standing position. The application provided us with an objective assessment of the swimmers’ posture during the two surveys [8].

The passive range of motion of the shoulder joint was measured using a Baseline® digital goniometer. We examined passive flexion and range of motion in internal and external rotation (at 90° of shoulder joint abduction). The strength of the shoulder rotator muscles was measured using a MicroFET®2 handheld dynamometer [9].

We also performed the following functional and diagnostic orthopaedic tests:

- Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST). Use of this test made possible the closed-chain examination and functional evaluation of joint stability in the upper limbs and shoulder girdle. The accuracy of the CKCUEST was confirmed in research carried out by de Oliveira et al. in 2017 [10]. The swimmers were instructed to perform as many alternating hand touches as possible in 15 s while maintaining the correct push-up position. The test was repeated three times, with 45 s of rest in between.

- The Lateral Scapular Slide Test (LSST). This is a stability test used to assess scapular asymmetry. The test was carried out in three positions. Physiologically, there should be a difference of not more than 1.5 cm when the measurements are compared bilaterally [11].

- Painful arc test. This test makes it possible to discern where pain may originate, based on where pain occurs during full shoulder abduction range of motion [12].

- Serratus anterior wall test. If, during this test, the medial margin of the scapula lifts from the chest wall, the test is positive and the result indicates serratus anterior weakness [13].

- During the painful arc test, we also examined the movement of the shoulder blades to check for asymmetry when raising and lowering the arms (scapular dyskinesia) [14].

Statistical analysis

For data analysis, we used Statistica for Windows 13.4 and Microsoft Office Excel. For data characterisation we used mean, standard deviation, and median, and we also
calculated percentages. We performed the chi-squared test to explore relationships among the data, and the Wilcoxon test to compare the results before and after the training. The significance level was set at $\alpha = 0.05$.

THE PREVENTION TRAINING PROGRAMME

The muscles that stabilise the scapula must not be neglected, since proper scapular movement provides a stable basis for movement in the shoulder joint. While the strengthening of these muscles is important for everyone, it is particularly important for athletes who perform overhead movements [15]. Among the muscles around the scapula, the focus is on the serratus anterior, the rhomboid major and minor, and the middle/lower part of the trapezius [16].

When swimming, core stability is essential due to the unstable nature of water [17]. As shown in the literature, exercises to strengthen the core muscles are an integral part of many swimming training programmes [18, 19]. Core muscles are engaged while swimming, as they connect and support arm and leg movements [18]. Strengthening the core muscles also develops pelvic control and maintains the physiological tilt angle of the pelvis [20]. The performance of core strengthening exercises is thus the most important part of the prevention programme [4].

Strengthening programmes for competitive swimmers should be supplemented with stretching. Decreased internal rotation and decreased horizontal adduction range of motion are common in swimmers, predisposing them to subacromial impingement. The most effective isolated static stretching exercises for the prevention of injuries are stretches of the pectoralis major and minor, the latissimus dorsi, and the posterior part of the shoulder joint capsule [21].

Self-myofascial release (SMR) therapy using a foam roller is a common technique employed by many swimmers to promote faster regeneration and prevent injuries. Aware of the respective scientific literature [22], we decided to teach the basics of this technique to this group of young swimmers as well.

We also made use of the posture correction work carried out by the Hungarian Spine Society to help give the swimmers a sense of correct posture [23].

Based on the literature mentioned above, we developed a prevention programme for the trained group that included the sport-specific development and strengthening of the rotator cuff, scapula-stabilising, and core muscles; the stretching of muscles prone to shortening; a series of posture correction exercises; and basic training on the use of the SMR technique with a foam roller (Figures 1–3). The sessions were made progressively difficult week by week. The goal was to include the abovementioned exercises during a one-hour session three times a week. In the course
of the three-month prevention programme, we included many different exercises, with variations and different degrees of difficulty. Progression always depended on individual status: difficulty increased only when the individual was able to perform an exercise perfectly.

RESULTS

The swimmers in the groups had learned to swim at an average age of 4.21 ± 0.98 years. At the time of the first measurement, the amount of time they had spent as competitive swimmers (i.e., their “swimming age”) was on average 3.4 ± 1.1 years.

The main swimming strokes in the groups were butterfly (7), backstroke (9), breaststroke (11), freestyle (26), and medley (5) (multiple main strokes were also possible).

None of the swimmers had suffered acute injuries as a result of swimming at the time of the first measurement, although, since becoming competitive swimmers, 19% (i.e., 7 of the 37 participating swimmers) had experienced shoulder pain and 5% (2 swimmers) had experienced knee pain.

At the time of the first measurement, none of the swimmers were experiencing shoulder pain at rest, during the warm-up in the water, during the main part of the training, or after the training.

As part of our questionnaire, the children completed the Swimmer’s Functional Pain Scale, which did not indicate current shoulder pain.

During the analysis, when examining the combined trained and control groups (objectively, using the values from the PostureScreen©11.1 application; and semi-objectively, using the reference points in the application), we identified numerous problems in relation to sagittal and frontal posture. Forward head posture was found in 11 swimmers; asymmetric shoulder position in 13; increased dorsal kyphosis in 1; increased lumbar lordosis in 1; a tilted pelvis in 4; and hyperextended knees in 5 (Fig. 4). The trained group – unlike the control group – regularly performed a series of posture correction exercises, the results of which are detailed below.

In the control group, no differences were identified in the posture analysis during the three-month period.

The results of the range of motion and shoulder joint strength measurements are shown in Table 1.

During the serratus anterior wall test, which indicates weakness of the serratus anterior muscle, we observed weakness/test positivity in 22 (59%) cases in the trained and control groups at the first measurement.

During the LSST, we did not measure a difference greater than 1.5 cm between the right and left inferior angle of the scapula and the closest point of the spine in any swimmer. According to Kibler [24], a difference greater than 1.5 cm can be clinically evaluated as scapular dyskinesis.

Last, but not least, the painful arc test was negative during both measurements.

DISCUSSION

Researchers approach the relationship between competitive swimming and shoulder pain from many different angles [25, 26]. In our questionnaire survey, we likewise attempted to collect comprehensive relevant information about shoulder pain. Among the surveyed swimmers (average age 10.8 ± 1 years), a total of 19% had experienced shoulder pain since starting the sport.

Our posture analysis revealed a number of postural faults. Similar to the research findings of Lynch et al., forward head posture and abnormal shoulder posture were observed in our research, along with other postural faults [27]. Riemann et al. found that rotational arc range of motion was significantly larger up to the age of 14 years than among older individuals [28]. In our research, the rotational arc of the shoulder prior to the programme was predominantly, albeit minimally, below the physiological 180°, thus there were visible signs of a phenomenon that can also be seen in adult competitive swimmers, which is one of the risk factors for shoulder pain.

One of the most effective ways to stretch the back capsule of the shoulder joint is the so-called sleeper’s stretch exercise, which can improve range of motion by 15% in athletes performing overhead movements [29]. Progress was also made in this respect as a result of our programme: the range of motion of internal rotation significantly improved in the swimmers in the trained group (dominant arm: \( P = 0.04 \), non-dominant arm: \( P = 0.03 \)).

Lower muscle strength ratios should be considered a risk factor for the development of pain [30]. In 1995, Rupp et al. found that swimmers have a significantly lower external rotation to internal rotation (ER:IR) muscle strength ratio compared to non-swimmers [31]. According to Moradi et al., a ratio lower than 0.76 is an accepted risk factor for shoulder injuries [32]. Our results show that even the youngest swimmers had a lowered muscle strength ratio. Although the measured ER:IR ratio was not below 0.76, based on the literature to date this finding is still of concern, considering that it is an important risk factor in the development of shoulder pain.

The CKCUEST can be used to investigate and functionally evaluate joint stability in the upper limb and shoulder girdle.

![Figure 4](image-url)
Table 1. Results of range of motion and shoulder joint strength measurements, CKCUEST test, serratus anterior wall test, and scapular dyskinesia test (*Wilcoxon test; †chi-squared test)

<table>
<thead>
<tr>
<th>Test</th>
<th>1st measurement</th>
<th>2nd measurement</th>
<th>P value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dominant limb</td>
<td>Non-dominant limb</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External rotation ROM of the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shoulder joints</td>
<td>Trained group 93.4 ± 4.3 (91.5) ²</td>
<td>92.7 ± 4.9 (92)²</td>
<td>0.0793</td>
<td>0.0002</td>
</tr>
<tr>
<td>Control group 91.8 ± 4.7 (91.7) ²</td>
<td>91.9 ± 3.1 (93)²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal rotation ROM of</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the shoulder joints</td>
<td>Trained group 87.5 ± 5.5 (7.2)²</td>
<td>86.2 ± 5.8 (86.6)²</td>
<td>0.0002</td>
<td>0.0001</td>
</tr>
<tr>
<td>Control group 86.7 ± 7.4 (90)²</td>
<td>87.4 ± 7.3 (90.25)²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total arc of motion of the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shoulder joints (internal +</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>external rotation)</td>
<td>Trained group 180.9 ± 8.4 (178.5)²</td>
<td>178.9 ± 6.1 (177.2)²</td>
<td>0.0008</td>
<td>0.001</td>
</tr>
<tr>
<td>Control group 175.8 ± 9.1 (178.1)²</td>
<td>179.3 ± 8.1 (18.7)²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isometric shoulder</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>external rotator muscle strength</td>
<td>Trained group 33.4 ± 5.8 (33.8)N</td>
<td>36.1 ± 6.7 (34.7)N</td>
<td>0.005</td>
<td>0.0007</td>
</tr>
<tr>
<td>Control group 28.4 ± 6.7 (29.4)N</td>
<td>27.6 ± 8 (27.1)N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isometric shoulder</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>internal rotator muscle strength</td>
<td>Trained group 43.2 ± 7.6 (44.9)N</td>
<td>44.1 ± 9.8 (45.4)N</td>
<td>0.0002</td>
<td>0.3869</td>
</tr>
<tr>
<td>Control group 35.2 ± 7.1 (36)N</td>
<td>33.8 ± 7.6 (35.8)N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotator muscle strength ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(internal/external)</td>
<td>Trained group 0.78 ± 0.12 (0.77)</td>
<td>0.83 ± 0.15 (0.81)</td>
<td>0.244</td>
<td>0.0023</td>
</tr>
<tr>
<td>Control group 0.81 ± 0.16 (0.82)</td>
<td>0.82 ± 0.19 (0.82)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CKCUEST (touches)</td>
<td>Trained group 60.1 ± 7.7 (58)</td>
<td>62.6 ± 7.6 (63)</td>
<td>0.0003</td>
<td>0.0029</td>
</tr>
<tr>
<td>Control group 57.6 ± 5 (58.5)</td>
<td>58.9 ± 4.5 (58.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serratus anterior wall test</td>
<td>Trained group 10</td>
<td>6</td>
<td>P = 0.21</td>
<td></td>
</tr>
<tr>
<td>(persons)</td>
<td>Control group 12</td>
<td>10</td>
<td>P = 0.46</td>
<td></td>
</tr>
<tr>
<td>Scapular dyskinesis</td>
<td>Trained group 8</td>
<td>6</td>
<td>P = 0.52</td>
<td></td>
</tr>
<tr>
<td>(persons)</td>
<td>Control group 8</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant results are marked in bold.

in a closed chain [10]. The CKCUEST is a useful and reliable way to assess an athlete’s upper limb stability [33]. As a result of our dryland programme, the swimmers’ upper limb stability improved significantly (P = 0.0003).

The stability of the scapula can be examined using the quick serratus anterior muscle test [13]. By strengthening the muscles that stabilise the scapula, the extent of scapular winging, the elevation of the medial margin of the scapula, can be reduced, thereby also indirectly stabilising the shoulder joint. Serratus anterior muscle weakness was observed in 59% of the survey participants, which can be considered a very high percentage at such a young age. Although there was no significant improvement, positive signs were observed in the results of the trained group that had participated in the prevention programme.

LIMITATIONS OF OUR STUDY

This study has two main limitations. One is the relatively small number of swimmers, while the other is the age of the swimmers, as the youngest was 9 and the oldest was 12 years old. This resulted in a less homogeneous group, although it is worth pointing out that we were able to achieve minimum resistance of prevention and the use of appropriate strengthening and stretching exercises.

In their 2020 research, Tooth et al. stated that previous shoulder injuries, the shoulder joint’s range of motion, and
weakness in the muscles of the rotator cuff increase the risk of injuries. Furthermore, in their conclusions, Tooth et al. state that range of motion, rotator cuff muscles, and training load are the most important modifiable factors in terms of influencing shoulder pain [35].

Based on the data in the literature as well as our own experience and results, we conclude that swimmers can be helped by the implementation of a targeted prevention programme on dry land – as one of the many prevention options. During our research, we expected to make advances in the field of prevention and thus reduce the injuries and pain caused by elite sports.

In summary, the results of both groups can be said to have improved in several areas; however, the swimmers in the trained group also showed significant improvement in the shoulder joint rotational arc, rotational range of motion, rotational muscle strength, and the stability of the upper limbs following the programme. Progress was also made in terms of postural correction, shoulder rotator muscle strength ratio, and the strength of the muscles stabilising the scapula, although these results were not significant.

The most important finding of the present study is that shoulder pain and its risk factors can be observed even among the youngest group of competitors. Another finding is the lack of research on such young children in the international literature. A tailored, dryland training plan can reduce the incidence of shoulder injuries. The role of physiotherapists is important in the treatment of competitive swimmers, while prevention and early treatment should be considered as the primary focus [36].

Authors’ contributions: MC, ÁAM, GSz and AV developed the research plan; MC summarised the scientific background of the paper; ÁAM, GSz and AV conceptualised and designed the methodology of the survey; and MC conducted the survey. MC and ÁAM carried out the statistical analysis. The prevention programme for the swimmers was implemented by MC. All the authors critically discussed the results, contributed to the final manuscript, and approved it as submitted.

Ethical approval: The study was performed in accordance with the Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects. Participants received both oral and written information about the study and signed an informed consent form.

Conflicts of interest/funding: The authors declare no conflict of interest. The study was supported by the UNKP-21-1 New National Excellence Programme of the Ministry for Innovation and Technology through the National Research, Development and Innovation Fund.

ACKNOWLEDGEMENTS

NA.

REFERENCES


