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Evaluation of general joint laxity, shoulder laxity and mobility in competitive swimmers during growth and in normal controls

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The aim of the study was to evaluate differences between competitive swimmers and a reference group of school children concerning general joint laxity, laxity of the glenohumeral joint and range of motion in the shoulder. Materials and methods. Competitive swimmers (*n* = 120) were compared with references consisting of age and gender matched school children (*n* = 1277). General joint laxity was evaluated with the Beighton score. Anterior glenohumeral laxity was assessed according to the drawer test, and inferior glenohumeral laxity according to the sulcus test. Shoulder rotation was measured with a goniometer.

Results. Male swimmers of both age groups showed a higher degree of general joint laxity compared with the reference group while 9-year-old female swimmers alone had a lower degree of general joint laxity compared with references. No significant difference concerning shoulder laxity was noticed between groups. There was a decreased internal rotation in male and female swimmers as compared with the reference group. External rotation was reduced in female swimmers as compared with the female references. The same result was observed in male swimmers, but only at the age of 12 years. *Clinical consequence:* Competitive swimming in children seems to lead to a decreased range of motion with regard to shoulder rotation. However, the reason for this is still unclear and further investigations are needed.

Little is known about the normal physiological, age and gender-dependent laxity in asymptomatic shoulders. The anterior drawer and sulcus tests are the most commonly used clinical examination techniques to determine the degree of laxity of the static stabilizing components of the shoulder (Gerber & Ganz, 1984; Boublik & Hawkins, 1993; Bak, 1996). These represent subjective evaluations relying on the examiners subjective perception of laxity.

Laxity portrays the actual translation within a joint without influence of pain during a passive motion (Noyes et al., 1989). An extended laxity is a necessary feature of the soft tissue surrounding the shoulder for normal glenohumeral rotation. The degree of laxity differs between individuals and is suggested to depend on several factors including age and gender (Emery & Mullaji, 1991; McFarland et al., 1996; Borsa et al., 2000). The most common opinion about the importance of gender in this area is that females have a larger amount of laxity compared with males (McFarland et al., 1996; Borsa et al., 2000). Others, however, claim that there are no differences between males and females (Emery & Mullaji, 1991). Instability, on the other hand, is experienced by the patient and presupposes an excessive mobility of the joint with effect on pain perception during an active motion (Noyes et al., 1989). A spectrum of instability exists and represents, among other factors, an increasing degree of injury to either the dynamic and/or static stabilizing components of the shoulder (Warner & Boardman, 1999). These concepts may be divided into anterior, posterior and/or inferior laxity/instability. A multidirectional laxity/instability implies an excessive inferior laxity/instability in combination with an additional direction (anterior and/or posterior) (Neer & Foster, 1980).

The term hypermobility can be described as an excessive motion compared with normal range of motion, and describes an angular movement (compared with laxity describing translation). Joint hypermobility is a result from genetic variations with the result of excessive tissue stretch. Two types of hypermobility are described in the literature. The first is occurring in people whose joints are just like everyone else's but which have the capacity to move more than most people's joints, so-called benign hypermobility syndrome. The other, a more marked form, has features that suggest that it may be part of an inherited connective tissue disorder (Grahame, 2000).

Several studies have shown that hypermobility can either be inherited and/or acquired (Child, 1986; Klemp & Chalton, 1989). Gender, age, ethnic background and hormonal influences are factors suggested to have an impact on the degree of joint mobility (Beighton et al., 1973; Al-Rawi et al., 1985; Silman et al., 1987; Bulbena et al., 1992; Larsson et al., 1993). Carter and Wilkinson (1964) designed a score evaluating general joint laxity of five joints, and this was modified later in Beighton et al. (1973).

Hypermobility, as well as locally increased or decreased laxity and/or range of motion of the shoulder, are discussed as potential risk factors for injuries during sporting activities (Warner et al., 1990; Kocher et al., 2000; Hovis et al., 2002). However, there is yet no consensus on any causal relationship.

Bak and Magnusson (1997) reported that there was a difference between competitive swimmers with and without symptomatic shoulders concerning the degree of rotation, but concluded that these changes were not related to their symptoms. Disorders of the shoulder joint are common in competitive swimming (Richardson et al., 1980; Bak & Magnusson, 1997). Competitive swimmers appear to need excessive mobility of their shoulder joints in order to perform an efficient swimming technique (McMaster et al., 1998). There is a very subtle balance between excessive mobility and instability. On the one hand an excessive motion allows the athlete to perform more powerful swim strokes, but on the other hand this extensive motion might stretch those structures responsible for producing stability resulting in future instability problems.

Subsequently, there are only a few studies with proven significant relationship between general joint laxity or joint specific laxity and athletic injuries. Soderman et al. (2001) found a significant relationship between generalized joint laxity and increased risk of traumatic injuries of the lower extremity in female soccer players. This finding is of great value and similar studies are needed to obtain specific knowledge about the normal physiological general joint laxity as well as joint specific laxity to be able to detect discrepancies. In this context, children and adolescent constitute a very important group since growth is one factor affecting laxity (Emery & Mullaji, 1991). One crucial question is if intensive sports participation can influence the normal growth development of joint laxity and, thereby develop, e.g. unstable, symptomatic joints.

The aim of the present study was to evaluate general joint laxity, laxity of the glenohumeral joint and range of motion of the shoulder joints in competitive swimmers and a reference group of school children.

Materials and methods

This investigation was conducted as a part of a Swedish nationwide cohort-based, cross-sectional, multidisciplinary research study ("Skolprojektet, 2001"). School classes representing two age groups participated voluntarily in the present study with a total of 1277 school children included constituting the reference group. The only inclusion criteria for the subjects of the reference group were to be listed as a student of the class of interest. No subject was excluded because of an injury of the upper extremity. The school classes were randomly selected by the Statistiska Centralbyrån of Sweden. The study group comprised a group of 120 age and gender-matched competitive swimmers. The inclusion criteria for this group were participation in a minimum of three training sessions per week at least for 1 year. Age and gender for both groups are presented in Table 1.

General joint laxity was evaluated according to the score by Beighton et al. (1973), which includes the following five maneuvers:

1. passive opposition of the thumb to the flexor aspect of the forearm (right and left);
2. passive hyperextension of the fifth finger to $>90^\circ$ (right and left);
3. hyperextension of the elbow $>10^\circ$ (right and left);
4. hyperextension of the knee $>10^\circ$ (right and left);
5. flexion of the trunk with knees extended, and both palms resting on the floor.

One point was given to each correctly performed maneuver (right and left) with a total score ranging from 0 to 9. The examiner demonstrated every maneuver together with an oral instruction to each individual whereupon the child imitated the movement. The child was instructed to try to do his/her best to perform the above-presented maneuvers without pain.

Anterior glenohumeral laxity was assessed according to the drawer test with a subjective four-grade system. Grade 1: normal translation, grade 2: excessive translation within the glenoid, grade 3: translation of the humeral head onto the glenoid rim, and grade 4: translation of the humeral head over the glenoid rim (frank dislocation) (Bak, 1996).

Inferior glenohumeral laxity was evaluated according to the sulcus test using a subjective three-grade system. By an inferior pull of the arm just above the elbow, the distance between the acromion and caput humerii was estimated according to the following grades: grade 1 equals ≤ 1 cm, grade 2 equals 1–2 cm, and grade 3 equals >2 cm inferior translation (Gerber & Ganz, 1984; Boublik & Hawkins, 1993). Examinations of

Table 1. Mean (M) and standard deviation (SD), of the study groups, competitive swimmers ($n=120$) and reference group ($n=1277$) concerning number of subjects (n) and gender in different age (year) groups

	Competitive swimmers			Reference group		
	n	Age, year (M)	SD	*n*	Age, year (M)	SD
Males	17	10.4	0.6	317	9.0	0.3
Males	36	13.3	1.2	349	12.0	0.3
Females	30	10.4	0.8	256	9.0	0.3
Females	37	13.8	1.2	355	12.0	0.5
Total	120			1277		

anterior and inferior glenohumeral laxity were performed with the subjects in a seated position.

Range of rotation was recorded with a Myrin™ OB Goniometer (Lic Rehab AB, Linköping, Sweden), measuring internal and external rotation with a weighted pointer controlled by gravity and axial rotation with a compass (Fig. 1). The measuring procedures recommended by the American Academy of Orthopedic Surgeons were followed (Greene & Hechman, 1994). Using Velcro straps the inclinometer was placed proximally on the subjects forearm, just proximal of the head of ulna. The subject was in supine position with the shoulder in 90° of abduction and the elbow in 90° of flexion. Maximal active internal and external rotation was measured until noticeable movement of the trunk. The same examiner (A. J.) performed all the examinations.

A written informed consent was obtained from the parents or guardians of all subjects. The present investigation was performed in collaboration with the Stockholm University College for Physical Education and Sports, Stockholm Institute of Education and Karolinska Institutet, Stockholm, Sweden. The study was approved by the Ethical Committee of the Medical Faculty at the Karolinska Institutet, Stockholm (Dnr: 00416, 98–348).

Statistics

Descriptive statistics were used to summarize all variables (median, mean, range, standard deviation). Factorial ANOVA was used to test for significant differences between means concerning shoulder rotation. Fisher LSD was used as post hoc test to compensate for the multiple comparisons. Because of positively skewed data Mann–Whitney's *U*-test was used to analyze differences in sum of ranks concerning distribution of the Beighton score and the shoulder laxity test. The significance level was set at $P < 0.05$ (two-tailed).

Fig. 1. Myrin™ OB Goniometer.

Results

General joint laxity

Male swimmers showed a higher degree of general joint laxity at both age groups (9 years, $P = 0.013$; 12 years, $P = 0.003$) compared with the reference group (Fig. 2). Female swimmers showed a lower degree of general joint laxity compared with their references at the age of 9 years ($P = 0.021$). No significant difference was found at the age of 12 years (Fig. 3).

Shoulder laxity (differences in and between right and left shoulders)

Fifty-nine percent of male and 62% of female competitive swimmers at the age of 9 years showed no significant difference between right and left shoulders concerning degree of anterior laxity. The references displayed a similar result as competitive swimmers (64% of males and 62% of females). None of the subjects at the age of 9 years had a side-to-side difference of more than two grades of their shoulders. At the age of 12 years, 56% of male and 65% of female competitive swimmers showed no significant difference between right and left shoulder concerning anterior laxity. Among the references no side-to-side difference was found between shoulders in 68% of males and 67% of females. None of the subjects at 12 years had a side-to-side difference of more than two grades of their shoulders.

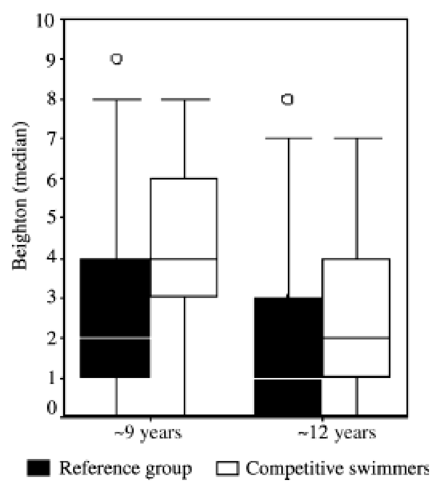

Fig. 2. Boxplot of Beighton score for males, 9 years ($P = 0.013$) and 12 ($P = 0.003$) years old, competitive swimmers (open boxes) and the reference group (black boxes).

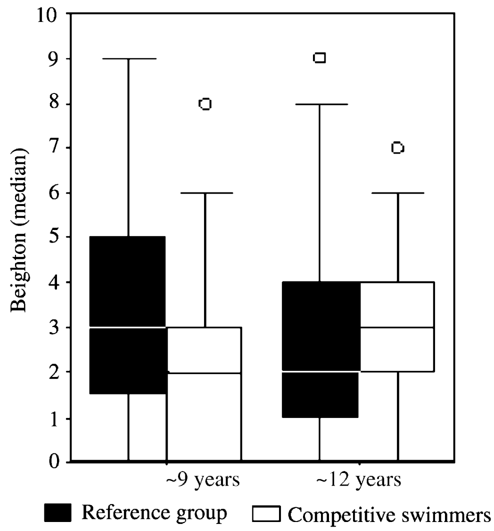

Fig. 3. Boxplot of Beighton score for females, 9 ($P = 0.021$) and 12 (NS) years old, competitive swimmers (open boxes) and the reference group (black boxes).

For inferior laxity, 82% of male and 83% of female competitive swimmers had no difference between right and left shoulders at the age of 9 years. Male references (84%) and female references (83%) also did not differ in inferior laxity between right and left shoulders at the age of 9 years. None of the subjects had a side-to-side difference of one grade or more between their shoulders. Twelve-year-old competitive swimmers (86% of males and 62% of females) had no side-to-side difference between shoulders in inferior laxity. The references showed a similar result (83% of males and 67% of females) with no significant difference between shoulders concerning inferior laxity. None of the subjects had a side difference of one grade or more between their shoulders.

Shoulder laxity (unilateral and multidirectional laxities)

There were no significant differences between competitive swimmers and references concerning anterior or inferior laxity of the shoulder. Neither were there any significant differences between competitive swimmers and references when combining the two directions (anterior and inferior laxity).

Shoulder rotation

Internal rotation of the shoulder was significantly smaller in both male and female swimmers at the age of 9 years (male: right $P = 0.000$ and left $P = 0.003$; female: right $P = 0.000$ and left $P = 0.000$) and 12 years (male: right $P = 0.001$ and left $P = 0.000$; female: right $P = 0.000$ and left $P = 0.000$) in comparison with the references.

No significant difference was observed at the age of 9 years concerning external rotation between swimmers and references. External rotation of the left shoulder was significantly smaller in male swimmers at the age of 12 years compared with references ($P = 0.000$). Female swimmers had a significant smaller external rotation at both the age of 9 and 12 years compared with references (9 years: right $P = 0.000$ and left $P = 0.000$; 12 years: right $P = 0.006$ and left $P = 0.000$).

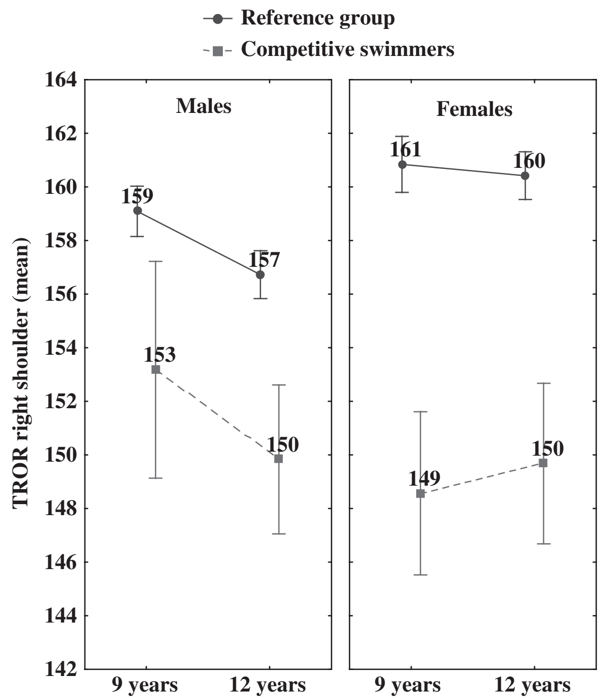

Fig. 4. Differences in mean values of total range of rotation (TROR) of the *right* shoulder in males at ages 9 years ($P = 0.005$) and 12 years ($P = 0.000$) and in females at ages 9 years ($P = 0.000$) and 12 years ($P = 0.000$). Vertical bars display 95% CI.

There was a significant difference between competitive swimmers and references concerning total range of rotation (TROR = internal and external rotation added together). Competitive swimmers (both gender) showed a lower TROR at the age of 9 years (male: right $P = 0.005$ and left $P = 0.046$; female: right $P = 0.000$ and left $P = 0.000$) and at the age of 12 years (male: right $P = 0.000$ and left $P = 0.000$, female: right $P = 0.000$ and left $P = 0.000$) (Figs 4 and 5).

Discussion

The purpose of the present investigation was to evaluate general joint laxity as well as laxity and range of motion of the glenohumeral joint in young competitive swimmers and an age and gender-matched reference group.

Our results revealed a significantly lower general joint laxity in female swimmers compared with females of their reference group at the age of 9 years,

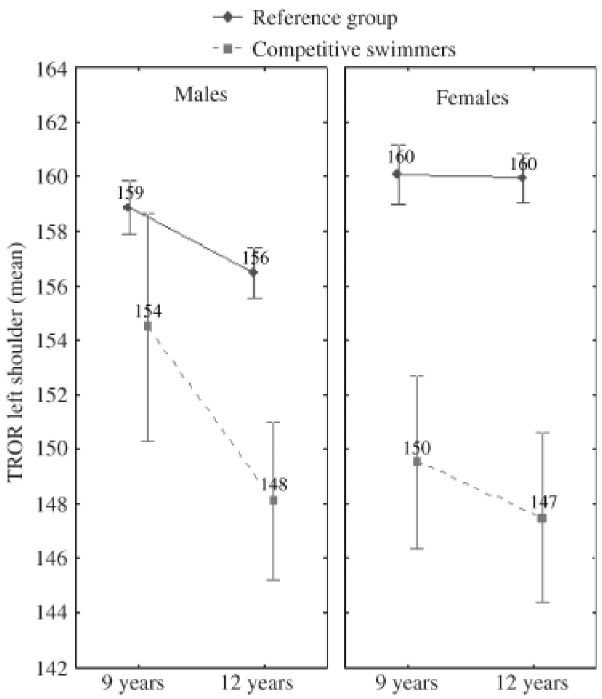

Fig. 5. Differences in mean values of total range of rotation (TROR) of the *left* shoulder in males at ages 9 years ($P = 0.046$) and 12 years ($P = 0.000$) and in females at ages 9 years ($P = 0.000$) and 12 years ($P = 0.000$). Vertical bars display 95% CI.

while no difference was shown at the age of 12 years. Male swimmers, on the other hand, showed a higher degree of general joint laxity at both the age of 9 and 12 years when compared with males of their reference group.

One possible explanation to our findings could be that as a result of swimming, female swimmers develop increased muscle mass around the shoulder joint leading to a decreased joint laxity. Jansson et al. (Acta Paediatrica, in press) found that school boys developed a lower degree of general joint laxity with increasing age, while girls showed the opposite pattern. This reduction in general joint laxity with age in boys may be counteracted by a high amount of swim training. The different gender responses to training may be explained by the gender differences in the onset of puberty and levels of sex hormones.

Another explanation to the differences between competitive swimmers and references could be because of the age discrepancies in and between groups. Competitive swimmers displayed overall a higher mean age compared with references because of logistics. Variances between 9- and 12-year old subjects have been presented in this paper and perhaps could a discrepancy of 1 year, as the case is in and between competitive swimmers and references, involve hormonal differences.

Another thought in this matter is whether a natural selection could be the reason for these observed differences. Is it possible that "favorable genes" could determine the level of success in a specific sport in the young athlete and therefore a longer career? This question is also necessary to consider but also difficult to answer based on this study. A 3-year follow-up study of both competitive swimmers and references are, however, under progress and might hopefully generate any explanation.

There were no significant differences in anterior and/or inferior laxity between competitive swimmers and the reference group with respect to side differences between the shoulders. Lintner et al. (1996) did not find an increase in shoulder laxity in college competitive swimmers compared with non-overhead. However, they reported a greater degree of laxity in the non-dominant side in athletes. These findings are in contrast to McFarland et al. (1996) who studied high school and college athletes in both overhead and non-overhead sport and reported a greater degree of laxity in the dominant shoulder of athletes. Jobe et al. (1989) suggested that overhead college athletes were prone to have an increased shoulder laxity as a result of the technical demands of their sport. There is, in other words, no clear consensus concerning a higher degree of laxity in the dominant or non-dominant shoulder. Also, there is no agreement as to whether or not overhead athletes have greater shoulder laxity compared with non-overhead athletes. This lack of agreement is exacerbated for children and adolescents, where little research is available.

One explanation worth considering for the result of the present study might be the examination technique used. Anterior drawer test and sulcus test are subjective evaluations relying on the examiners "feeling" of laxity. Previous authors have reported poor reproducibility and poor diagnostic value using these subjective evaluations as such (Warner et al., 1990; Rodkey et al., 1993; Lintner et al., 1996; Levy et al., 1999; Ellenbecker et al., 2000). Furthermore, it has been suggested that the results from studies using subjective methods depend on factors such as the experience of the examiner, the inconsistencies of force applied, humeral head centering, patient positioning and muscular tension (Cofield et al., 1993; Rodkey et al., 1993; Levy et al., 1999; Oliashirazi et al., 1999). The latter factor might be even more important when comparing athletes, especially competitive swimmers with non-competitive swimmers. Large and well-defined muscles surrounding the shoulder girdle could furthermore contribute to an apparent underestimation of laxity. Training in different sports, e.g. swimming, have been shown to result in specific arm strength gains, even in the young athlete (Ramsay et al., 1990). Similar studies concerning the effects of muscle volume in the young athlete are, however, more difficult to find.

When performing the anterior drawer test, the examiner should press the humeral head along the structure of the fossa glenoidalis. In case of slightly protracted shoulders, the examiner needs to redirect the pressure of the humeral head to the existing and sometimes varying anatomy, otherwise a false degree of laxity may be observed.

The applied force has been proven to be highly important when measuring laxity (Jorgensen & Bak, 1995; Pizzari et al., 1999; Sauers et al., 2001). Sauers et al. (2001) found an increase in anterior–posterior (AP) laxity when applying 89 N compared with 67 N.

Furthermore, the importance of the examiner being blinded to which group the subject belonged might be worth discussing. Randomized double-blind controlled trials are the gold standard when performing scientific experiments. Unfortunately, this is not always applicable. In the present study, the examiner was not blinded to the subject. The importance of this factor is uncertain, but the question is whether this deliberately influences these results in any direction.

The different degrees of laxity are difficult to define and the distinction can be unclear (Levy et al., 1999). These well-defined grades, in theory, are perhaps somewhat difficult to transfer into practice, without using objective measurements. In future research there may be a need for a modification when using laxity tests on pure subjective grounds. However, in the clinic the examiner should exercise caution when using laxity tests for diagnosing and evaluating the patient in order to suggest the most effective treatment.

In the present study no significant difference in degree of either anterior or inferior laxity was found between competitive swimmers and the reference group. Epidemiological studies of the prevalence of this condition in males and females are rare. Neer (1985) described an equivalent number of males and females with multidirectional laxity. It is generally believed that females tend to be more lax than males and this may result in a higher risk for females to develop overuse syndromes. There is, however, no consensus whether athletes, without consideration of gender, have a higher frequency of multidirectional laxity/instability than non-athletes.

With the knowledge of poor reproducibility and poor diagnostic reliability of these subjective tests, the need for objective measurements is important. There are some reports on instrumented arthrometry of the glenohumeral joint (Jorgensen & Bak, 1995; Lintner et al., 1996; Levy et al., 1999; Sauers, et al., 2001). Jorgensen and Bak (1995) used a Don Joy® (DJ Orthopedics, Inc., Vista, CA, USA) knee laxity tester and found differences between the symptomatic shoulders compared with the non-symptomatic shoulders. Nevertheless, there were some setbacks concerning the application with the result of a 20% drop-out in their study material. The use of the KT1000 in the shoulder with a known force of 67 N revealed a moderate-to-good reliability (Pizzari et al., 1999). The fitting of both these instruments to the shoulder could perhaps be questioned especially when examining children and adolescents with relatively short humerus in comparison with the size of these instruments. However, an obvious benefit of the instruments is the possibility to use them in both a clinical environment and on field-like non-invasive applications. In order to be the golden standard of future instrumented arthrometry for the glenohumeral joint, the technique needs to show high accuracy, high reproducibility, be non-invasive and easy to use.

Evaluation of active internal and external rotation in the present study showed a significant difference between competitive swimmers and the reference group. Internal rotation of both shoulders was smaller among competitive swimmers, in both males and females. These data are in agreement with Bak and Magnusson (1997), who explained their findings as a result of the technical demands in competitive swimming. They found that competitive swimmers had an excessive external rotation and a decreased internal rotation of the shoulder joint compared with a control group (Bak & Magnusson, 1997).

External shoulder rotation was smaller at the age of 12 years in male swimmers compared with their reference group. Female swimmers showed a significant smaller external rotation at both 9 and 12 years compared with their references. These data are in contrast with other studies, where an excessive external rotation have been observed in overhead athletes (Toussaint et al., 1988; Beach et al., 1992). Lintner et al. (1996) found no significant relationship between the number of years in competitive sports (both overhead and non-overhead athletes) and degree of rotation in the shoulder joint. These observed differences in shoulder rotation are statistically significant, although the clinical importance may be questioned. The shoulder joint has greater mobility than most other joints and can be moved in several planes, with, e.g. a normal abduction of about 184° (Greene & Hechman, 1994). With this background, one could question the clinical importance of a difference of less than 5° in the shoulder joint between competitive swimmers and references. However, additional years of competitive swimming may exacerbate these differences.

When measuring rotation in the shoulder joint it is highly important to be aware of the smallest tendency in movement of the trunk to decrease the risk of a falsely large movement. This could be somewhat easier to account for in supine position. The choice of measurement tool is another important factor when measuring range of motion. The universal goniometer (international standard goniometer) is the most commonly used tool, especially when evaluating the hip and shoulder joints (Norkin &

Biohannon, 1995). This type of instrument can, however, be difficult to use when evaluating rotational movements, i.e. internal and external shoulder rotation. A Myrin™ OB Goniometer, based on a compass method, is therefore suggested when measuring rotation (Kettunen et al., 2000).

The variety of findings in the present study in comparison with other studies could also be explained by the choice of reference group. Symptomatic shoulders are often compared with non-symptomatic shoulders (Bak & Magnusson, 1997). Another well-studied reference group are non-overhead athletes in comparison to overhead athletes (McFarland et al., 1996). In the present study, we used a reference group consisting of school children. The main reason for this was trying to obtain further knowledge about the normal physiological course of events concerning general joint laxity as well as laxity and range of motion of the shoulder joint to be able to detect possible discrepancies. In the present study, we wanted the reference group to be unaffected by external factors, such as early specialization in sports. Therefore, caution should be taken into account in generalizing beyond the scope of the present investigation.

Perspectives

Competitive swimming in children seems to lead to a decreased range of motion with regard to shoulder rotation. However, the reason for this is still unclear and further investigations are needed.

Key words: Beighton score, drawer test, glenohumeral joint, rotation, sulcus test.

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