最高の競技力の発揮を求めて

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Toward a Peak Performance in Swimming

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The children who become intersted in swiming and begin to participate seriously often do so at very early ages, sometimes as young as six or seven. This early involvement very often exposes them to types of stress that can effect the growth and development of their maturing musculoskeletal system in an adverse way, producing a disruption of the normal growth pattern. The most potentially serious of these growth disorders for swimmers is scoliosis or spinal curvature, because it alters spinal rotation function and repositions the shoulder structure.

FUNCTIONAL AND STRUCTURAL SCOLIOTIC CURVATURE.

The vertebral curvature which is defined as scoliosis has been broadly categorized as either structural, or functional. The structual curvature category has been described by Willner[29], Hauser[9], and Portillo[18], as being a deviation of over 10°, accompanied by rotation. This definition specifiee the inclusion of bone and ligament malfunction as a criteria for structural torsion associated with a lateral curvature. Functional scoliosis has been referred to by Keim[11] as a "Mild", form of the vertebral disorder, and Arkin[1] described a functional curve as an initiating cause of the more severe structural curvature. It is notably a postural fault which alters the relative position of the thoracic skeleton and the suspended position of the shoulders.Pediatric orthopedic physician Tachdjian[27], noted that functional scoliosis generally has a single long thoracolumbar curve with a predominately left convexity. His work indicates functional scoliosis produces little rotation of the vertebral body with accompanying rib deformity and the curve will be noted to disappear during recumbency and suspension, and when the spine is flexed in a standing posture.Additionally, Tachdjian[27] noted that some degrll of functional scoliosis is a common occurrence with poor posture, which results when the musculature adapts to the relative position of the skeleton and the physical requirements of work.

INCIDENCE OF SCOLIOSIS

The incidence of idiopathic structural scoliosis has been normally low among the general population, but is notably higher among the adolescents. In a 1955 survey of 50,000 adolescents in the general population, Shands and Eisberg[24] found 1.9 percent or approximately 1000 subjects to have confirmed cases of scoliosis which would be considered for surgical correction. Avikainen and Vaherto[2] in 1983 reported scoliosis to be present in 3－16 percent of the population, depending on the degree of curvature which had been chosen as the limit of scoliosis, and on the age of the subject. These percentages are similar to the findings of Willner[29], who in 1984 reported. 35－13 percent being the incidence of idiopathic structural scoliosis. Additionally, Eckerson and Axelgaard[6] in 1984 also reported that idiopathic scoliosis comprised 75 to 80 percent of all scoliosis in the United States.

Studies focusing on the incidence of males and females include the work of Shands and work of Shands and Eisberg[24], which showed a predominance among females that may be five times as great as the incidence found in like male populations. Avikainen and Vaherto[2] reported that of all cases of scoliosis requiring treatment, 90 percent are females, and mild functional scoliosis is observed to be nearly as frequent in boys as in girls. Other investigations by Wynne-Davies[31], and Fisher and DeGeorge[7], surveyed familial incidence of scoliosis and the relationship to mothers' age. These studies showed a significantly greater than expected number of scoliotic curvatures among the offspring of mothers who were considered to be older. In additional investigations, Yaron, Wolf and Robin[31], indicated that growth that growth and sex hormomes may be decisive factors in the propagation of the scoliotic deformity. This is of particular interest to the swimming population where athletic amenorrhea and a delayed onset of menses is a notable factor that can have an effect on the estrogen level. In preliminary studies by Stager and Becker, 350 female collegiate competitive swimmers were found to have an onset of menses at 16.1 years of age. It is thus possible that buring the growth period and onset of puberty females are subjected to exercise training which not only effects their reproductive function but also in turn effects their skeletal growth.

Further work on the incidence of scoliosis reported by Kuprian, Ork and Meissner[13] indicates that Jenschura found the average frequency of idiopathic scoliosis in athletes to be two precent. Krahl and Steinbruck[12], in examining 571 top athletes in 1971−1977, found a 33.5 percent incidence of functional scoliosis and a 1.6 percent idiopathic scoliosis, similar to the incidence noted by Shands and Eisberg[24]. Kuprian, Ork and Meissner[13] postulated that the high incidence of functional scoliosis among athletes is notable among those participating in sports where muscular exertion in the upper extremity causes extreme torques to be developed in the performance of throwing, and overarm motions. Richardson[19] has also speculated that the rotational torque in overarm swimming likewise produced muscular imbalances between the anterior and posterior shoulder components.

The clinically observed scoliosis in swimmers does present the aquatic sports physician and therapist with a potentially interesting investigation as to etiology and incidence. Due to the great number of adolescents engaged in competitive swimming programs each year, a preliminary study was conducted to ascertain the incidence of scoliosis among this group. In August of 1983, at the junior Olympic Swimming Championships East, held at the Indiana University Natatorium, Indianapolis, 336 of 1200 competitors underwent evaluative screening for scoliosis. The procedure was patterned after the protocol of Dendy, Chase, and Determann[5], and Risser[20], and Willner[29]. This screening procedure included observations with the athlete in the standing erect position, and then in the forward bending position. In the standing erect

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position observations were made for asymmetries of the lateral contours of the trunk, shoulders, scapulae, and the lateral deviation of the spinal processes. In the forward bending position, the observed rib hump asymmentry was considered to be the positive clinical finding for structual idiopathic scoliosis.

Of the 336 athletes who participated, 193 females, and 173 males, 6.9 percent were found to have structural idiopathic signs in each group. Each of these groups were found to have a 16 percent incidence of mild functional scoliosis. The 6.9 percent figure represents an incidence 3 1/2 times the normal incidence, and is well above the 1.9 percent figure in other studies[12,24] while the 16 percent is similar to the high figures of Avikainen and Vaherto, and Willner[29], yet below the 33.5 percent figure of Krahl, and Steinbruck[12].

The screening investigation at the Junior Olympic Swimming Championships East, in which 16 percent were noted to have mild functional curvatures, did produce a unique statistic. In this study the 16 percent figure included a 100 percent occurrence of lateral curvature to the hand dominant side of the body. This supports the muscular imbalance according to Hauser[9], and the dominant arm strength as noted by Yeater et al[32], as possible contributors to these particular investigations. It is obvious that the incidence in this small population is of interest to the swimming community, due to the fact that the event at which the screening clinic was conducted is noted to be a select event, Competitors were entered based on their being capable of swimming at an acceptable level prior to entry, thus placing this population in an elite category, Similar to those athletes studied by Krahl, and Steinbruck[12].

INTRINSIC EFFECTS OF SWIMMING

It has been stated by Magel and McArdle[16] that the propelling force in swimming depends on muscular strength and effective stroke mechanics. Swimming speed increases depend in part on buoyancy, the hydrodynamics of correct stroke technique, and wave making resistance. The propulsive force must equal water resistance, and swimming velocity will result from the relative equilibrium found between force and resistance. Piette and Clarys[17] electromyographic date revealed the muscles most responsible for the propulsion of the competitve swimmer were the latissimus dorsi, rectus abdominis, gluteus maximus, biceps brachii, and pectoralis. Their investigation revealed the latissimus dorsi, rectus abdominis and gluteus maximus were the most active muscles during the freestyle stroke. Results of the study showed that competitive swimmers tested had significantly greater electromyographic results than a like number of noncompetitive swimmers. This study also found the muscular efforts of competitive swimmers were significant for the level of activity in the back, abdominals, and muscles of the pelvic girdle. In succeeding electromyographic studies Clarys [3] again investigated the latissimus dorsi and rectus abdominis muscles and the results confirmed these to be the most active in duration and strength during the freestyle of all the muscles investigated.

Propulsive efficiency studies by Svec [26] examining the freestyle stroke note the first stage of the arm motion produces a pressure curve that is very close to linear from the point of hand entry and pull, through to the initial inward scull. The second phase of the stroke, where pressure curves are greatest, occurs during the last stage of propulsion, where the hand passed mid chest in the push, and finishes in an outward scull phase. High pressure during the proqulsive phase of freestyle is almost always present with a duration that is considered to be variable. Yeater et al [32] in examining the force traces for the crawl stroke observed that many individuals consistently produced greater peak force with one arm or the other during all phases of propulsion. In another study on the analysis of swimming motions Gallenstein and Huston found there are dips in the output velocity for all strokes, due to upper extremity work.

Morphological studies by Sahgal et al [23], Yarom, Wolf, and Robin [31], and Tachdjian [27] show there are generalized myopathic changes in the paraspinal and gluteus muscles of individuals with idiopathic scoliosis. The structural skeletal changes would then be expected to be accompanied by secondary adaptation of the supporting vertebral soft tissues. The change in soft tissue function is characterized by Tachdjian [27] and Hauser [9] as being atrophy, weakness and fibrosis on the convex side of the spine, and thickening and contractions on the concave side. Of all muscle types tested [23, 31], there was significant glycogen content, and the mitochondria were found to be significantly higher on the convex side and in the gluteus, but not on the concave side of the apex, where siguificantly high Z band values were found.

The histographic work by Yarom, Wolf and Robin [31] dealt with analyses of the deltoids, trapezius, and quadriceps muscles. These authors reported no striking morphologic pathology to note, but results of interest included fewer type I fibers on the concave side than on the convex side. In several cases the decline was noticeably marked, and the diameters of the fibers were frequently small or hypotrophic, especially on the concave side.

Fiber distribution and size of fibers were shown by Yarom, Wolf, and Robin [31] to be clearly characteristic, with a constant decrease in the deltoids of the concave side for the idiopathic sample. The conclusion that was drawn indicated there may be many factors responsible for the noted changes, including intrisic and hormonally induced membrane abnormalities.

Muscular adaptation has been the focus of several studies by Maas[15], and Jenesen and Bullow[10]. Maas reported the shape of the pectoralis in swimmers was significantly different than in gymnasts, indicating that the sport activity was functionally specific in relationship to the development of the musculature. Jensen and Bullow[10] report similar information, with evidence that modeling of drag and inertial forces in the freestyle stroke conceivably provide a sufficient load so as to produce functional changes in the muscles, with an expected increase in the contraction moments that correspondingly determine the propulsive force of the shoulder.

Hauser[9] previously observed that an inability of the musculature of the back to perform up to the requirements of the demand will ordinarily produce an increase in all the normal curves of the spine. He attributes this to the functional adaptation of the spine, with a subsequent muscular imbalance between the anterior and posterior structures. This subsequently produces an increase in the anterior／posterior curves recognized as 〝poor posture〞. Hauser[9] further reported that if muscular imbalance is uncorrected a lateras curvature may develop, ultimately producing a compensatory structural scoliotic development. He concluded that whenever there is a decrease in strength of the structure of the back, or loss of capacity, or if there is an increase in the demand made on the back, such as an overload, or a combination of the two exists, scoliosis will develop. If the occurrence of lateral and anterior／posterior curvatures are combined the spine will be subject to increasing stress, if it is exposed to torsional rotation. Krahl and Steinbruck[12] noted unilateral upper limb motion in athletics is a torsional repetitive motion. This occurs in combination with trunk rotation, due to strong pectoralis contraction such as that required in the freestyle, which therefore represents a considerable etiological development in swimmers' scoliosis.

EFFECT OF VERTEBRAL CURVATURE ON SWIMMING PERFORMANCE

The precence of scoliosis among preadolescent and adolescent swimmers may be indicative of skeletal maturity having a direct relationship on muscular adaptation, or vice versa. Research by Risser and Ferguson[21] has shown the spine grows slowly from seven to ten years of age, and three to five degrees of curvature may develop each year during that period. The preadolescent age of 10 to 15 years is a period of rapid spinal growth, and curvature increase may develop as quickly as one degree per month. Additional evidence of this age group being a primary population for alteration in vertebral growth has been shown by Zaousais and James[33], and Risser[21], who noted spinal growth in females stops at an average age of 14 1/2 years and at 16 1/3 years for males. This would be considered a primary age for obvious scoliotic developments among the many swimmers who have followed prolonged training in order to reach high levels of competition.

It may be assumed that the repetitive exercise motions required in swimming that produce physiological adaptations, as noted by Lavoie, Taylor and Montpetit[14], are also capable of producing muscular adaptation and thus a contracted spinal curve. The alteration of soft tissue function about the spine would thus act as a limiting factor in trunk rotation causing shoulder position to be similarly effected. Tachdjian[27] indicated muscle power of the scoliosis patient should be examined, in the anterior and lateral abdominals, erector spinae, quadratus lumborum, and thoracic groups. He found this to be required because of the possibility that weakened muscle groups may be an area where unequal upper extremity strength would cause a considerable torsional force about the vertebrae resulting in the scoliotic spine. The inequality of upper extremity torque production also presents the swimmers with overdevelopment of shoulder musculature and exposure to overuse syndromes.

CONCLUDING

The incidence of scoliosis among swimmers noted by Kuprian, Ork and Meissner[13], and knowledge of the movements that compress the spine, while requiring frequent repetition of vertebral torsion and lateral flexion give cause for further investigation into the contributory effects that performance of the swimming activity has on upper extremity and spinal development. Stroke technique errors often seen among novice and beginning competitive swimmers, such as inequality in trunk rotation and poor arm position during the propulsive phases of strokes can be responsible for the unequal development of the uppey extremity girdle and thoracic musculature.

The functional scoliosis which is prevalent in swimmers often is accompanied by over, development of one upper extremity, similar to the athletic scoliosis noted by Kupyian[13] among athletes whose sports require extreme unilateral upper extremity torque and repetitive motions. Cobb[4], Keim[11], Kuprian[13], Roaf[22], and Tarr[28], believe that exercise of the competitive trainning nature is not inhibiting to the development of the vertebral scoliotic structure.

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liosis among swimmers remaines to be totally convincing, and the cause of the problem has yet to be determined. It is, however, obvious that the repetitive swimming activity will definitely cause adaptation of the primary structures and musculature, with the possibility that a secondary adaptation can occur in the musculoskeletal structure of the shoulders and vertebrae. Although there has been no conclusive evidence to support the role hormonal development has played in the scoliotic curvature, the incidence among the adolescent and preadolescent gives impetus for the need of study in this area. In addition, biomechanical assessment of stroke technique among swimmers should be an area of investigation, due to the high incidence of mild curvatures, to determine if kinesthetics and/or hand dominance play a role in musculoskeletal adaptation of the shoulder and spine.

RECOMMENDATIONS

The prevention of shoulder and spinal muscular problems lies with the coaching and training of young swimmers. Of particular importance is the attention to stroke patterns and equality of the propulsive phases of the individual strokes. Always stress that the swimmer "feel" the length of the stroke with a good entry and finish. This emphasis will help prevent the muscles from developing in a fashion that causes inequality of strength bilaterally thus preventing this aspect of the sport from being a contributor to spinal problems.

Exercises for strenthening should incorporate some form of specific program to concentrate on the upper and middle thoracic areas so as to enhance scapular retractory function and overal shoulder position. Equality of trunk rotation and lateral trunk motion is also important for proper positioning of the shoulder and upper extremity. When these muscular functions are working propery the arm can be positioned most advantageously for the propulsive phases of the stroke.

Finally, all coaches must develop their observational skills and screening abilities so as to detect the early signs of muscular imbalance and developmental irregularities in the growth pattern of young swimmers.

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