Comparative upper-quarter posture analysis of female adolescent freestyle swimmers and non-swimmers

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Repetitive upper-quarter limb movements imposed by freestyle swimming, may lead to muscle length and tension changes, predisposing adolescent swimmers to postural malalignment. The study aimed to quantify the static upper-quarter postural alignment of competitive female adolescent freestyle swimmers, and compare their results to non-swimming peers and to angles of spinal sagittal posture available in the literature. A cross-sectional study design was employed. The evaluation group (EVAL) consisted of 35 competitive swimmers (15±3 y; 166.5±9.9 cm; 65.5±7.7 kg) and the control group (CON) of 36 peers (15±3 y; 164.2±6.7 cm; 62.1±9.1 kg). Spinal sagittal posture was measured by photographic posture analysis. Median ± interquartile range and inter-group differences were calculated. Significant differences ($p = 0.00$) between groups for all variables, with a moderate – large effect, was observed. EVAL demonstrated restricted median scores for head-tilt angle (-8.7°), cervical angle (-13.3°) and shoulder protraction - retraction angle (-24°), and a greater score for thoracic angle (+7.4°), when compared to CON. EVAL and CON deviated from proposed criterion scores for cervical and thoracic angles, with EVAL also deviating from head-tilt angle and shoulder protraction - retraction angle criteria. In this group of adolescent participants, postural malalignment may have been exacerbated by years of freestyle swim training.

Keywords: sagittal spinal posture; adolescent; freestyle swimming; photographic posture analysis

Highlights:

- Significant differences with medium to large effect sizes were noted in the angles of spinal sagittal posture between the competitive female adolescent freestyle swimmers and their non-swimming peers.
- Competitive female adolescent freestyle swimmers appeared to be more vulnerable to postural features in the upper-quarter that were not within the desirable angles of spinal sagittal posture.
- The inherent nature of competitive freestyle swimming and the natural consequence of long-term training may explain the moderate to large effect sizes observed.

Introduction

Swimming is a popular sport in South Africa. It is estimated that over 248 thousand individuals swim recreationally, with an additional 399 thousand individuals competing in high school teams, 301 thousand registered as Swimming South Africa (SSA) members competing in club teams, and 22 thousand swimmers participating in leagues (Sport & Recreation South Africa, 2016; Swimming South Africa, 2020). Within the group of registered club swimmers, 43.5% of the members are female between the ages of 13-18 years (Sport & Recreation South Africa, 2016).

Competitive swimming is a demanding discipline that requires repetitive shoulder rotation movements. Research indicates that competitive swimmers can swim approximately 10 000 to 14 000 meters per day, equating to an average of 2500 shoulder revolutions per day (Kluemper *et* *al*., 2006). In fact, it has been approximated that the average adolescent competitive swimmer performs more than 1 million strokes per annum with each arm (Kluemper *et al*., 2006). Thus, it is expected that athletes, who specialise in freestyle swimming at an early age, may be at an increased risk of developing postural malalignment as they mature into adulthood (Lewis *et al*., 2005; Atalar *et al*., 2009).

Thigpen *et al*. (2010) and Wanivenhaus *et al.* (2012) identified modifiable postural intrinsic risk factors associated with the development of upper-quarter malalignment in overhead sports, such as freestyle swimming. The risk factors include: (i) excessive anterior orientation of the glenohumeral joint or the head relative to the body's vertical plumb line, (ii) excessive protraction of the scapula with anterior and inferior rotation of the glenoid fossa, (iii) posterior capsular tightness, (iv) increased midthoracic spine kyphosis, and (v) hyperextension at the atlanto-occipital articulations and a flattening of the midcervical spine lordosis (Thigpen *et al*., 2010; Wanivenhaus *et al.*, 2012). Literature points toward training-induced adaptive shortening or lengthening of musculature (Stirn *et al*., 2011; Laudner *et al*., 2015). According to the late Vladimir Janda MD, muscles that undergo adaptive shortening may become tight and strong, placing the opposing muscles in a lengthened and weakened position (Page, 2011). This pattern of muscle imbalances in the upper quarter is often referred to as *Janda's Upper Crossed Syndrome*, and is associated with a forward head, rounded-shoulder posture and a midthoracic spinal kyphosis (Page, 2011).

Upper crossed syndrome typically presents with a weakness in the cervical flexors, lower and middle trapezius, serratus anterior, and rhomboids major and minor; as well as with a tightness of the suboccipitals, upper trapezius, levator scapula, latissimus dorsi and pectoralis major and minor (Page, 2011). In freestyle swimming, specifically, the primary movements, namely shoulder adduction and internal rotation (Cools *et al*., 2008;Virag *et al*., 2014; Matthews *et al*., 2017), tend to develop excessive shoulder internal-rotation and adduction strength (Matthews *et al*., 2017); contributing to the development of the upper crossed syndrome and its associated postural features in swimmers.

Considering the demands of freestyle swimming and the exposure to repetitive shoulder rotation movements over the course of years, young competitive swimmers are vulnerable to the development of unfavourable upper quarter postural features, that may subsequently lead to soft tissue injury and shoulder pain if left untreated (Liaghat *et al*., 2018). The study, therefore, aimed to quantify the static upper-quarter postural alignment of competitive female adolescent freestyle swimmers, and compare their results to non-swimming peers and to angles of spinal sagittal posture available in the literature.

Methods

Participants

An evaluation group (EVAL) of 35 female adolescent competitive freestyle swimmers (age = 15±3 y body stature = 166.5±9.9 cm; body mass = 65.5±7.7 kg; BMI = 23.6±1.4 kg/m^2) and an age-matched control group (CON) of 36 female adolescent non-swimmers (age = 15±3 y body stature = 164.2±6.7 cm; body mass = 62.1±9.1 kg; BMI = 23.0±1.7 kg/m^2) participated in this study. Table 1 presents the inclusion and exclusion criteria applied. The similarities between the groups allowed for reliable comparisons. Female adolescent competitive freestyle swimmers were recruited from three swimming clubs located in Tshwane, Gauteng. Female adolescent non-swimmers were recruited from an all-girls secondary school in Tshwane, Gauteng. They were recruited by means of personal approach, word of mouth and notices placed on announcement boards at the school. Information regarding the requirements of this study was liaised through a letter to the participants. Following a comprehensive explanation of the study, participants and their legal guardians were required to complete a pre-participation questionnaire, an assent form and informed consent form to determine their suitability for the study. Ethical approval was obtained for this study (124/2017). All the procedures followed in this study were in accordance with the Declaration of Helsinki.

Table 1. Inclusion and exclusion criteria

EVAL	CON
Inclusion criteria	
Competitive female adolescent swimmers who: ● Specialised in freestyle swimming events. ● Qualified in one of the SSA Level 3 freestyle events before the end of the swimming season. ● Were between 13 and 18 years of age. ● Trained a minimum of five (5) swim training sessions per week. ● Did a minimum of two (2) calisthenic exercises or weight training sessions per week. ● Completed the pre-participation screening questionnaire. ● Completed the child consent and informed consent forms.	Female adolescent non-swimmers who: ● Did not engage in any form of overhead sporting activity. ● Were between 13 and 18 years of age. ● Did not participate in calisthenic exercises or weight training. ● Completed the pre-participation questionnaire. ● Completed the child consent and informed consent forms.
Exclusion criteria	
● Participants with an acute or sub-acute injury or severe illness within the 12 weeks prior to testing. ● Participants who used any external posture correction device. ● Participants who performed rehabilitation (strengthening and stretching) exercises that targeted the upper-quarter of the body.	● Participants with an acute or sub-acute injury or severe illness within the 12 weeks prior to testing. ● Participants who were using any external posture correction device. ● Participants who performed rehabilitation (strengthening and stretching) exercises that targeted the upper-quarter of the body.

<u>Procedures and instruments</u>

Physical testing was done towards the end of the swimmers' competition season. The testing sessions were performed at the all-girls secondary school. Prior to the commencement of the physical testing session, an informative demonstration of the testing procedures was presented to the participants. The testing sessions were conducted before the participants' normal swim training. The International Society for the Advancement of Kinanthropometry method was followed to assess the height and body mass of the participants (Marfell-Jones *et al.,* 2006).

The Photographic Posture Analysis Method (PPAM) described by Straker *et al*. (2009) and Brink *et al*. (2009) was used to assess the four angles of spinal sagittal posture. Head tilt angle, cervical angle, shoulder protraction - retraction angle and thoracic angle was measured as defined by Brink *et al*. (2009) and Straker *et al*. (2009). The validity and reliability of the PPAM was tested by Van Niekerk *et al*. (2008) and yielded good results. This method measures the seated posture by placing visual markers (9 mm circle, harlequin green) on bony landmarks (Brink *et al*., 2009; Straker *et al*., 2009). The bony landmarks identified to form the four angles of measurement were the canthus, the midpoint of the tragus, the spinous process of C7 and T8, the superior border of the manubrium and the midpoint of the humeral head (Brink *et al*., 2009; Straker *et al*., 2009).

The four angles of spinal sagittal posture were analysed by means of Dartfish video analyser (Dartfish.exe, 6.0.13480, Fribourg, Switzerland) and were assessed on the right side of the body. The participants were requested to sit on an adjustable chair, maintaining their hips and knees in 90 degrees flexion, feet positioned shoulder width apart with arms relaxed and palms placed parallel to and on top of their quadriceps. The participants maintained a head position by viewing a designated point ahead at eye level (Brink *et al*., 2009; Straker *et al*., 2009). Two lateral photographs (image resolution 2594 × 1944 pixels) were taken of self-orientated erect seated posture, looking at a designated point. To minimise parallax error, the camera (Nikon, AF-S DX VR 55-200/4-5.6G IF-ED, 3610489 Digital Zoom, Europe), was positioned on a tripod 80 cm from the floor and 250 cm from the chair, with the participant's right side aligned to face perpendicular to the camera (Brink *et al*., 2009; Straker *et al*., 2009). Figure 1 provides a graphical representation of the four angles of spinal sagittal posture measured.

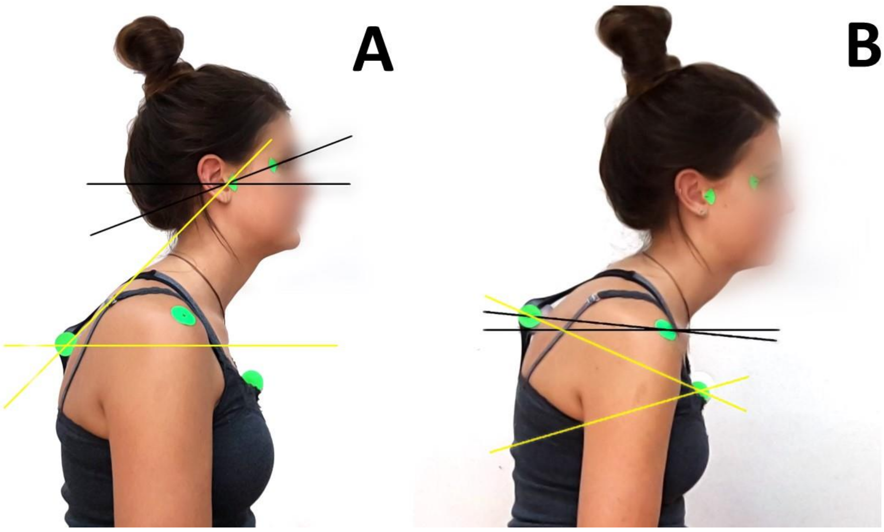

Figure 1. (A) Head tilt (black line) and cervical angle (yellow line); (B) Shoulder protraction/retraction (black line) and thoracic angle (yellow line)

Study design and statistical analysis

A cross-sectional study design was used. Data was analysed using the STATA 13.1 SE (LLC Statacorp, Texas, USA) statistical software. Quantitative data of the different variables were collected and subjected to descriptive and inferential statistics. Normality was verified by the skewness and kurtosis test. Descriptive statistics were reported as medians (p50) with inter-quartile ranges (iqr). The two-sample Wilcoxon rank-sum (Mann-Whitney) test was used to gauge differences between the EVAL and CON groups. Statistical significance was determined by P value equal to or less than 0.05. The difference (*z* score) and the number of observations were used to calculate the effect size – represented as *r* (Fritz *et al*., 2012). Cohen's criteria for *r*, namely a small effect is 0.1, a medium effect is 0.3 and a large effect is 0.5, was used to determine the magnitude of the effect between the two groups (Fritz *et al*., 2012).

Results

Table 2 represents the descriptive statistics in p50 and iqr for the measured angles of spinal sagittal posture of the competitive female adolescent freestyle swimmers and non-swimmers.

Table 2. Descriptive statistics for the measured angles of spinal sagittal posture

Variables	CON (n = 35)	EVAL (n = 36)
	p50±iqr	p50±iqr
Head tilt angle (degrees)	19.1±10.9	10.4±6.4
Cervical angle (degrees)	46.8±13.5	33.5±18
Shoulder protraction - retraction angle (degrees)	59±9.6	35±13.9
Thoracic angle (degrees)	58.8±9.1	66.2±13.1

Data is presented as median (p50) ± interquartile range (iqr); CON = Control group [non-swimmers]; EVAL = Evaluation group [competitive female adolescent freestyle swimmers]

Across all the measured angles of spinal sagittal posture, significant differences were noted between the two groups (Table 3). The EVAL group had significantly smaller head-tilt, cervical and shoulder protraction- retraction angles than the CON group. The effect on these variables was consistently large. The measured thoracic angle of the EVAL group was significantly larger than the CON group. The effect proved to be large, but the true value of the effect could range between moderate to large.

Table 3. Differences in the measured angles of spinal sagittal posture between groups

Variables	*z* score	P value	*r*	95% CI
Head tilt angle (degrees)	5.56	0.00**	0.6	0.62- 0.69
Cervical angle (degrees)	4.74	0.00**	0.6	0.57-0.63
Shoulder protraction - retraction angle (degrees)	6.0	0.00**	0.7	0.67-0.74
Thoracic angle (degrees)	3.93	0.00**	0.4	0.38-0.42

Data is presented as comparative statistics between CON and EVAL groups: difference (*z* score), significance (P value); effect size (*r*) and confidence interval for the effect size (CI).
* $p \leq 0.05$; ** $p \leq 0.01$

Discussion

The purpose of this study was to describe and compare the static upper-quarter posture of female adolescent competitive swimmers to their non-swimming peers. Overall, significant differences with medium to large effect sizes were noted in the angles of spinal sagittal posture between the two groups. However, both groups presented with the postural features commonly observed in adolescents (Kratěnová *et al*., 2007) and which are clinically believed, but not yet clearly established, to be exaggerated in competitive swimmers (Hibberd et al. 2016), namely a forward head, rounded-shoulder posture and a midthoracic spinal kyphosis. Interestingly, the exaggerated postural deviation in the competitive freestyle swimmers become more evident when comparing the median scores of the angles of both groups to spinal sagittal posture angles reported in studies on adolescents (Chansirinukor *et al*., 2001; Van Niekerk *et al*., 2008; Brink *et al*., 2009; Hibberd *et al*., 2012) and upper-quarter pain and injury (De Wall *et al*., 1996; Walker *et al*., 2012; Ruivo *et al*., 2014; Szczygieł *et al*., 2015), respectively.

A forward head posture (i.e. anterior translation of the head), is assessed by considering the head-tilt and cervical angles in the sagittal plane. According to Chansirinukor *et al*. (2001) a head-tilt angle of 16.3 degrees is considered normal. Additionally, an angle of ≤15 degrees from the horizontal line is associated with undesirable upper-quarter posture and neck pain (Ruivo *et al*., 2014). A cervical angle of less than 50 degrees is reported to be indicative of a forward head posture (Van Niekerk *et al*., 2008; Ruivo *et al*., 2014).

The analysis of the head-tilt and cervical angles of the EVAL and CON participants of this study, showed that the EVAL participants had significantly smaller head-tilt - and cervical angles than the CON participants. Similarly, when compared to the reported criterion value for head-tilt angle, the EVAL participants' median head-tilt angle was smaller than 16.3 degrees. This finding was similar to the findings reported in the literature (De Wall *et al*., 1996; Chansirinukor *et al*., 2001). De Wall *et al*. (1996) investigated the head-tilt angle of 32 female adolescent competitive swimmers and reported that the competitive swimmers had significantly (p=0.003) smaller head-tilt angles when compared to the normative value of 15.7 degrees. When assessing the effect of external loads (i.e. swimming with a kicking board) on the upper-quarter posture in active female adolescents, Chansirinukor *et al*. (2001) noticed that the active adolescents had significantly smaller head-tilt angles (p=0.0004) when compared to the value of 16.3 degrees.

Interestingly, the median cervical angles of both the EVAL and CON participants in this study were below the reported value of 50 degrees. Van Niekerk *et al*. (2008) reported that a cervical angle less than 36 degrees may lead to greater upper-postural deficiencies and pain. Similarly, Brink *et al*. (2009) stated that a cervical angle smaller than 39.2 degrees was considered to contribute towards pain in the upper-quarter. Although the median cervical angle of the CON participants was below the reported value of 50 degrees, it was above the reported unfavourable range of 39.2 – 36 degrees. The median cervical angle of the EVAL participants, however, was below the unfavourable range of 39.2 – 36 degrees.

When assessing for rounded shoulders in this study sample, the shoulder protraction - retraction angle was used (Brink *et al*., 2009; Ruivo *et al*., 2014). A protraction - retraction angle smaller than 50 degrees was reported to be associated with rounded shoulders and shoulder pain (Van Niekerk *et al*., 2008). The median protraction - retraction angle of the EVAL participants was significantly smaller than the CON participants' angle, and smaller than 50 degrees. The small protraction - retraction angle observed in the EVAL participants, indicates that they have anteriorly orientated glenohumeral joints with protracted scapulae, hence rounded shoulders (Meeuwisse *et al*., 2007).

Hyperflexion of the thoracic spine was assessed by the thoracic angle. A midthoracic spinal kyphosis is associated with an excessive curvature of the T1 – T12 greater than 45 degrees (Hibberd *et al*., 2012; Walker *et al*., 2012). Moreover, Szczygieł *et al*. (2015) reported that a thoracic angle greater than 56 degrees is classified as kyphotic. Although there was a significant difference between the CON and EVAL participants' thoracic angle, the median thoracic angles for both groups were larger than 45 and 56 degrees, respectively (Hibberd *et al*., 2012; Walker *et al*., 2012 and Szczygieł *et al*., 2015).

Considering the findings of this study, and their comparison to reported angles of spinal sagittal posture, female adolescent competitive swimmers do not only present with postural features typical to competitive swimmers, but they also present with angles of spinal sagittal posture that are within ranges that are associated with pain and injury. The effects of swim training in this group of female adolescents was at least moderate to large. This group of female adolescent swimmers, swam an average of 13.5 hours per week, equating to approximately 594 hours of swim training per year. A correlational study by Wojtys *et al*. (2000) indicated that thoracic angles of sagittal curvature increase significantly with the number of annual training hours in adolescents. Furthermore, Wojtys and colleagues stratified swimming an average of 379 hours per year as the second highest contributor towards altered spinal development in their cohort of 2,270 children between the ages of 8 and 18 years (Wojtys *et al.*, 2000). The study concluded that the harmful effect on immature bone morphology and its mechanical integrity in adolescents, appeared to be related to the long-term exposure to forces associated with strenuous exercise (Wojtys *et al.*, 2000). Similarly, a cross-sectional study by Ziana *et al.* (2015) stated that competitive swimming significantly influences growing spines negatively; contributing to trunk asymmetries and hyperkyphosis in adolescent swimmers. The authors owed the increase in thoracic curvature to the mechanical stresses in the thorax during swimming (Ziana *et al.* 2015).

It is important to consider the injury free status of the adolescent groups in this study in relation to the notion that the observed postural adaptions may be functional in nature, instead of impairing. According to the literature, the development of postural malalignments in freestyle swimmers is multifactorial (Meeuwisse *et al*., 2007; Walker *et al*., 2012). The recurrent exposure to extrinsic factors, such as repetitive shoulder rotation movements, the improper use of hand paddles or kickboards and insufficient recovery from strenuous training sessions, predispose swimmers to muscle length - tension changes and alignment modifications in the cervical and thoracic spine, as well as in the shoulder complex (Meeuwisse *et al*., 2007). The literature indicates that swimmers perform approximately 17 freestyle strokes per 25 meters (Kluemper et al., 2006). The competitive freestyle swimmers of this study swam an average of 5300 to 6100 meters per session, equating to about 3604 freestyle strokes per session. The training-induced increases in internal rotation and adduction strength may lead to weak scapular stabilizers and posterior capsular tightness of the glenohumeral joint (Hung *et al*., 2010; Hibberd *et al.*, 2016). Overtime, the associated distractive stresses may cause repetitive microtrauma to the posterior capsule. Furthermore, if left uncorrected, the muscle length - tension changes may change the alignment of the glenohumeral joint, the scapula, and the articulations of the cervical and thoracic spine (Hibberd *et al.*, 2016). More specifically, these alignments include excessive anterior orientation of the head and glenohumeral joint; excessive protraction of the scapula with anterior and inferior rotation of the glenoid fossa; increased midthoracic spine kyphosis; and hyperextension at the atlanto-occipital articulations and a flattening of the midcervical spine lordosis (Guth, 1995; Thigpen *et al.,* 2010; Wanivenhaus *et al.*, 2012).

Although these changes may be necessary to minimise water resistance and increase the movement efficiency of the freestyle swimming stroke (Wanivenhaus *et al.*, 2012; Liaghat *et al.*, 2018), their long-term influence on postural health should be considered. Adult postural balance is regarded as a desirable health outcome of regular sporting participation (Oja *et al.*, 2015). It is stated that a forward head, rounded-shoulder posture is a postural irregularity that could play a part in the development of shoulder pain and pathologic conditions (Cole *et al.,* 2013). A number of practitioners and researchers believe that a forward head, rounded-shoulder posture modifies scapular kinematics and muscle activity about the shoulder complex, resulting in altered force couples and scapular motions that cause tissue overuse, injury, and pain (Michener *et al*., 2003; Thigpen *et al.,* 2010).

Considering these statements, the authors concur with Wanivenhaus *et al.* (2012) and Hibberd *et al.* (2016) that the inclusion of strengthening exercises for the abdominal, core, scapular, and rotator cuff muscles in the training regime of adolescent competitive swimmers, holds promise. Trunk and shoulder stability strengthening exercises may slow down the progression of the forward head, rounded-shoulder posture by correcting the muscle –length tension changes associated with freestyle swimming (Houglum, 2016; Prentice, 2017). Moreover, adolescence is considered a phase of critical skeletal and muscular growth (Patton & Viner, 2007; Kohl & Cook. 2013). It is during this phase that adolescents experience the greatest amount of postural adaptations and adjustments for their bodies to align with the new proportional changes in body segments (Kohl & Cook. 2013). Therefore, additional recurrent exposure to the extrinsic factors associated with freestyle swimming, makes this population particularly vulnerable to undesirable postural changes (Brink *et al*., 2012).

It is also important, however, to acknowledge that the median thoracic angle of the non-swimming adolescent females was above the reported criterion values (Hibberd *et al*., 2012; Walker *et al*., 2012 and Szczygieł *et al*., 2015). A possible explanation for this finding may be found in the conclusions made by Hibberd *et al.* (2016) that lifestyle factors, such as time spent using laptop computers and other devices, give rise to upper quarter postural deviations in adolescents. Moreover, long studying hours, backpack carrying, school desk design and a slouched walking posture may also play a role in the adaptation of physical characteristics in adolescents (Kratěnová et al., 2007; Ruivo *et al*., 2014; Hibberd *et al.*, 2016).

To the authors' knowledge, this was the first study conducted on the postural traits of a South African female adolescent competitive swimming population. Additionally, this study was unique in its selected methodology. The photographic analysis measures used in this study are considered reliable (Van Niekerk *et al*., 2008) and yielded invaluable results to determine spinal sagittal posture. Despite this method of postural assessment being different to the methods used by other studies, it produced findings that were similar to those found by other authors. Moreover, the method and equipment required is accessible and easy to recreate, thus offering researchers and practitioners, with a new and easy to apply methodological approach to postural assessment.

Nevertheless, there were limitations to this study. The first is the study's cross-sectional design. Although the study revealed significant postural differences between the adolescent groups, studies exploring postural changes over a macrocycle, or the influence of an intervention, or the level of impairment on the level of symptoms, may improve the understanding of postural malalignment and its influence on future pain and injury in competitive adolescent freestyle swimmers. The second limitation includes the focus on a specific gender and on one swimming stroke only. Assessing the postural angles of both male and female adolescent competitive swimmers alike, will provide a more inclusive description of the postural features of this population. While the freestyle swimming stroke is considered to be performed most often by swimmers, investigating the upper-quarter postural changes associated with the other swimming strokes (namely, butterfly, backstroke and breaststroke) may also prove beneficial to the understanding of postural alignment in adolescent competitive swimmers. Lastly, the use of technological devices, such as smartphones or laptops, in this adolescent group was not recorded. The use of these devices and their effect on upper-quarter posture should be considered in future studies of this nature.

From a sport science practitioner perspective, the repetitive monotonous upper-quarter movement patterns associated with freestyle swimming render young competitive female adolescent swimmers vulnerable to exacerbated functional upper-quarter postural deviations. Early detection of postural deviations with ranges that could predispose adolescent swimmers to fixed postural abnormality and associate movement dysfunction, is suggested. Where possible, and when feasible, the swim training load incurred should be varied/modified before short-term changes in upper-quarter postural alignment progress to longer lasting and fixed adulthood malalignment. Pre-rehabilitative, corrective exercises focused on the strengthening of the muscles of the shoulder girdle, cervical and thoracic spine should be considered for inclusion in the training programme. However, the total training load imposed on the afflicted area should always be kept in mind. In this regard soft tissue manipulation, myofascial release and stretching may be helpful during periods of high training load. A pre-session warm-up that potentiates the intended muscle groups toward desirable movement patterns should be a priority, as is the monitoring of fatigue during training sessions to preserve the desired freestyle technique. Furthermore, sport scientists and coaches – especially those working in secondary school or club settings - should be sensitive to the notion that competitive female adolescent swimmers are vulnerable to ~~exacerbated~~ functional postural deviations and may possibly consider including posture education and whole body conditioning in their periodization plans.

Overall, the literature and the results of this study indicate that female adolescents risk developing upper-quarter postural malalignment, which may initially be functional in nature. The female adolescents participating in competitive freestyle swimming, however, appeared to be more vulnerable to features in the upper-quarter that were not within the desirable angles of spinal sagittal posture. The inherent nature of competitive freestyle swimming and the natural consequence of long-term training for optimizing body position and stroke length in competitive swimmers, may explain the moderate to large effect sizes noted in the current study. Future research should investigate the relationship between static and dynamic postural changes over time, and their associated medical and training related indices, such as functional limitations, pain and injury. Furthermore, since adaptive postural malalignment is often visible in world-class swimmers, future studies should evaluate whether these malalignments may be detrimental to performance, associated with pain/impairment, or required for swimming excellence.

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