Coaching Applications

Lumbar Alignment and Trunk Muscle Activity during the Underwater Streamline Position in Collegiate Swimmers

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Abstract

We investigated the relationship between lumbar alignment and trunk muscle activities during the underwater streamline position. Twenty-two male collegiate swimmers participated in the study. Firstly, spinal alignments of 22 participants were evaluated during standing and underwater streamline position using image analysis. Thoracic kyphosis angle and lumbar lordosis angle were measured to evaluate the spinal alignment. Secondly, eleven swimmers participated to the continued investigation: 6 participants who had the smallest alteration in lumbar lordosis between the two positions (these became the smallest group) and 5 participants who had the largest alteration (these became the largest group). Their spinal alignments and their trunk muscles activities were measured during two positions in the same manner as was performed in the first experiment. The muscles activities were measured using surface electromyography. As a result, a significant difference between the two groups was observed in the internal oblique/transversus abdominis muscle activities during the underwater streamline position ($p<0.05$). Therefore, it was considered that the internal oblique/transversus abdominis muscle activities were related to the magnitude of the lumbar lordosis alteration during the underwater streamline position.

Introduction

In swimming, streamline position is a fundamental posture in all swimming strokes. Streamline position is characterized as a streamline-shaped body posture with both arms elevated and is essential to maintain a horizontal straight position for less resistance underwater. Keeping a streamline position can reduce a swimmer's passive drag and improves the swimming performance.

While keeping a streamline position is important for all strokes, it is considered that streamline position is a risk factor for the development of low back pain in competitive swimmers, because all swimming strokes maintain hyperextension of the lower back to achieve a streamlined position and this position is exaggerated during "undulating" style of breaststroke and butterfly that repetitively load the posterior structure of the lumbar spine. Repetitive lumbar hyperextension with swimming stroke is can result in low back injury. Low back pain is a common symptom in competitive swimmers, therefore, it is important to avoid a hyperextension of the lower back during streamline position to prevent low back pain.

In clinical medicine, the evaluation of lumbar alignment is the first step for the prevention of lumbar disorders. However, to our knowledge, there are no study that measured the lumbar alignment during underwater movement. If a swimmer's lumbar alignment during underwater streamline position can be investigated, it may be possible to evaluate whether the swimmer has a hyperextension position or not.

On the other hand, trunk muscle activity is considered to be an important factor to control lumbar alignment, therefore, trunk muscle activity may influence the control of lumbar alignment during streamline position. Previous study indicated that to control spinal stability and to strengthen trunk muscle is important for competitive swimmers in order to prevent lumbar disorders. However few studies have investigated trunk muscle activity during streamline position. Most of the studies that measured electromyography (EMG) during swimming reported upper limb muscle activity related to propulsive force. Therefore we considered that swimming researchers should focus on the trunk muscle activity related to keeping a streamline position for reducing the risk of low back pain.

The purpose of this study was to evaluate spinal alignment during the streamline position in competitive swimmers and to clarify the relationship between lumbar alignment and trunk muscle activity during the streamline position.

Methods

Participants

Participants were 22 male collegiate competitive swimmers (height: 1.75± 0.05 m, weight: 69.5±5.2 kg, athletic career: 13.1±3.1 years).

Procedures and Tasks

This study was constructed by Experiment 1 and Experiment 2.
In Experiment 1, spinal alignments (thoracic kyphosis angle and lumbar lordosis angle) and shoulder angle were measured for 22 participants who performed 2 tasks: keeping a standing position and an underwater streamline position. The standing position was defined as a neutral position at rest on land, and was set for excluding the effect of individual alignment. The streamline position was defined as the body position during maximal voluntary horizontal gliding in

water. The participants were instructed not to breath during the underwater streamline position for excluding the effect of breathing which may influence the trunk muscles activity.

After Experiment 1, eleven participants participated to further experiment. They were selected from the original 22 participants, according to the difference of lumbar lordosis between the standing position and the streamline position. The five members with the largest difference between the two positions became the largest group and the six members with the smallest difference between the two positions became the smallest group. These 11 participants participated in Experiment 2 which investigated the 6 trunk muscles (rectus abdominis, RA; external oblique, EO; internal oblique / transverse abdominal, IO/TrA; erector spinae, ES; gluteus maximus, Gmax; rectus femoris, RF) activities during the standing position and the streamline position by measuring surface EMG.

These experiments were performed at indoor 50 m pool. Throughout these experiments, the water temperature was set to 28.4±1.4 degree. Three trial data were collected in each experiment.

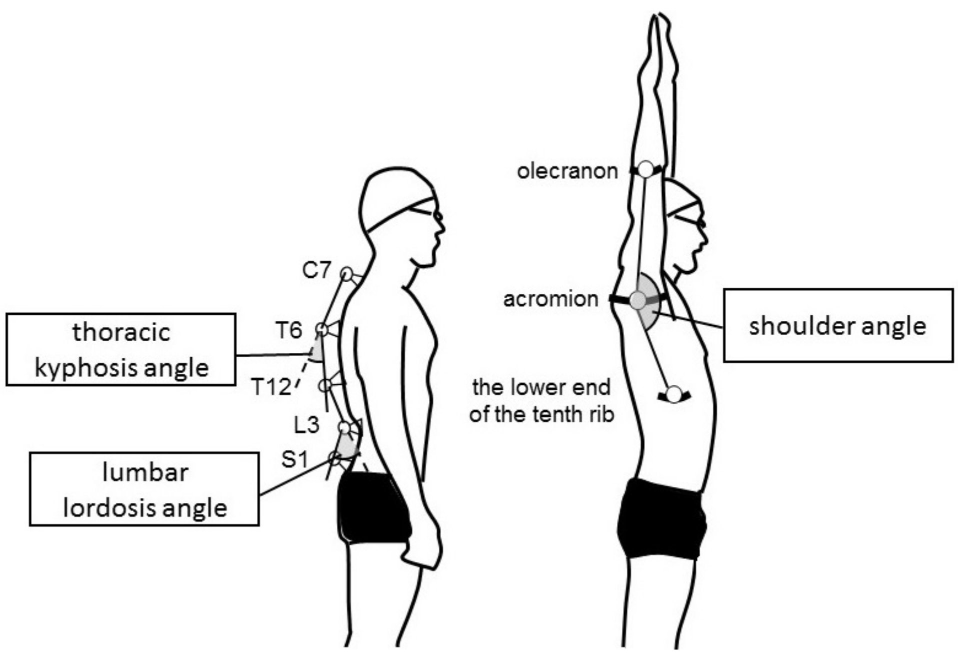

Figure 1. Definition of the thoracic kyphosis angle, the lumbar lordosis angle and the shoulder angle. The 5 spinous processes were chosen as landmark points (the 7th cervical vertebrae, C7; the 6th thoracic vertebra, Th6; the twelfth thoracic vertebra, Th6; the 3rd lumbar vertebra, L3; the 1st sacral vertebra, S1). The lumbar lordosis angle was defined as the angle between the base line connecting Th12 to L3 and the variant line from L3 to S1. The thoracic kyphosis angle was defined as the angle between the base line of C7 to Th6 and the variant line of Th6 to Th12. The shoulder angle was defined as the angle between the base line of the acromion to the lower end of the tenth rib and the variant line of the acromion to the olecranon.

Results

In Experiment 1, significant differences between the two positions were identified in the comparisons of the lumbar lordosis angle (standing position: 10.8±4.9 degree vs streamline position: 15.6±4.2 degree; $p < 0.001$; ES = 1.05) and the thoracic kyphosis angle (standing position: 21.8±5.2 degree vs streamline position: 11.4±5.3 degree; $p < 0.001$; ES = 1.98). The shoulder angle during underwater streamline position was 166.2±4.8 degree. As the results of correlation analysis, significant positive correlations between the standing position and the underwater streamline position were observed on thoracic kyphosis angle ($r = 0.586$, $p = 0.004$) and on lumbar lordosis angle ($r = 0.770$, $p < 0.001$). However, no significant correlation were shown between the shoulder angle and the thoracic kyphosis angle ($r = -0.410$, $p = 0.058$), and between the shoulder angle and the lumbar lordosis angle ($r = -0.198$, $p = 0.377$). The Δ lumbar lordosis angles were calculated (mean±SD = 4.9±3.1 degree; median = 4.6 degree) and the normality was ensured by the result of Shapiro-Wilk test ($p \geq .05$). Based on the results of the alterations of lumbar lordosis angle, the fourteen participants were selected as the largest group and the smallest group. Table 1 shows a comparison of the mean difference of spinal alignments between the smallest and largest groups measured in Experiment 2. Significant differences between the two groups were identified in the comparison of the lumbar lordosis angle during the streamline position (largest group: 20.5±3.6 degree vs smallest group: 13.6±4.6 degree; $p = 0.018$; ES = 0.72) and in the comparison of the Δ lumbar lordosis angle (largest group: 6.8±1.2 degree vs smallest group: -2.3±3.3 degree; $p = 0.006$; ES = 0.83). As the result of shoulder angle, no significant difference was shown between two groups (largest group: 163.6±6.3 degree vs smallest group: 165.4±4.1 degree; $p = 0.714$; ES = 0.11). The results of the amount of muscle activity in each group are shown in Table 2. A significant difference between the two groups was identified only in a comparison of the IO/TrA during streamline position (largest group: 7.6±6.4% vs smallest group: 29.5±14.0%; $p = 0.006$; ES = 0.83) and in the comparison of the Δ %MVC value of IO/TrA (largest group: 3.6±4.7% vs smallest group: 21.9±12.8%; $p = 0.045$; ES = 0.61).

Table 1. Results of spinal alignment and shoulder angle measurements in Experiment 2.

Variable			Largest group	Smallest group	Significance (*p*)	Effect size (*r*)
Streamline	thoracic kyphosis angle	(degree)	14.2±3.6	11.8±4.6	. 522	. 19
	lumbar lordosis angle	(degree)	20.5±3.6	13.6±4.6	. 018	. 72
	shoulder angle	(degree)	163.6±6.3	165.4±4.1	. 714	. 11
△ thoracic kyphosis angle		(degree)	-10.7±3.9	-12.1±6.7	. 465	. 22
△ lumbar lordosis angle		(degree)	6.8±1.2	-2.3±3.3	. 006	. 83

deg: mean ±s

Table 2. Results of %MVC value during streamline position in Experiment 2.

Variable		Largest group	Smallest group	Significance (*p*)	Effect size (*r*)
%MVC Value	(%)				
RA		1.6±3.1	5.2±3.9	. 465	. 22
EO		2.7±11.9	14.1±14.1	. 855	. 06
IO/TrA		7.6±6.4	29.5±8.4	. 006	. 83
ES		2.3±4.7	12.5±7.9	. 410	. 25
Gmax		2.0±2.5	4.8±8.4	. 410	. 25
RF		2.2±4.7	7.1±2.4	. 360	. 28
Δ %MVC Value	(%)				
RA		2.2±3.0	3.6±2.8	. 714	. 11
EO		8.2±10.9	11.3±13.9	. 784	. 08
IO/TrA		3.6±4.7	21.9±12.8	. 045	. 61
ES		6.1±5.7	10.3±6.7	. 361	. 28
Gmax		0.7±4.5	2.8±9.0	. 855	. 06
RF		5.0±4.3	4.9±1.4	. 584	. 17

%: mean±s

Discussion

This present study evaluated the spinal alignment during the streamline position in 22 competitive swimmers and additionally investigated the relationship between lumbar alignment and trunk muscle activity during the streamline positions through each experiment. In this study, we found the changes of spinal alignment caused by keeping a streamline position, and we additionally found the difference of IO/TrA activity during the streamline position between largest group and smallest group.

From the results of correlation analysis in Experiment 1, strong positive correlations were observed between the two absolute spinal angles during the standing and the streamline position. This suggested that a poor thoracic and lumbar alignment on land are related to a poor thoracic and lumbar alignment during underwater streamline position. Therefore, it was suggested that the measurement of thoracic and lumbar alignment on land is good for evaluating a poor thoracic and lumbar alignment during underwater streamline position.

The results of Experiment 2 showed that the difference of mean Δ lumbar lordosis angle between each group was approximately 10 degree. In general, the lumbar maximal extension angle has been reported to be approximately 50 degrees. The 10 degree change in the lumbar lordosis angle corresponds to 20% of the maximal lumbar extension angle. Surprisingly, large difference of the inducing lumbar extension keeping the streamline position was observed in collegiate male competitive swimmers who had athletic career over 10 years. From this result, it was indicated that, even with the skilled swimmers, lumbar alignment during the streamline position should be evaluated and improved.

Furthermore, large changes of lumbar extension during the streamline position may increase the risk of development of low back pain. If the swimmer, who has large changes of lumbar extension during the streamline position, do undulatory swimming motion (e.g. butterfly, breaststroke, underwater dolphin kick), it can be speculated that their lumbar extension will be additionally stressed. Therefore, it is important to prevent an increase in lumbar lordosis and to maintain an appropriate spine curvature during the streamline position.

In the results of Experiment 2, we demonstrated that the muscle activity of IO/TrA during the streamline position were significantly different between the two groups. Furthermore an increase of lumbar lordosis may be related to deteriorated muscle activity of the IO/TrA. The pelvis moves backward when the IO contracts, and the posteriorly tilted pelvis contributes to the lumbar lordosis decrease. On the other hand, the TrA controls abdominal internal pressure and segmental stability of the lumbar spine. Consequently, it was suggested that the increment of IO/TrA activity in the smallest group contributed to straight lumbar alignment and removed the mechanical stress of lumbar segments. Therefore, it was considered that swimmers and their coaches should adopt the training to enhance functions of IO and TrA for injury prevention and swimming performance improvement.

Based on the results of this study, we have two recommendations to swimmers and coaches; 1) the measurement of absolute thoracic and lumbar alignment on land is good for evaluating a poor thoracic and lumbar alignment during underwater streamline positon, 2) a swimmer with lumbar hyperextension should obtain a function to activate IO and TrA during underwater streamline position by conducting specific exercise (e. g. abdominal hollowing or abdominal drawing-in maneuver).

Conclusion

In this study, we evaluated the spinal alignment during the streamline position in competitive swimmers and investigated the relationship between lumbar alignment and trunk muscle activities during the underwater streamline position. Consequently, we found that streamline position induced an increase of lordosis in the lumbar spine. Also, the absolute thoracic kyphosis and lumbar alignment during underwater streamline position was related to the absolute thoracic kyphosis and lumbar alignment on land. Furthermore, it was considered that the IO/TrA activities were related to the magnitude of the lumbar lordosis alteration during the underwater streamline position. Further study is warranted to evaluate IO/TrA activity and investigate whether the spinal alignment would change when muscle activity changes during an underwater streamlined position.