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Muscle Activity during Dryland Swimming while Wearing a Triathlon Wetsuit

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ABSTRACT

Background: Triathletes typically wear a wetsuit during the swim portion of an event, but it is not clear if muscle activity is influenced by wearing a wetsuit. **Purpose:** To investigate if shoulder muscle activity was influenced by wearing a full-sleeve wetsuit vs. no wetsuit during dryland swimming. **Methods:** Participants (n=10 males; 179.1±13.2 cm; 91.2±7.25 kg; 45.6±10.5 years) completed two dry land swimming conditions on a swim ergometer: No Wetsuit (NW) and with Wetsuit (W). Electromyography (EMG) of four upper extremity muscles was recorded (Noraxon telemetry EMG, 500 Hz) during each condition: Trapezius (TRAP), Triceps (TRI), Anterior Deltoid (AD) and Posterior Deltoid (PD). Each condition lasted 90 seconds with data collected during the last 60 seconds. Resistance setting was self-selected and remained constant for both conditions. Stroke rate was controlled at 60 strokes per minute by having participants match a metronome. Average (AVG) and Root Mean Square (RMS) EMG were calculated over 45 seconds and each were compared between conditions using a paired t-test (α=0.05) for each muscle. **Results:** PD and AD AVG and RMS EMG were each greater (on average 40.0% and 66.8% greater, respectively) during W vs. NW ($p<0.05$) while neither TRAP nor TRI AVG or RMS EMG were different between conditions ($p>0.05$). **Conclusion:** The greater PD and AD muscle activity while wearing a wetsuit might affect swimming performance and/or stroke technique during a long distance event.

Key words: Electromyography, Endurance Exercise, Shoulder Muscle Activity, Fatigue, Upper Extremity

INTRODUCTION

Wetsuits have been used among many water sports including SCUBA diving, surfing, open water swimming, and triathlon competitions. Wetsuit design is often unique to the demands of the sport. For example, wetsuits designed for surfing tend to have a thick and rough material to account for how the surfer paddles the surf board. In contrast, a wetsuit designed for swim performance such as a triathlon typically has a smooth surface and thickness needs to be within specific governing body rules. The commonality between wetsuits is that they assist in theromoregulation in part by insulating properties of wetsuit material as well as warming of water between the skin and the material of the wetsuit ultimately providing insulation from cold temperatures (Corona et al., 2017; Naebe, 2013; Wakabayashi, et al., 2006).

During the sport of triathlon, it is very common for athletes to wear a wetsuit to take advantage of both the thermoregulation properties as well as the potential swim performance benefits (Chatard & Millet, 1996; Chatard, Senegas, Selles, Dreanot, & Geyssant, 1995). For example, Chatard et al. (1995) reported that triathlete subjects were on average 19 s faster during a 400 m swim using a wetsuit vs. no wetsuit. However, it is important to note that not all swim performances will be improved when wearing a wetsuit (Chatard et al., 1995; Cordain & Kopriva, 1991; Ulsemar, Rust, Rosemann, Lepers, & Knechtle, 2014). For example, Chatard et al. (1995) also reported that 400-m swim performance was not influenced by wearing a wetsuit for swimmers. It was concluded that the influence of wetsuit on swim performance was related to swim ability – that is, faster swimmers did not benefit from the wetsuit whereas slower swimmers did. Similarly, Cordain & Kopriva (1991) reported that body composition was related to the influence of wetsuit on swim performance. These observations indicate that a single wetsuit design does not benefit swim performance of all people equally and has led to the development of a wide variety of wetsuit models that incorporate different design features. Two main general categories of wetsuit design are full-sleeve (Figure 1a) and sleeveless (Figure 1b) wetsuits.

Anecdotally, a widely-discussed topic in the triathlon area is whether a triathlete should use a full-sleeve or sleeveless wetsuit. The debate is typically centered on whether or not a full-sleeve wetsuit causes a possible additional resistance to upper extremity movement due to the neoprene sleeve

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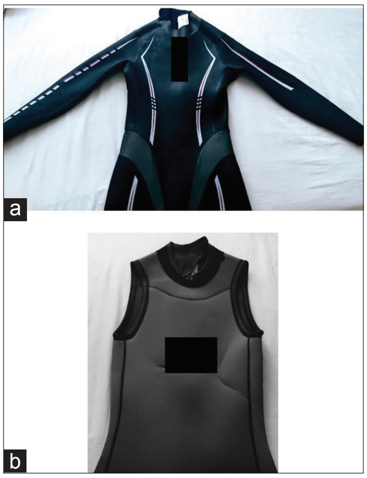

Figure 1. Illustration two main categories of wetsuits used in triathlon: a) Full-sleeve and b) sleeveless.

portion of the wetsuit. An increase in resistance to shoulder movements may influence how active shoulder muscles are. Although it is difficult to relate muscle activity and force during dynamic movements (Deluca, 1997), there is evidence that muscle activity is related to swim performance. For example, Ikuta et al. (2012) demonstrated that swim velocity was related to muscle activity of several muscles combined. Likewise, Figueiredo et al. (2013) reported that upper extremity muscle activity changed during an intense 200 m swim as swimmers experienced fatigue.

Presently, there are no empirical data on the influence of a full-sleeve wetsuit on muscle activity. However, Nessler, Silvas, Carpenter, & Newcomer (2015) investigated the influence of surfing wetsuit design on shoulder movement and muscle activity during simulated surf paddling. In that study, it was reported that shoulder movement pattern and muscle activity were affected by the use of a long sleeve wetsuit when compared to a traditional swimsuit while simulated surfing paddling (Nesser, et al., 2015). However, triathlon wetsuits are designed specifically for swimming (vs. the combination of paddling and surfing) and there are no data on muscle activity during swimming in triathlon wetsuits. Therefore, the purpose of this study was to investigate if shoulder muscle activity was influenced by wearing a full-sleeve wetsuit vs. no wetsuit during simulated dryland swimming. The sleeveless wetsuit was not used in part because funds were not available to purchase additional wetsuits. Nevertheless, it was also considered important to first explore if muscle activity was influenced by the two potentially extreme conditions (i.e., full-sleeve vs. no wetsuit).

METHODS

Participants

Participants (n=10 males; height: 179.1±13.2 cm; mass: 91.2±7.25 kg; age: 45.6±10.5 years) gave written informed consent to participate in the study. In order to be included in the study participants had to fit in at least one of the wetsuit sizes as per manufacturer recommendations. Participants also had to have swum in a wetsuit and be familiar with the front crawl swimming stroke but not be necessarily swimmers. The level of swimming expertise of participants varied from novice to elite. In addition, participants were free of any acute or chronic shoulder injury.

Experimental Protocol

The experimental approach was a within-subject design where all participants completed two conditions. The two conditions were dryland swimming while wearing a wetsuit and not wearing a wetsuit. Participants were fit to one of four sizes of wetsuit (same model) available for this study (HUUB Design Limited, size: small medium-tall, medium, medium-tall, and medium-large; Aerious model 4 mm:4 mm thickness, Derby, UK) (Table 1). A telemetry EMG system (Noraxon Telemyo, Az) was used to collect muscle activity of four muscles on the right shoulder girdle and arm. An Electrogoniometer was attached to the right elbow joint to track arm flexion and extension with data recorded simultaneously with EMG using the same system.

All dryland swim conditions were completed using a swim ergometer (VASA Inc., Essex Junction, VT) with participants mimicking a crawl stroke technique they would use swimming in water. Participants were given sufficient time to practice using the swim ergometer prior to testing. The swim ergometer was equipped with a digital metronome that was set to 60 strokes per minute (i.e., 1 beat per side per second) with participants asked to maintain that stroke rate for both conditions. Resistance was controlled between conditions with participants self-selecting the resistance needed to maintain a somewhat hard intensity using 60 strokes per minute without wearing the wetsuit.

After practicing and being comfortable using the swim ergometer at the set cadence, the locations for surface EMG were prepared by shaving, abrading, and cleaning the sites where the EMG leads were placed. EMG leads were placed on the right-arm on the surface of the skin of the following muscles: Anterior Deltoid (AD), Posterior Deltoid (PD), Trapezius (TRAP), Triceps Brachii (TRI). Placement of the EMG leads followed the SENIAM guidelines (Hermens, Freriks, Disselhorst-Klyg, 2000). An electrogoniometer was placed on the elbow joint to measure elbow flexion-extension movements. After instrumentation, participants performed a maximal voluntary isometric contraction (MVIC) against maximal scapula elevation load for the trapezius and shoulder press for remaining muscles (anterior, posterior deltoids and triceps Brachii), for 5 second duration. All EMG data were subsequently normalized to the greatest 1-second average from the MVIC per muscle. That is, 100% EMG during a condition means the signal was the same magnitude as during the isometric condition. The normalized EMG data were used for analysis. Following MVIC procedures, Participants completed two dryland swim conditions using a crawl stroke swim technique: 1) with No Wetsuit (NW) and 2) with wetsuit (W). Order of conditions was always NW then W with about 3-5 minutes rest between conditions. The set order was used in order to minimize disrupting EMG lead and electrogoniometer placement when taking the wetsuit off. Each condition lasted 90 seconds with data collected the final 60 seconds of the condition.

Statistical Analysis

EMG data were processed by first removing any zero offset and then full-wave rectifying data. Average (AVG) and Root Mean Square (RMS) EMG was calculated over 45 seconds. Stroke rate was measured by identifying the time to complete 10 right-side strokes by inspecting the elbow flexion-extension data. The dependent variables were AVG and RMS EMG of each muscle (i.e., 8 total dependent variables) as well as stroke rate. Paired t-tests were used to test each dependent variable between conditions using SPSS (IBM SPSS Statistics, version 22.0.0.0; $\alpha = 0.05$).

RESULTS

Stroke rate was not different between conditions (NW: 0.52±0.04 Hz; W: 0.51±0.05 Hz; $t(9)=-1.249$, $p = 0.243$). EMG for PD (AVG: $t(9)=-3.066$, $p = 0.013$; RMS: $t(9)=-2.940$, 0.016) and AD (AVG: $t(9)=-3.491$, $p = 0.007$; RMS: $t(9)=-3.418$, $p = 0.008$) were each different during NW vs. WS (Figure 2, Table 1). Neither TRAP (AVG: $t(9)= -0.079$, $p = 0.939$; RMS: $t(9)=-0.239$, $p = 0.817$) nor TRI (AVG: $t(9)=-0.885$, $p = 0.399$; RMS: $t(9)=-0.587$, $p= 0.572$) EMG were different between conditions (Figure 2, Table 1).

Table 1. Group means and standard deviation of electromyography for each muscle. Data are presented in percentage of the EMG during maximal voluntary isometric contraction (MVIC).

Muscle	No Wetsuit (% MVIC)	Wetsuit (% MVIC)
Trapezius	58.2±45.1	59.5±35.3
Anterior Deltoid	20.9±13.1	34.8±10.7*
Posterior Deltoid	55.6±29.0	77.8±27.4*
Triceps Brachii	46.4±18.3	50.7±21.3

Note: * The Anterior Deltoid and Posterior Deltoid were each different during W and NW ($p<0.05$)

DISCUSSION

The most important observation of this study was that muscle activity of the PD and AD were each greater while wearing a wetsuit vs. not wearing a wetsuit when simulating swimming on dryland at equivalent stroke rates. On average, PD was about 40% greater while wearing the wetsuit vs. no wetsuit and the AD about 66.8% greater. In contrast, there was no influence of wearing a wetsuit on the muscle activity of the TRAP and TRI muscles. These observations seem to indicate that wearing the wetsuit resulted in increased resistance to shoulder movements.

The observation of greater muscle activity of the PD and AD during simulated swimming while wearing a wetsuit compared to not wearing a wetsuit is similar to what was observed by Nessler, et al. (2015). Although in that study, the muscle investigated was the middle deltoid and the exercise was simulated surf paddling with and without wetsuit. Even though a wetsuit designed for surfing is different than a triathlon wetsuit, Nessler et al. (2015) also reported greater middle deltoid muscle activity while wearing the wetsuit. Although the middle deltoid was not studied in our study, both Nessler et al. (2015) and the results from our study are consistent in that wearing a wetsuit influences shoulder muscle activity. These observations are reasonable given the function of the deltoid muscle as a whole during swimming. Pink, Perry, Browne, Scovazzo, & Kerrigan (1991) studied 12 muscles of the front crawl stroke in order to better understand muscle activity during specific phases of the stroke. Predominately, the AD and PD are recovery phase muscles with its muscle activity peaking during late pulling phase to early recovery for PD, and mid to late recovery for AD. Although we did not analyze the data for different phases of the stroke (i.e. pull and recovery phases), based upon the observations reported by Pink, et al. (1991), it is hypothesized that the difference in the muscle activity of the PD and AD during dryland swimming in wetsuit was mostly during the recovery phase. However, it is important to recognize the individual differences in stroke technique and therefore muscle activity. Martens, Daly, Deschamps, Staes, and Fernandes (2016) analyzed muscle activity during swimming and reported that there is high variability in muscle patterns during swimming. However, in a review of research on muscle activity during swimming, it was noted that the crawl stroke had the least

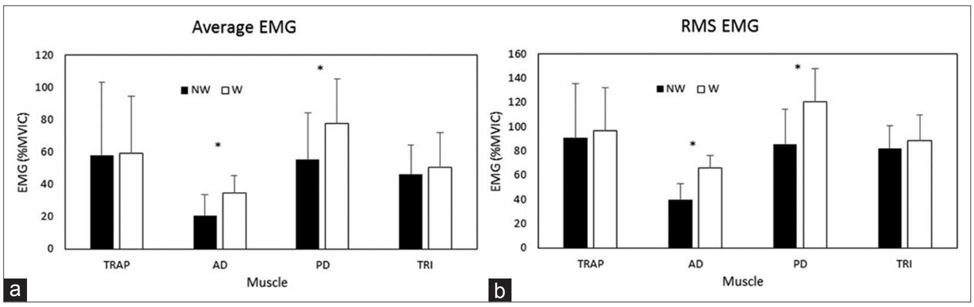

Figure 2. Illustration of Average (a) (AVG) and root mean square (b) (RMS) electromyography (EMG) of the trapezius (TRAP), anterior deltoid (AD), posterior deltoid (PD), and triceps brachii (TRI) during simulated swimming while wearing a wetsuit (W) or no wetsuit (NW). Note: * The AD and PD were each greater during W and NW ($p<0.05$). Muscle activity of TRAP and TRI were not different between conditions.

variability of muscle activity as compared to other swim strokes (Martens, Figueiredo, & Daly, 2015). Importantly, in the present study, we examined average muscle activity over 45 s vs. comparing patterns. It is important to recognize that it is not clear if the increased muscle activity that we observed while wearing a wetsuit influences swim performance. Hawley et al. (1992) indicated the importance of arm power during swim distances longer than 400 m. Arm power in this work was measured using an arm ergometer (on land). The relationship of predicting front crawl swimming speed based on arm power production was established based on the peak sustained workload during arm ergometer exercise and a 400-m swim comparison. Given the importance of upper body power generation and that triathlon swim segments are typically 750 m and longer, a greater muscle activity of the PD and AD may be an indication that swim performance could be negatively influenced. However, Ikuta et al. (2012) reported that swim velocity was related not specifically to a single muscle but rather velocity was related to the coordination of several muscles. In any case, the added buoyancy of a wetsuit, reduced resistance of water moving along the surface of the wetsuit, and thermoregulation benefits of a wetsuit may negate any potential negative influence of increased shoulder muscle activity. Additional research is needed to determine if an increased muscle activity while wearing a wetsuit would influence swim performance. Although we asked participants to use the same swim technique for each condition, there is the possibility that stroke pattern changed when wearing or not wearing the wetsuit. Qualitatively, it did seem that the stroke pattern changed between conditions. For example, elbow flexion and/or shoulder circumduction may have been different when wearing the wetsuit. Although we measured elbow flexion and extension, we used those data only to check for stroke rate and those data were not sufficient to describe the kinematics of the swim stroke. Future studies should add kinematic analysis to track changes in both sagittal and frontal planes during the recovery phase of the stroke and measure stroke pattern with and without wetsuit. Likewise, we maintained the same swim ergometer resistance setting and controlled stroke rate between conditions. We do not know if participants would have manipulated either of these parameters when using the wetsuit. These controls were put in place to try to isolate a possible influence of wetsuit design on muscle activity. It is also important to recognize that we tested only one model of wetsuit. Furthermore, the wetsuit was dry. It is not known whether or not the wetsuit would influence resistance to shoulder movements the same way if wet or if there was a layer of water between the skin and neoprene (i.e., within the wetsuit). Future studies will need to use water proofed EMG systems to measure muscle activity during swimming in the water. We also recognize that simulated swimming on dry land may not fully replicate swimming movements in the water. For example, Murry, McManus, & Parry (2014) reported that participants achieved similar blood lactate levels during an incremental intensity test on a swim ergometer (VASA) and in the water. However, HR and RPE were different between swimming in the water and on the swim ergometer. Although the present study is the first to measure muscle activity while simulated swimming in a wetsuit – future research is needed to measure muscle activity while swimming in the water using a water proofed EMG system. An advantage of using a swim ergometer, however, is that the resistance and stroke rate could be controlled. With those parameters controlled, we did observe an increase in shoulder muscle activity. It is important to determine if this observation is consistent while swimming in the water.

Finally, we did use a specific order of conditions in that the no wetsuit condition always preceded the wetsuit condition. This was done from a logistic perspective of managing EMG leads – in pilot work, we determined it was easier to put the wetsuit on in a way that minimized any chance to disrupt the EMG set up. We do not know if there was a learning effect; however, the exercise time was short for each condition and participants seemed comfortable using the swim ergometer throughout testing.

Practical Application

When selecting between different brands or models of full-sleeve wetsuits, the athlete should consider shoulder movement allowed by the wetsuit. Some triathlon events favor strong run ability vs. cycling or swimming (Fröhlich et al., 2013). However, considering some swim events involve swimming for over an hour, any added resistance to shoulder movement may cause an athlete to tire sooner. It is important to remember that our study was conducted on land and it may be important for the athlete to try the wetsuit in the water. The athlete should also incorporate regular wetsuit swims in a training program in order to prepare the shoulder muscles for any potential increase in resistance. Furthermore, prior to swimming in a wetsuit, it is important for the athlete to adjust the wetsuit as best as possible to reduce shoulder resistance. This can be partly achieved by pulling the wetsuit up as high as possible as well as adjusting the neoprene around the shoulder/arm region to allow easier shoulder movements. Unfortunately, there are no clear objective criteria for selecting the right sized wetsuit for a triathlete. Although it is common for athletes to be advised to select a wetsuit that is too tight – the athlete must consider selecting a wetsuit to minimize shoulder resistance.

CONCLUSION

It is concluded that muscle activity of the shoulder (i.e., PD, AD) during dryland swimming at a fixed cadence was influenced by wearing a wetsuit. It is important to follow up this study with measuring muscle activity during swimming in the water. As a practical application, it would seem that a wetsuit should be selected that minimizes restrictions to shoulder movements. This could be related to wetsuit size, design, fit, and/or materials used. Manufacturers frequently use a more flexible material on high end wetsuits. However, future research is needed to determine if swim performance is negatively influenced due to increased activity while wearing a full sleeved wetsuit.

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