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Muscle activation behavior in a swimming exergame: Differences by experience and gaming velocity

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A B S T R A C T

The effects of playing intensity and prior exergame and sport experience on the activation patterns of upper limb muscles during a swimming exergame were investigated. Surface electromyography of *Biceps Brachii*, *Triceps Brachii*, *Latissimus Dorsi*, *Upper Trapezius*, and *Erector Spinae* of twenty participants was recorded, and the game play was divided into normal and fast. Mean muscle activation, normalized to maximum voluntary isometric contraction (MVIC), ranged from 4.9 to 95.2%MVIC and differed between normal and fast swimming for all techniques ($p < 0.05$), except for Latissimus Dorsi during backstroke. After normalizing the %MVIC to playing velocity, selective behaviors were observed between muscles which were sufficient for pragmatic game play. Moreover, prior exergame and real sport experience did not have any effect on the muscle activation changes between normal and fast swimming. These behaviors are likely to happen when players understand the game mechanics, even after a short exposure. Such evaluation might help in adjusting the physical demands of sport exergames, for safe and meaningful experiences.

1. Introduction

Exergames provide ample opportunities to play virtual sports aiming to increase physical activity levels and to improve motor skills and performance capabilities [7,26]. Previous research confirmed that neck and upper limbs muscle activations are higher during exergaming compared to sedentary games [16], and subjects have higher muscle activity when playing against a human opponent than a computer counterpart [23]. Electromyography (EMG) related studies try to capture the emotional and physical reactions to game events [20], which could be used to control the movements in computer games [24], or to measure unconscious emotional expressions; for example, increased activation of *Zygomaticus Major* and *Corrugator Supercilii* muscles are related to positive and negative emotions, respectively [25].

While challenges in sedentary games are usually controlled by adjusting the complexity of mental tasks, employing body movements can be unique characteristics of exergame design. It has been reported that subjects who used a video game to perform an exercise task, did not have different muscle activation levels compared to those who performed the same activity without visual feedback [6,27]. Moreover, although earlier studies provided convincing results regarding increased energy expenditure compared to sedentary gaming [12], later studies showed that as players gain experience, there are chances of low-effort playing by performing surrogate movements without activating the intended muscles while acquiring similar results [3].

As different types of feedback, competitiveness, and learning effects may contribute to exergame engagement [16], rapid responses of EMG have become a proper objective tool in recognition of players' preferable actions and behaviors, and might be useful in scenario development of video games [9]. With higher exergame engagement, muscle activation levels also increase [16,29], and speed-based exergames might be employed to create physical demand and to avoid boredom when players' engagements diminish. While real-world sport activities may usually generate higher muscle activation compared to virtual equivalents, EMG profiling can be used to make sport exergames closer to real activities [4].

Although these low-cost and commercially available gaming platforms look promising (e.g., short-term increase in energy expenditure and rehabilitation), still little is known about muscle activation during exergame play. While the chance of low-effort playing exists, it is also not clear if playing at higher speeds leads to higher muscle activation. Moreover, few studies have been performed to determine muscle

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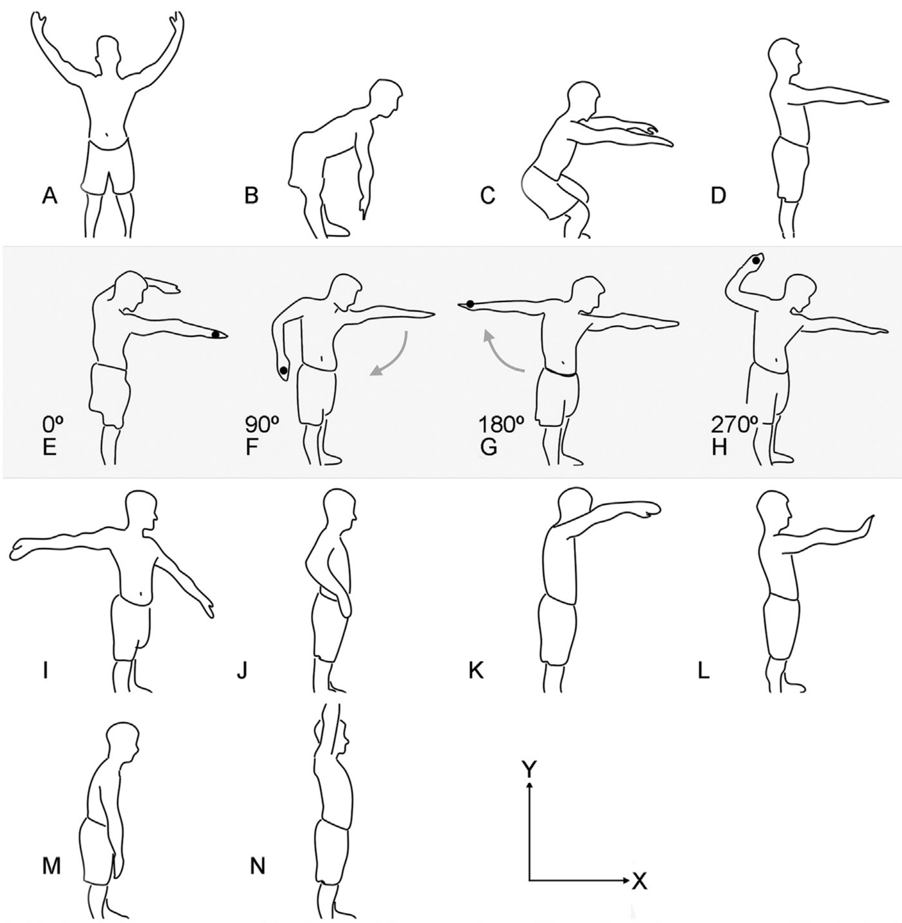
Fig. 1. Body positions during different events.



A: Hyping; B: Preparatory position for crawl, breaststroke, and butterfly; C: Preparatory position for backstroke; D: Diving; E: Hand center marker at maximum X coordinate; F: Hand center market at minimum Y coordinate; G: Hand center marker at minimum X coordinate; H: Hand center market at maximum Y coordinate; I: Backstroke; J: Breaststroke; K: Butterfly; L: Return; M: Preparation for termination; N: Terminating the race.

activation (relative to maximum voluntary isometric contraction – MVIC – and with regard to movement velocity) of upper limbs and trunk during exergame playing. It is also important to check how participants with prior real sport experience, play related sport exergames. Therefore, the purpose of this study was to assess muscle activation levels elicited during a swimming exergame with two different playing velocities in players with different exergame and real sport experience.

2. Methods

Twenty male college students (mean ± SD 24.2 ± 3.1 years of age, 177.6 ± 8.1 m of height, and 73.3 ± 10.4 kg of body mass), were recruited for this study. The procedures were approved by the local ethics committee (Process number: CEFADE 01/2013) and were conducted according to the declaration of Helsinki, imposing that, prior to testing, participants signed a written informed consent.

Muscle activations of the *Biceps Brachii* (BB), *Triceps Brachii* (TB), *Upper Trapezius* (UT), *Latissimus Dorsi* (LD), and *Erector Spinae* (ES) of the preferred limb (and side) were recorded using a Trigno™ wireless surface EMG apparatus (Delsys, USA) with a common mode rejection ratio of > 80 dB, input impedance of 10^{12} Ω, input range of 11 mV with a 16-bit amplifier, and sensitivity of 168 nV/bit at a sampling rate of 2000 Hz, for both MVIC and exergame trials. These muscles were chosen due to their importance in swimming [17] and hypothesized activation during this exergame (ES). Electrodes were placed according to SENIAM project [10] and, for LD and BB, we adapted the procedures from Lehman et al. [14]. Placement sites were shaved (if necessary), lightly abraded, and cleaned with an alcohol swab to decrease skin impedance, in accordance with standard electromyographic procedures. EMG sensors employed four silver bipolar Ag/AgCl surface bar contacts (fixed inter-electrode distance of 1 cm and 5 × 1 mm contact area) for maximum signal detection and were placed on the skin using specially-designed 4-slot adhesive skin interface minimizing motion artifacts (Delsys, USA).

The Biodex System 4 (Biodex Medical Systems, NY) was used to obtain MVIC in accordance with the manufacturer instructions. The positioning of Biodex for BB and TB was performed according to Gennisson et al. [8] and Lategan and Krüger [13], respectively. For UT and LD, we followed Hong et al. [11], and for ES, we used the procedures of Moreau et al. [21]. Three MVIC attempts of 10 s each were recorded for each muscle, with 2 s of ramping from rest to maximum contraction, sustained by 5 s, and more 3 s to progressively reduce the activation to resting levels, with a 1 min rest [1]. While verbal encouragement was provided throughout the MVIC attempts, the mean highest value of the three attempts was used to normalize the trial data. To remove the effects of playing velocity, MVIC of the filtered signal was also divided by the average velocity [16] during each gaming phase, using the following equation:

$$\text{True normalized EMG} = \text{RMS expressed as\%MVIC/Average velocity}$$

Three-dimensional kinematics was monitored at 200 Hz using a 12 camera motion capture system in acquisition software (Qualisys AB, Sweden). Twenty-two reflective markers were placed on the anatomical landmarks over the skin (cf. [22]): 7th cervical vertebrae, acromio-