Muscle Activation during Swimming Exergame.

Conference Paper · April 2014


Pooya Soltani
Faculty of Sport, University of Porto


Pedro Figueiredo
Portuguese Football Federation


Ricardo Fernandes
University of Porto


Pedro Fonseca
University of Porto

Muscle Activation during Swimming Exergame

Pooya Soltani[1], Pedro Figueiredo[1], Ricardo J. Fernandes[1,2], Pedro Fonseca[2], João Paulo Vilas-Boas[1,2]
[1]Center of Research, Education, Innovation and Intervention in Sport (CIFI^{2}D), Faculty of Sport, University of Porto, Porto, Portugal, [2]Porto Biomechanics Laboratory (LABIOMEP), University of Porto, Portugal

Keywords*:* Biomechanics, muscle activation, virtual swimming, surface electromyography

Abstract

Swimming exergames may provide low-cost opportunities for teaching and practicing real swimming. The purpose of this study was to characterize the muscle activation during a swimming exergame. Ten healthy subjects played four swimming techniques using "Michael Phelps: Push the Limit" exergame by standing in front of Xbox360 and Kinect. Muscle activation for *Biceps Brachialis* (Bi), *Triceps Brachialis* (Tri), *Latissimus Dorsi* (LD), *Upper Trapezius* (UT) and *Erector Spinae* (ES) was recorded on dominant upper limb using a wireless EMG Trigno system (Delsys Inc, USA) at sampling rate of 2000 Hz, and was normalized to the maximal voluntary isometric contraction. EMG recordings were divided into a low intensity phase and a second phase of fast swimming. Both phases were evaluated in terms of EMG morphology (average peak value). Preliminary results show high contributions of UT. Particularly high activation values were obtained for back crawl, where more expressive shoulder flexion is required. Lower contributions of other muscles might be related to lack of sufficient mechanical resistance. Prevalence of the activity of the Tri relatively to the Bi was also observed, as expected, considering the final acceleration of the lower part of the arm in all swimming techniques. Due to great activity of UT, proper warm up and the use of strategies to transfer the muscle activity are advisable. More results of this ongoing project will be available in the future.

Introduction

Video game playing is increasing among youth (Lenhart et al., 2008) with the gaming experience being changed significantly in the last years. As they are part of screen-based activities which account for players' sedentary time, high exposures to video games has raised physiological and psychological concerns (Roberts et al., 2004). This has led to design a new type of video game (tagged as active video games or *Exergames*) in which the players can interact with the game physically and in a more natural way, hypothetically increasing physical activity levels regarding other screen-based activities. These gaming platforms use accelerometers, infra-red depth sensors, and cameras to detect player's movements to simulate on-screen game play. Using Kinect (see Leyvand et al. (2011) for details), players can interact with the game without holding anything, as it can detect full body joint segment (Zhang, 2012).

According to the Entertainment Software Association (2011), sports video games are the second "action" genre in terms of popularity. Hayes and Silberman (2007) suggested that exergames should be of interest in physical education to increase motivation and facilitate motor skill learning. However, detailed evaluation is needed to "prove" the benefits of sport exergames. If it shows similar movement patterns as real sports, they can potentially be a low-cost and effective tool in teaching and training sports.

Understanding muscular activation while playing exergames allows safe playing for both players and their peers. As most of the exergames consist of repetitive tasks, excessive playing of exergames have led to injuries and medical doctors introduced Wii shoulder (Cowley & Minnaar, 2008), Wiiitis (Bonis, 2007; Nett et al., 2008) and X-boxitis conditions after playing too much active video games. Risks caused by the game may be controlled by monitoring muscle activation during playing, which is especially important when the games are so engaging that the players would not be completely aware of their body and the time they spend on playing. Moreover, as exergames might be a good tool for unsupervised and self-directed rehabilitation, understanding muscular involvement is also necessary for considering prescription and for effective and secure training sessions (Tanaka et al., 2012).

The design of games and different controllers may affect posture and muscle loading (Lui et al., 2011). As enjoyment and other factors may contribute to high exposure of people to these games, a detailed biomechanical analysis during game design may prevent potential musculoskeletal symptoms. In order to make video games more realistic, “Naïve Physics” which is human perception of knowledge about the physical world, was introduced by Jacob et al. (2007). Applying the same physical principles of real sports while designing exergames may allow a more meaningful game play. This is important when participating in real sports happens before playing the exergame (Mueller et al., 2009). Characterizing exergames is helpful in designing harder levels while preventing a sudden occurrence of fatigue.

It seems that sport exergames have the potential to be used within the physical education settings. However, this needs to be supported by empirical evidence. To date, very few studies analyzed and compared muscular activity in exergames. Thus, to build a muscular activity profile for exergames, the purpose of this study was to provide the level of muscle activation in a swimming exergame.

Methods

Ten healthy male subjects who had no physical injuries (age 24.1±3.3 yr; weight 71.7±6.1 Kg; height 175.1±7.2 cm) played bouts of a swimming exergame. The pilot study was conducted at the University of Porto Biomechanics Laboratory (LABIOMEP). Participants were recruited online, face-to-face and through flyers. Informed consent forms were signed by participants prior to testing and procedures were approved by the local ethics committee. Anthropometric measures were taken and the participants were familiarized with the equipment and the procedure. As part of the game, they watched a brief instructional video in which playing with the game was demonstrated.

EMG sensors were placed on the dominant upper limb/side of players (Figure 1B). The muscles of interest for this study were the *Biceps Brachialis* (Bi), *Triceps Brachialis* (Tri), *Latissimus Dorsi* (LD), *Upper Trapezius* (UT) and *Erector Spinae* (ES), which are frequently used in swimming (Mcleod, 2010). Erector Spinae was considered as players had to lean forward in the beginning and at the end of the game play. Electrodes were placed according to SENIAM recommendations (Freriks et al. 1999). Skin Preparation involved cleaning, dry shaving, rubbing with alcohol-soaked pads and then allowing alcohol to vaporize. Muscle activation was recorded using a Trigno Wireless EMG System (Delsys Inc., USA) at a sampling rate of 2000 Hz, for both MVIC and Exergame trials.

The Biodex System 4 (Biodex Medical Systems, Shirley, NY) was used to obtain MVICs and was calibrated before each use according to the manufacturer´s instructions. Three MVIC attempts for each muscle were obtained, Each one lasted 10 s (2 seconds rest in the beginning, 5 seconds of muscle contraction and 3 more seconds to reduce gradually ending with a new isoelectric line) with one minute rest between attempts. The MVIC values were chosen from the highest value of the three attempts and used to normalize the trial data. Verbal encouragement was provided throughout the MVIC attempts. Positioning of Biodex for Bi and Tri were performed according to Gennisson et al. (2005) and Lategan & Kruger (2005), respectively. For UT and LD, MVICs were performed according to Hong et al. (2012) and for ES, we followed Moreau et al. (2001).

The exercise task was a swimming exergame designed for Xbox gaming platform. The software used was “Michael Phelps: Push the Limit” (505 Games, Milan, Italy), a game that offers different swimming techniques and uses Kinect (Figure 1A), which connects to the Xbox via a USB cable, allowing users to interact physically with the game. A promotional video is available here: http://goo.gl/zPvHZL. Four swimming techniques mimicking the four competitive swimming techniques were played randomly during this study. Each event consisted of 100-meters of virtual swimming. Subjects had to stand in front of the Kinect sensor, bent forward and, as soon as they saw the “Go!” command, they had to return back to normal playing position: slightly bent forward, with shoulder partially flexed, and upper limbs in front of the body (shoulder extension) (Figure 1C). After that, they had to swing their arms according to the technique to move the avatar in the game (100 meters front crawl swimming). At the end of the event, they had to drop both hands and then raise one of them to finish the race (corresponding to virtually touching the end of the lane). To prevent the player from swimming too fast or too slow, there is a spectrum on the screen with a blue zone in the middle which indicates if the cycle frequency is at the moderate level. At the middle of the second lap, there is a possibility to swim as fast as possible called “Push the Limit”. If players swim with a constant speed, they could reserve energy on a so called energy bar to exert more in the push the limit phase.

Figure 1. Game screenshot (A), positioning of sensors (B) and participants as they play (C).

EMG data processing was performed using EMG Works Analysis 4.0 (Delsys Inc, USA), and it included signal filtering between 20-450 Hz, full-wave rectification and Root Mean Square (RMS) envelope calculation using a 150 ms window. This process was performed for both the MVIC and the trial data. To determine whether there is a statistically significant mean difference between the five muscles in normal and fast mode, a paired t-text was run on each technique ($p < 0.05$).

Results

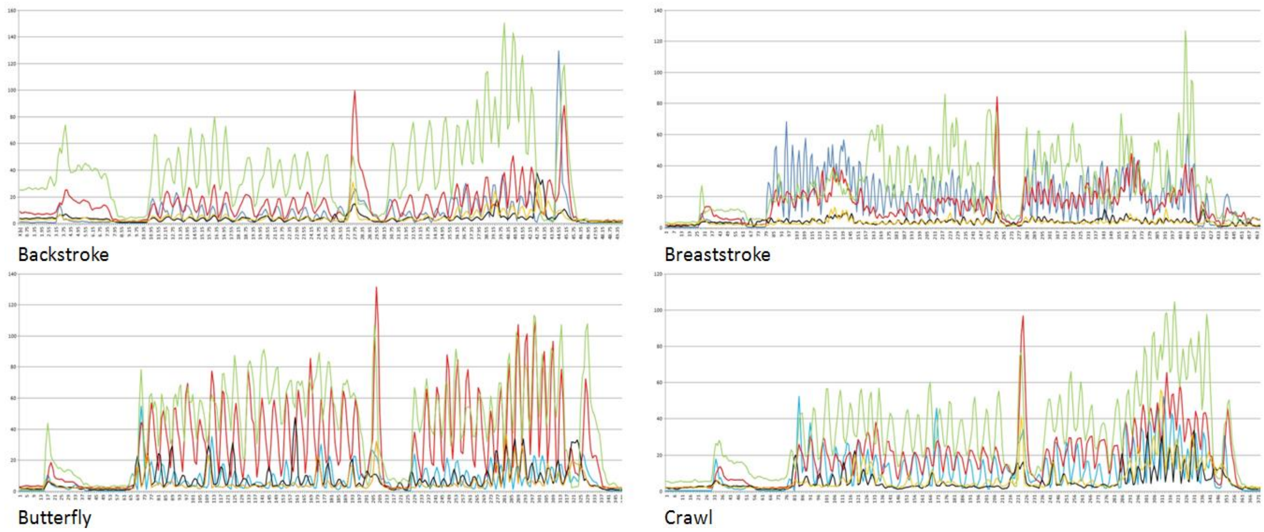
Table 1 presents EMG RMS mean±SD data expressed as a percentage of MVIC, obtained during “normal” and “fast” swimming from the selected muscles. The paired t-test showed significant change between normal and fast swimming in breaststroke, butterfly and crawl ($t(4) = -4.27$, $p = 0.01$; $t(4) = -3.49$, $p = 0.02$; $t(4) = -3.80$, $p = 0.01$, respectively). There was not a significant change in back crawl between the muscles from normal to fast swimming phases ($t(4) = -2.67$, $p = 0.06$).

Table 1. Muscle activation levels (normalized to % MVIC) during swimming exergame for all muscle groups in two virtual swimming phases.

		Bi	**Tri**	**LD**	**UT**	**ES**
Back Crawl	Normal	4.9±2.4	17.0±16.2	15.4±10.4	47.0±15.5	6.8±4.1
	Fast	8.2±5.0	23.7±22.1	21.7±18.1	69.3±18.6	13.4±7.3
Breaststroke*	Normal	10.0±5.5	19.0±18.2	11.1±6.7	29.0±19.3	5.0±2.6
	Fast	18.3±7.2	28.8±31.7	20.6±12.4	46.1±40.8	8.1±4.5
Butterfly*	Normal	5.6±2.0	23.4±21.3	24.4±32.7	43.8±19.0	5.5±2.4
	Fast	9.7±3.9	33.1±26.2	50.8±66.8	65.4±34.4	15.8±10.2
Crawl*	Normal	8.2±3.1	16.2±15.6	11.8±7.6	39.7±22.5	7.1±4.1
	Fast	15.2±4.8	23.0±24.6	22.9±14.9	63.7±31.5	18.1±13.0

*: significant changes were observed between normal and fast swimming in muscle groups; Bi = *Biceps Brachii*; Tri = *Triceps Brachii*; LD = *Latissimus Dorsi*; UT = *Upper Trapezius*; ES = *Erector Spinae*

Figure 2 presents a visual time sequencing of muscle activation.



_ Biceps Brachii, _ Triceps Brachii, _ Latissimus Dorsi, _ Upper Trapezius, _ Erector Spinae (Bigger Image: http://goo.gl/FYaCPh)

Figure 2. Time sequencing of muscle activation

Discussion

Preliminary results show high contributions of UT in all techniques. This is probably because players always have to hold their upper limbs up/front during playing (shoulder flexed). Particularly high activation values were obtained for back crawl, where more expressive shoulder flexion/rotation is required. In addition, players tended to face the screen and avoided rotation their bodies, which may justify why there were not any significant changes between normal and fast swimming as players had to exert a lot during both phases.

The activation pattern for Bi and Tri were similar in crawl, back crawl and butterfly. After the elbow reaches a point of maximal flexion (which occurs when the arms are down), Tri assists the arms to be lifted (starting push phase) progressing into an extended position. Interesting to note is the persistent pattern of co-contraction of this pare of antagonists, probably for elbow stabilization. Shortly after recruitment of the Tri, UT would be activated again holding the arms all the way through the push and recovery phase.

In crawl, the activation of LD is in accordance with Bi. As the arms are down, the activation of LD finishes leading to recruitment of Tri. The activation pattern of LD and ES fades away as players switch from playing emotionally (really completing the cycles) to technically (in a way that much of the work is being done by gravity). As they start the fast swimming phase, these patterns become visible again showing that those muscles are helping extending the upper limbs again to complete the cycles. As activation of ES serves a key in coordination of the body roll, lack of activation of this muscle shows that players tended to face the television and do the movement without rotating the body (the same situation occurs in butterfly). This happens as the players wanted to synchronize their cycle frequency with the visual feedback on the screen. In the fast phase of swimming, where no visual feedback was given, players tended to rotate their body (activation of ES) along with other muscles.

In breaststroke, the activity pattern of Tri and UT were similar. Tri extends the arms completely to the front and meanwhile UT is bearing the weight of upper limbs. UT remains active even in the so called recovery phase as it is still holding the upper limbs. Due to great activity of UT, proper warm up and the use of strategies to transfer the muscle activity is advisable. Lower contributions of other muscles are most probably related to lack of sufficient mechanical resistance of air. This suggests that increasing mechanical resistance to arms' movements may be a solution to implement the game playing conditions. Prevalence of the activity of the Tri relatively to the Bi was observed, as expected considering the final acceleration of the lower arm in all swimming techniques.

The empirical evidence that supports the effectiveness of sport exergames systems in teaching and training real sports is limited, since no study characterized sport exergames to provide an insight on how real they are when played. This study aims to create a muscle activation profile during playing a sport exergame. Although this swimming exergame is mostly different than real swimming (e.g. body position and forces applied to the body), swimming technique needs to be the same for a meaningful experience. More results of this ongoing project will be available in the future.

References

Entertainment Software Association. (2008). Essential facts about the computer and video game industry. *Retreived November*, *1*, 2013. http://www.theesa.com/facts/pdfs/videogames21stcentury_2010.pdf

Bonis, J. (2007). Acute wiiitis. *New England Journal of Medicine*, *356*(23), 2431-2432.

Cowley, A. D., & Minnaar, G. (2008). New generation computer games: watch out for Wii shoulder. *BMJ: British Medical Journal*, *336*(7636), 110.

Gennisson, J. L., Cornu, C., Catheline, S., Fink, M., & Portero, P. (2005). Human muscle hardness assessment during incremental isometric contraction using transient elastography. *Journal of biomechanics*, *38*(7), 1543-1550.

Hayes, Elisabeth, & Silberman, Lauren. (2007). Incorporating video games into physical education. *Journal of Physical Education, Recreation & Dance, 78*(3), 18-24.

Freriks, B., Merletti, R., Stegeman, D., Blok, J., Rau, G., Disselhorst-Klug, C., & Hägg, G. (1999). *European recommendations for surface electromyography*(pp. 1-122). H. J. Hermens (Ed.). The Netherlands: Roessingh Research and Development.

Hong, J. S., Kim, J. H., Hong, J. H., & Chun, K. J. (2012). Electromyograph analysis during Isokinetic testing of shoulder joint in elderly people. *Journal of Biomechanical Science and Engineering, 7*(4 SUPPL), 379-387.

Jacob, Robert JK, Girouard, Audrey, Hirshfield, Leanne M, Horn, Michael S, Shaer, Orit, Solovey, Erin Treacy, & Zigelbaum, Jamie. (2007). Reality-based interaction: unifying the new generation of interaction styles. Paper presented at the CHI'07 extended abstracts on Human factors in computing systems.

Lategan, L., & Krüger, P. E. (2007). Effect of two different handgrip positions on elbow peak torque values. *South African Journal for Research in Sport, Physical Education and Recreation*, *29*(2), 67-74.

Lenhart, A., Kahne, J., Middaugh, E., Macgill, A. R., Evans, C., & Vitak, J. (2008). Teens, Video Games, and Civics: Teens. *Pew internet & American life project*, 76.

Leyvand, T., Meekhof, C., Wei, Y. C., Sun, J., & Guo, B. (2011). Kinect identity: Technology and experience. *Computer*, *44*(4), 94-96.

Lui, Donald P. Y., Szeto, Grace P. Y., & Jones, Alice Y. M. (2011). The pattern of electronic game use and related bodily discomfort in Hong Kong primary school children. *Computers & Education, 57*(2), 1665-1674.

McLeod, I. (2010). *Swimming anatomy*. Human Kinetics.

Moreau, C. E., Green, B. N., Johnson, C. D., & Moreau, S. R. (2001). Isometric back extension endurance tests: a review of the literature. *Journal of manipulative and physiological therapeutics*, *24*(2), 110-122.

Mueller, Florian'Floyd', Agamanolis, Stefan, Vetere, Frank, & Gibbs, Martin R. (2009). A framework for exertion interactions over a distance. Paper presented at the Proceedings of the 2009 ACM SIGGRAPH Symposium on Video Games.

Nett, Michael P., Collins, Mark S., & Sperling, John W. (2008). Magnetic resonance imaging of acute "wiiitis" of the upper extremity. *Skeletal Radiology, 37*(5), 481-483.

Roberts, Donald F., Foehr, Ulla G., Rideout, Victoria J., & Brodie, Maryanne. (2003). Kids and media in America. New York, NY US: Cambridge University Press.