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Handbook of Research on Holistic Perspectives in Gamification for Clinical Practice

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Chapter 15

Muscle Activation during Exergame Playing

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ABSTRACT

Exergames may provide low-cost solutions for playing, training and rehabilitation. Exergame user research, studies the interaction between an exergame and users, in order to provide feedback for game developers and safe and meaningful game play. Detailed evaluations and a coding system based on muscle activation levels are necessary to characterize. This is important when it comes to use exergames in purposes other than fun. The purpose of this chapter was to characterize the muscle activation during a swimming exergame and to compare the level of activation during different conditions. Healthy subjects played bouts of exergame using Xbox360 and Kinect. Muscle activation was monitored for desired muscles on dominant upper limb using wireless electromyography system. An investigation of muscular coordination was also conducted to provide activation sequences of studied muscles. Preliminary results showed that upper trapezius was the most active muscle in all techniques. Results can provide insights for practitioners to have a baseline on application of exergames in their routines.

INTRODUCTION

Since the beginning of the 21st century, videogames have become one of the main sources of entertainment for a wide range of individuals. Statistics show that fifty nine percent of Americans were playing video games in 2014 (Entertainment Software Association [ESA], 2014). By that time, fifty one percent of American households were playing computer or video games on different platforms such as computers, videogame consoles (Microsoft Xbox 360, Sony PlayStation, and Nintendo), handheld consoles (Sony PSP, Nintendo DS), iPods, and mobile telephones.

On the other hand, a growing body of research have shown negative effects associated with playing video games (Ferguson, 2007; Gentile, Lynch, Linder, & Walsh 2004). Indeed, in the recent years, research has linked excessive screen time to a variety of health and social problems

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(Brown & Witherspoon, 2002). According to Martínez-González, Martínez, Hu, Gibney, & Kearny (1999), there are inverse associations between leisure-time physical activity and BMI which works independently from the amount of time spent sitting down affecting BMI directly.

Other authors associated the time children spend watching television, playing electronic games, and using computers, with an increased risk of obesity (Janz et al., 2002; Puska, 2009; Salmon, campbell, & Crawford, 2006). However, new studies are showing that screen time is not the only factor responsible for obesity (Jackson, von Eye, Fitzgerald, Witt, & Zhao, 2011).

Over the past decade, the gaming market has been facing rapid changes and video games have attracted new audiences, such as women and the elderly. A recent development in video game industry has led to design interactive video games, often tagged as exergames. These games incorporate some degrees of physical activity during the game play and players have to use body movements to progress in the games (Peng, Lin, & Crouse, 2011). Such platforms offer motion-sensitive controllers (accelerometers, gyroscopes, cameras, exercise equipment, pads and mats, and pressure sensors) taking the human computer interaction to another level. These games are usually controlled using large body movements alleged to make the player exert or develop motor abilities during game play. Popular exergame platforms include Microsoft Xbox 360 and Kinect, Nintendo Wii, Sony Playstation Move, Cateye fitness, and Xavix. These platforms use gaming technology and mechanics to support various forms of physical activity.

Previous instruments to measure the impact of video games were questionnaires, observations, and video analysis while newer methods of performance analysis may use log files and biophysical tools. The main differences of methods lie in subjective versus technology driven aspects of evaluation (Mishler, Lo Bue-Estes, Patrick, & Tobin, 2014). Some methods might be very objective when it comes to applying them in other contexts (e.g. using log files in an exergame designed for healthy people while it is going to be used for stroke patients). In order to adapt traditional evaluation to exergames, technology-driven methods are required.

Today, measuring emotional levels of players is done using different methods. Many tools and methodologies have been proposed to understand user experience playing digital games (Chanel, Kivikangas, & Ravaja, 2012). Psychophysiological responses (e.g. electrocardiography (ECG), electrodermal activity (EDA), and electromyography (EMG) along with psychological questionnaires) are used more and more to measure user experience. By using psychophysiological analysis, researchers are able to analyze the game experience with greater detail (Nacke, Lindley, & Stellmach, 2008).

EMG measures the electrical signal associated with the neural activation of the muscle; it is an experimental technique which provides information in real time about what is physiologically occurring with respect to nerves and muscles. It offers an objective assessment of when a muscle is active or not and reflects the electrical activity in the muscle fibers of activated motor units (MU).

EMG also provides information on the sequencing, or timing, of the activity of several muscles which enables the researcher to focus on skill related parameters. It also allows studying the changes in muscular activity during training and learning processes. However, we should keep in mind that EMG can not totally reveal what a muscle is doing, particularly in multi-segment movements.

EMG measurements have not been widely explored in order to provide constructive feedback during developing an exergame. The main concern is how these games should be designed to be entertaining and physically suitable and safe for players. Due to the novelty of the field, different playing population, and lack of research in this field, such methods should be employed as part of the design process.

Looking at a great number of applications of surface EMG in video games, this chapter intends to provide basic description and some applications of EMG in exergame research. It also includes the description about equipment and methods used and the processing of EMG data.

BACKGROUND

Physiological Aspect of Contraction

The human motor system is responsible for variety of tasks. Contraction of muscle fibers starts with a neuromuscular synaptic transmission. The central nervous system (CNS) controls the muscle activation by sending/receiving signals called action potentials while causes calcium to enter muscle fibers. This electrical signal is usually proportional to the degree of muscle activation (Hunter, Ryan, Ortega, & Enoka, 2002). It spreads over the surface of muscle fiber and causes series of steps to occur including:

1. A chemical is released from the end of nerve fiber causing a fast change in the voltage of muscle.
2. The electrical signal travels on the surface and along the muscle fibers.
3. Calcium ions are released into the intracellular fluid of muscle fiber following the stimulation of electrical signals.
4. The calcium ions expose active sites of actin myofilaments to myosin filaments and cause them to attach.
5. Following these attachments, myosin filaments pull the actin which is a response to electrical signal. This means that the muscle is contracting.

Each individual muscle has several motor units with several fibers and each fiber has different action potential (caused by several factors including the deepness of fibers, blood flow, and body fat). There are three types of motor units based on physiological properties:

1. Fast-twitch (fatigable);
2. Fast-twitch (fatigue-resistant); and
3. Slow-twitch.

Recording and quantifying these action potentials that activate a muscle is done using electromyography study. The surface EMG sensors collect the sum of multiple action potentials and a combination of motor unit recruitment and firing rate are key factors for having greater force.

During electromyography, a motor unit action potential (MUAP) is recorded in the contracting muscle. Depending on type of electrode, the captured MUAP derives from small number of muscle fibers to great number of fibers. By using needle electrodes, physiology and pathology of the MU could be studied and by using modern surface EMG systems, other aspects related to behavior, temporal patterns, or fatigue of the muscle could be explored. They have important implications in sport and rehabilitation where using needle is not possible or when the assessments have to be repeated several times.

NEUROPHYSIOLOGICAL CONTROL OF MOVEMENT

Movement process is expressed as idea, plan, select, and move. The idea defines a goal to be reached which is then converted into a plan telling the best way to achieve it. Muscles are later selected to do the movement. Analyzing movements and muscle activation are ways of trying to understand how brain works which will lead to knowing the processes and decision making.

When the brain changes the signals (behavior) based on the outcome, this control of movement is called feedback. An important part of feedback is comparator in which we compare our current output with a desired output. For example, when we play exergames, we constantly use visual information within the game to progress. In case of sport exergames, a negative feedback leads to change movement from original (or real sport movement) to certain degrees which are enough to proceed in the game (Soltani & Vilas-Boas, 2013).

Learning is the ability to change the behavior with experience and might happen at the early stages of trying a new game. Memory, on the other hand, is the ability to maintain this change over time. In exergames, this might not involve doing the same movements but learning the mechanics underlying the games.

Another issue to consider is fatigue which is happens as a result of a drop in performance. Fatigue is a complex phenomenon and depends on several factors. Among apparent causes are the shortage of fuel and inability to remove the products of muscle metabolism. There are several muscular mechanisms of fatigue; namely slower conduction velocity (which is characterized by smaller muscle activation amplitude and longer duration when recorded by surface EMG) and slower relaxation phase.

In most motor experiments of sport games, there might be a difference between task (to do the movements according to real sport) and performance (what player is doing). Task parameters may include EMG amplitude, timing, load, and accuracy requirement. Performance parameters include kinematic variables (joint position, speed, and acceleration), EMG, variability from the real expected movements (accuracy). Before conducting such studies, there are always predictions about the relations between task and performance. Such predictions are comparable with postdictions or the relationship between task and performance.

Recording EMG during exergame play can provide information regarding agonist and antagonist muscles. Activation of agonist muscle accelerates the limb and if the muscle activation opposes to the acceleration, the muscle is considered as antagonist. EMG recording can reveal the patterns of activation (e.g. triphasic pattern) which become eminent when changing the task parameters can cause alterations in these patterns. This leads to a hypothesis called dual-strategy which classifies all the movements into two groups, with or without clear or hidden control over movement time (Latash, 2008).

Why Focus on Exergame?

The main purpose of designing a game is to be enjoyable as well as being profitable for game developers; that's why proper design leads to safe playing and greater game review scores and sales (Fullerton, Swain, & Hoffman, 2004). In the following paragraphs, we will address some of the other concerns with exergames.

Exergame Design

As mentioned in the circumplex model of affect, all feeling conditions come from two neurophysiological systems, one related to valence (pleasure-misery continuous sequence) and the other is related to alertness (Russel, 1980). Facial EMG is generally applied in human computer interaction (Hazlett, 2006) and in video games. With the occurrence of positive or negative emotions, EMG activity of facial muscles increases. For example, increased activity of zygomaticus major (cheek) is related to positive and corrugator supercilii (brow) muscle regions are related to negative emotions (Witvliet & Vrana, 1995). Based on this, Ravajaet, Saari, Salminen, Laarni, & Kallinen (2006), found their game positive and rewarding, but also concluded that using EMG for measuring emotional valence might be misleading.

Exergame and Rehabilitation

Motor function can be improved with therapy and repetitive practice of specific tasks. As rehabilitation is usually a long process which involves repetitive tasks, clinicians are looking for motivating tasks to make the process more meaningful (Weiss, Rand, Katz, & Kizony, 2004). Therapeutic exergaming includes functional and engaging exercises that, through improving motivation, could encourage patients to perform high volumes of practice (Sveistrup et al., 2003). By consequent improvements in adherence levels (Heuser et al., 2007), some studies have also reported increased exertion during training (O'Connor, Fitzgerald, Cooper, Thorman, & Boninger, 2001); that is why they have been described as innovative and promising in rehabilitation technology.

Yohannan et al. (2012) measured outcomes of several parameters including active range of motion (AROM) while using Nintendo Wii during rehabilitation of patients. They demonstrated that patients who used exergames in their rehabilitation process improved their AROM with less pain compared to the control group. Brown, Sugarman, & Burstin (2009) developed an EMG controlled video game in order to improve motor control of wrist muscles in patients who survived chronic stroke. In their pilot study, most of the participants improved maximal activation during game therapy sessions.

Howcroft et al. (2012) used different exergames on a group of children with cerebral palsy (CP) and showed that muscle activations did not exceed the maximum voluntary contraction (MVC). They also showed that whenever participants were using realistic movements (that could be successful in the real-world version of the game), muscle activation was even higher. Van Wijck et al. (2012) used the repetitive task training and feedback offered in their music-making exergame on stroke survivors to enhance functional recovery of their affected upper limb.

As most of the exergames are designed for healthy players, in order to use exergames in rehabilitation, the task should be tailored to the target audience and their needs.

For example, Hsu et al. (2011) considered using a bowling game in patients with upper extremity problems. They only found a significant increase in enjoyment (compared to standard exercise group). This proves the necessity of designing the specific game for the purpose of rehabilitation. The task should be continues until the patients are fatigued (Matsuguma, Hattori, & Kajiwara, 2014). Furthermore, it should ensure that the patients are performing the correct movements (Alankus, Lazar, May, & Kelleher, 2010) and the therapist should also be able to monitor their performance.

Based on suggestions of Doyle, Kelly, Patterson, & Caulfield (2011), initial requirements for a therapeutic exergame should be

1. Generality, covering a variety of upper- and lower-limb exercises;
2. Hands free interaction, so that subjects focus on the movements;
3. Easy setup, to reduce complexity and maintain adherence; and
4. Real time feedback, allowing patients to correct their movements.

Some other examples of exergames in rehabilitation are: Brain function rehab (Loureiro, Valentine, Lamperd, Collin, & Harwin, 2010; Saposnik et al., 2010), balance training (Brown et al., 2009; Kliem & Wiemeyer, 2010), and energy expenditure (Hurkmans, van den Berg-Emons, & Stam, 2010).

Exergame and Injuries

Many injuries come from overtraining and overuse (Marx, Sperling, & Cordasco, 2001) and low levels of muscle strength and endurance are considered as factors in development of injuries. Observations of Wilson and Brooks (2013) are suggesting that exergames (they evaluated) had at least one exercise considered unsafe by American College of Sports Medicine (2013), showing that users might be prone to injury. Therefore, developing games using musculoskeletal criteria may lead to more effective games and safer game play.

Weisman (1983) reported that 20% of elderly refused to play computer games because they were afraid of exposing their deficits. Shubert (2010) showed that most of the commercially available games are not suited for other populations and game developers should be attentive when designing games for different groups considering their needs and requirements (de Schutter & Vanden Abeele, 2008). Therefore, understanding physical condition (which for example, changes due to age) of players is an important factor when designing games, particularly for the elderly (Gerling, Livingston, Nacke, & mandryk, 2012).

As shown by Wollersheim et al. (2010), exergames do not increase physical activity significantly; possible explanations would be due to the gaming platform (e.g. Nintendo Wii only detects hand movements and not the whole body). Another possible explanation would be that as the games involve lots of repetitive movements or the movements are tiring, players are looking for strategies to exert less. This is happening as they switch from emotional playing to technical playing (Soltani & Vilas-Boas, 2013).

In exergames, fatigue is unavoidable but if it compromises performance, the experience of player will be affected (Bachynskyi, Oulasvirta, Palmas, & Weinkauf, 2013). Players should be challenged in a way so they don't lose their interest in playing games (Navarro, 2011). In order to keep the motivation and continuation of playing, unnecessary complex movements should be avoided. Monitoring muscle activation might adapt the challenges dynamically, which might help players to reach a good balance between challenge and skill levels (Borghese, Pirovano, Mainetti, & Lanzi, 2012).

Warm-Up

Warm-up is designed to increase the core body temperature, and stretching is designed to increase the range of motion (ROM) at a joint or group of joints. General warm-up movement is important in performance and to reduce the risk of injury in physical activity. Both active (low intensity movements to increase body temperature; Franks, 1983) and passive (using heating pads or ultrasound) warm-ups might be helpful prior to exergame playing. In addition, movement should imitate the actual movements of the activity (specific warm-up).

Warm-up prior to exergame play might prepare the tissues for greater stresses during the game play and may lower the risk of muscle tendon injury. Recommendation for effective warm-up routines varies depending on the nature and duration of the activity (Bishop, 2003).

MAIN FOCUS OF THE CHAPTER

Issues, Controversies, Problems

There are two pathways of EMG:

1. Clinical, which is a diagnostic tool in neuromuscular problems and
2. Biomechanical, which explores the muscle function and coordination during movements (Clarys, 2000).

Most of the studies conducted using EMG, analyzed if muscles are active or not and considered their role in complex sports, exercises, and rehabilitation, as well as quantifying muscular fatigue (de Luca, 1997).

EMG has great time resolution, provides quantitative data, requires small system setups, and once signals are recorded, different analyses are possible with the same data set. On the other hand, there is always a chance of movement artifacts which does not allow proper interpretation of the recorded signal. Moreover, EMG recording is generally an expensive and hard to interpret method.

The most common use of EMG in video game analysis is related to measuring facial muscle activities in which reactions and emotional moments inside a video game are recorded (Hazlett, 2006). As mentioned by Nacke, Drachen, & Göbel (2010), EMG of facial muscles allows mapping emotions in the valence part of the circumplex model of affect. Chanel, Rebetez, Bétrancourt, & Pun (2008) also used EMG and self-report analysis to measure emotional states. Muscular activity and physiological patterns were higher when playing in a conflicting situation rather than cooperative which leads to a richer interaction with the game.

Ibarra Zannatha et al. (2013) used EMG in their virtual game to determine muscle strength and fatigue effect in stroke rehabilitation. By using biopotential of carpis radialis and biceps brachialis muscles, they were able to determine fatigue in order to modify their training program. Park, Lee, & Lee (2014) examined the effects of virtual exercises on muscle activation of trunk and lower extremities. Their results showed that virtual training causes a significant increase in the activation of tibialis anterior and medial gastrocnemius and, therefore, it could be used in joint stability.

Types of EMG Electrodes

There are two main types of EMG electrodes; invasive and surface electrodes. Invasive electrodes (fine wire and needles) require a needle to be percutaneously inserted into the muscle. The advantages are:

1. An increased bandwidth,
2. Analysis of deeper muscles,
3. A more specific pickup area, and
4. The ability to test smaller muscles that are impossible to monitor with surface EMG due to the chance of receiving signals even from distant muscles (de Luca & Merletti, 1988).

This phenomenon is called cross talk and there are several technical and statistical approaches available in order to reduce cross talk (de Luca, 1997; Koh & Grabiner, 1993); such as using spatial filters (van Vugt & van Dijk, 2001). The disadvantages are:

1. Discomfort due to needle insertion,
2. Tightness or spasticity due to pain, and
3. Less repeatable testing situations, as it is hard to insert the needle in the same area of muscle each time.

Surface EMG, on the other hand, provides a safe, easy, and noninvasive way of measuring the energy of the muscle activity. It provides valuable information regarding the activation of a particular muscle group and can allow researchers and designers to implement this information accordingly in their practice and design. The advantages are that:

1. Sensors cause no pain,
2. They are mostly more reproducible than wire or needle EMG, and
3. They are very good for movement applications (Figure 1).

The disadvantages are that:

1. They have large pick-areas which make them prone to cross-talk from other muscles and
2. Electrodes can only be used for surface muscles.

Due to ease of use with large number of participants and applicability to be used with children and older adults, we decided to use surface electrodes in our study. From now on, wherever we mention EMG, we mean surface EMG or sEMG.

Recording EMG Signal

A full understanding of EMG and its application in exergame research requires knowledge of anatomy as well as consideration of signal processing and

Figure 1. Delsys Trigno wireless EMG system

recording. The general requirement is to detect the signal using electrodes, being able to modify the signal with amplifiers and store the signal with a recorder. The selection and placement of electrodes are important, and it could be acquired either with monopolar, or bipolar or multi-polar arrangement. Monopolar recording is mostly used in static situations (Ohashi, 1997) and situations involving needle electrodes; while bipolar or multi-polar are more common and records the electrical differences between the two or more recording electrodes over the muscle, reducing noise effects.

Muscle Selection

Once researchers considered which muscles might be associated with playing activity, they can place electrodes on those muscles to test their assumptions. This model encourages researchers to understand muscle synergy patterns too. Another strategy is based on clinical reasoning, in which researchers will consider additional muscles for a specific phenomenon and may have a strategy to switch from one level of assessment to another, until they discover possible contributing factors that are involved in their practice.

Data Acquisition

There are different models of EMG systems available such as hard-wired, wireless or data logger systems; each has their own pros and cons. Hard-wired systems are not affected by ambient noise easily, and allow as many channels as possible to be connected to the subject. On the other hand, they might be bulky and cumbersome; moreover using wires might limit the optimal movement during playing. In wireless systems, the researcher has to place small units on desired muscles which do not limit the subject's movements. Choosing EMG sensors depends on the task, research, and specific muscles to be investigated. As surface electrodes are commonly used for clinical applications (Oh, 2003), technical issues regarding placement and skin preparation can improve the quality of recording in this method.

Skin Preparation

Good EMG signal will be obtained if we prepare the placement site properly. Due to ease of use and non-invasive nature, many EMG studies currently use surface electrodes but good surface preparation is still beneficial. As technology advances, the need to reduce the impedance of skin and electrode is decreased. However, some skin preparation is still necessary for better contact of the electrodes with the skin in order to improve the quality of recorded signal (Hewson et al., 2003).

Generally, the preparation involves cleaning the skin with soap and water, dry shaving it and rubbing it with alcohol-soaked pad in order to reduce the impedance. This simple task can reduce the resistance of the skin by 200% (Rash & Quesada, 2006). Another important consideration is regarding test condition and exercise. If the task involves slow motion changes, a simple alcohol cleaning might be enough, but in more dynamic conditions (e.g. moving limbs), a more careful preparation is advisable.

Electrode Map of Placements

The European recommendations for surface electromyography, also called SENIAM project (Surface Electromyography for the Non-Invasive Assessment of Muscles) is attempting to standardize EMG assessment procedures (Hermens et al., 1999). For many clinical applications, the belly of the muscle is chosen for the electrodes to be placed and, in order to assure repeatability of the exact location of placing electrodes, using bony landmarks as reference is highly advisable.

As the recordings are usually contaminated by crosstalk from other muscles (which can cause misleading the identification of the muscle action), researchers should decide if they want a general or specific recording and place the electrodes according to their purpose. In general placement, the researcher can record from a general region. The specific electrode placement tries to record the muscle activity of certain muscles that are usually close to the surface and relatively easy to isolate. Here, we describe electrode placements for five muscles:

Upper Trapezius

The position of the arms in relationship to the torso may be the major factor influencing the muscle's activation. The electrodes are placed parallel to the muscle fibers of upper trapezius (UT). They are placed in the middle of the spine (C7) and lateral point of acromion, and approximately 2.5 cm away from the ridge of the shoulders (Figure 2). Raising the shoulders, rotating the head, and pulling the shoulder blades together help to identify the position of placement. Artifacts include ECG (which could be eliminated using proper filter range) and breathing.

Biceps Brachii

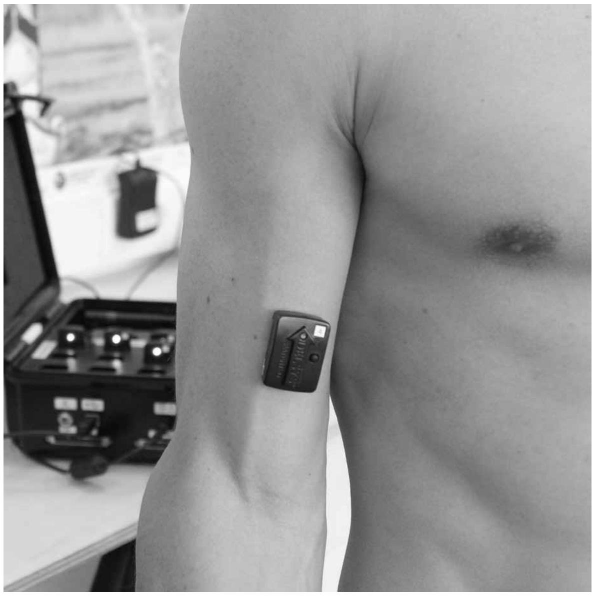
This muscle is responsible for forearm flexion, supination, and shoulder flexion. Placement of electrodes on this muscle which is two-blinded is done by flexing forearm on a supinated position and putting them on a line between the medial aspect of acromion process and the cubit fossa in the direction of muscle fibers (Figure 3).

Triceps Brachii

Placement of triceps brachii which is responsible for elbow extension and adduction and extension of the shoulder is done by monitoring the long head of the muscle; placing the electrodes parallel to the fibers and at the middle of the line between posterior crest of the acromion process and olecranon (Figure 4).

Figure 2. Electrode placement for the upper trapezius

Figure 3. Electrode placement for the biceps brachii



Latissimus Dorsi

Placement of electrodes of latissimus dorsi which is responsible to medial rotation, adduction, and extension of shoulder/arm, participation in rotation, lateral bending, and extension of torso is done by palpating the scapula; placing the electrodes approximately 4 cm below the inferior border of scapula, half the distance between the spine and the lateral edge of torso and positioned almost 25 degrees obliquely (Figure 5).

Erector Spinae

This muscle is responsible for main trunk moves and monitors stabilizers. The sensor is placed at the L3-4 level; about 4 cm lateral from midline (Hashemirad, Talebian, Hatef, & Kahlaee, 2009; Figure 6).

Noise and Artifacts

There are many sources of unwanted signal (noise) collected with the wanted signal. A common source of noise is related to heart beat, or ECG artifact. This should be specially noted when electrodes need to be placed on the left side of the body and close to the heart which will be shown both in raw and processed EMG signals. Movement artifact is another massive deflection in the EMG potentials of the raw EMG recording and happens because the electrodes move around (relative to the detection site). Improper placement of the sensors may result in movement artifacts. Using better gels, standard adhesive tapes, securing sensors with nets and taping are additional strategies to keep the sensors in place. Another source of noise is from 50/60 Hz energy of electrical cords that affects EMG signals significantly.

Figure 4. Electrode placement for the triceps brachii

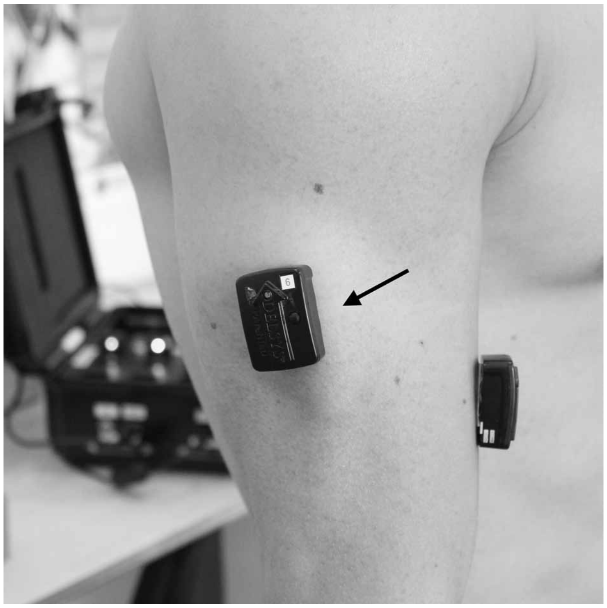


Figure 5. Electrode placement for the latissimus dorsi

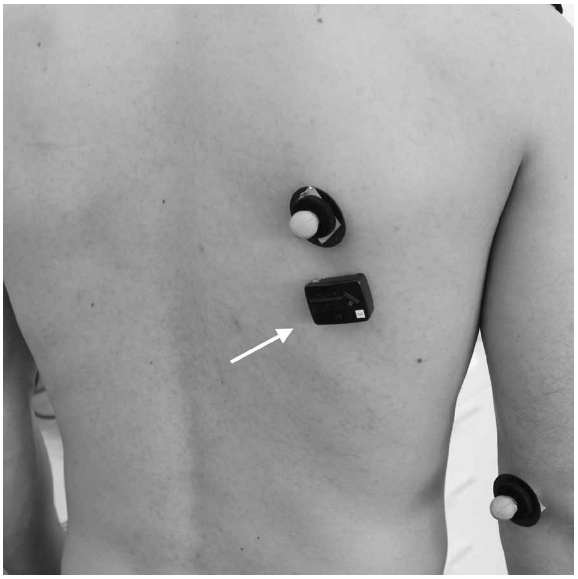
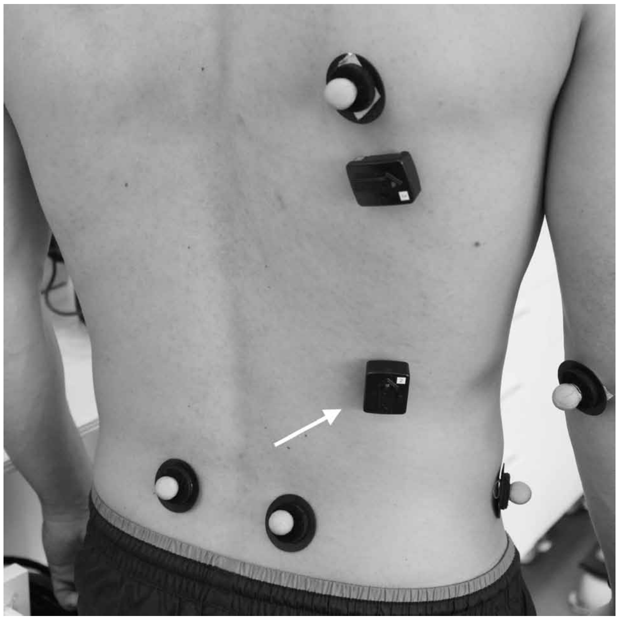


Figure 6. Electrode placement for the erector spinae



Assuming a good performance of the amplifier and proper skin preparation, the average baseline noise should not be higher than 3-5 mV. The human body is a good electrical conductor but this conductivity changes with tissue type (e.g. muscle vs. fat mass), thickness, physiological changes and temperature. These parameters vary from subject to subject and even within subject (if the tests are not done in the same conditions).

Pit Falls

Good history and physical examination is necessary before analyzing EMG. For example, sometimes a neck pain might be associated with paresthesias. However, abnormal results might not always represent pathology but due to an error by the eletromyographer. Temperature is another important factor that could affect amplitude and latency. Usually a 32°C temperature for upper limb and the lower limb above 30°C is ideal. As mentioned before, adipose tissue assuages the EMG signal and it is important that the researchers are attentive when selecting the population for the study. Ideally, researchers should measure the thickness of adipose tissue around the placing site, rather than just measuring the overall body fat percentage. Factors such as age, height, and weight can significantly affect EMG recording and they need to be addressed appropriately.

EMG Data Processing

Improvements in both hardware and software (signal processing techniques) have changed processing and analyzing of the data. As raw EMG is low voltage and could be covered by electrical noise, the signal should undergo treating processes in order to be correctly interpreted.

Filtering EMG Signal

In most of movement studies, raw signal is used; however, the main problem associated with raw EMG is the true interpretation of the signal. Researchers developed ways to process the EMG signals and make it easier to understand. Rectification and smoothing out the signal are among normal procedures to obtain interpretable data. Rectification changes the raw EMG signal to a single polarity (usually positive) and it eases signal processing (Landa-Jimenez et al., 2014).

As comparing the quantified EMG would be affected by adipose tissue, muscle mass/ cross sectional area, age, and sex between the subjects, a technique called *normalization* is being used to control these variables. Several forms are available for normalization and among all, *maximum voluntary isometric contraction* (*MVIC*) is frequently used (Ekstrom, Soderberg, & Donatelli, 2005).

MVIC normalization provides an estimation of relative invested neuromuscular effort during exergame task, and shows at what capacity levels the muscles are working. After warming up, which includes stretching and low aerobic exercises lasting 5 to 10 minutes, participants are asked to do three MVICs for the muscle groups of interest. In our study, each MVIC lasts for 10 seconds (first three seconds for preparation and gradual increase in exertion, four seconds for maximal exertion, and the last three second for gradual decrease and resting) and the middle four-second contraction is considered and then averaged over three trials of the MVIC. All the EMG data points are divided by MVIC value, and it represents a percentage between 0 and 100%. All values are relatively compared to the maximal effort and therefore comparisons between muscle and different subjects would be possible.

Working with special population (e.g. patients with cerebral palsy or low-back pain), they can't/ shouldn't perform MVIC and alternative methods should be considered. A clinical concept called "accepted maximum effort" which is the maximal level of exertion that could be tolerated by a person is advisable and could act as a MVIC replacement (Khalil et al., 1992).

Lower cutoff point filters will delete much of the electrical noise and upper cutoff point deletes tissue noise. This is practical while using different systems with different technologies. Upon amplification and filtration, the signal is ready for visual display and quantitative presentation.

Analyzing and Interpreting EMG

Amplitude (indicator of magnitude of muscle activity) and frequency (firing rate ranging between 1 Hz and 500 Hz) are important characteristics of EMG signal. For analyzing amplitude, one might use peak to peak amplitude, average rectified amplitude, root mean square (RMS) amplitude, linear envelope, or integrated EMG. Following amplitude analysis, and in order to analyze frequency characteristics of the EMG, turning points and zero crossings, or mean and median frequency might be used.

Other techniques such as onset-offset analysis (which is important for time analysis), phase-plane (which tries to link the kinematics of the movement with EMG), and polar plots (which describes the spatial distribution of EMG during an activity) diagrams and other analysis techniques might be also used (Robertson, Caldwell, Hamill, Kamen, & Whittlesey, 2013). The muscle on- and off-timing patterns and relative increase and decrease in muscle activity are the main parameters extracted from the signal. Beside this, researchers might also use EMG as changes in the signal as the muscle fatigue; particularly in the frequency domain.

Documentation

Documentation allows the researchers to know what has been done during the test, allowing them to have a basic understanding of analysis and enables them to share information. It covers four main items: Subjective documentation, Objective documentation, Assessment, and Planning. Subjective documentation involves a self-report of the subject. If the assessment is related to pain, the researcher should ask subjects to rate their pain on a scale of 1 to 10 for each part of the study/visit and should chart the subjects' pain (Borg, 1970).

The second part is objective documentation, in which EMG offers useful information to share with others. The next part is assessment of the information where comments about how to improve the games and what's potentially dangerous (especially by using repetitive movements) are mentioned. The last layer refers to treatment planning, in which the researchers decide about the plan they want to use. For example if they are using exergames in rehabilitation, the results might help if such games are helpful for patients or not. Comprehensive list of elements to document may include:

1. Target muscles (anatomical markers usage if relevant).
2. Electrode location and electrode locator templates.
3. Electrode type and manufacturer.
4. Inter-electrode distance and orientation to muscle fibers (which should be standard).
5. Ground electrode placement (if relevant).
6. Instrumentation specification; band pass filter range, site of pre-amplification, notch filter, type of signal display (raw versus processed), integration times (time constants), common mode rejection ratio, input impedance, signal-to-noise ratio, time constant, type of signal processing (i.e., RMS), and sampling rate for computerized systems.
7. Informed consent for procedures and objectives of analysis.
8. Positioning and movement of the subject.
9. Work: rest times, number of repetitions, task duration.
10. Verifying if EMG signals are being received from the muscles.
11. Verifying if the researchers attempted to document/eliminate the cross-talk from other muscles.

12. Normalizing methods (maximum voluntary isometric contraction, submaximal voluntary isometric contraction, EMG defined as a percentage of the peak magnitude recorded during a defined dynamic movement, EMG defined as a percentage of the average magnitude recorded during a defined dynamic movement, EMG values averaged over a defined movement sequence are expressed as a percentage of the average during another reference movement, EMG values from homologous muscles are expressed as a left–right percent difference, frequency spectral analysis).

Assessment Consideration

General reports regarding the findings might include the following:

1. Body posture/position of limbs (Kinematics).
2. Baseline values (resting).
3. Peak amplitude attained during the movement.
4. Recovery from movement (baseline level and rate of recovery).
5. Multi-channel comparison of muscles (relative timing recruitment/silence during phases of movement).
6. Interpretation of the findings.
7. Recommendation for further assessment.

Sample Size in Exergame Research

One of the main questions in exergame research is 'How many subjects are needed for the research?' The answer is important since the amount of collecting data is not always a quick matter. Sample size estimation is an important aspect of exergame experimental design, because without these calculations, sample size may be too high or too low. If sample size is too low, the experiment will lack the inferential power to provide reliable answers to the questions under investigation. If sample size is too large, time and resources will be wasted, often for minimal gain (but always tending to increase inferential power). The main purpose of statistical power analysis is to guide the planning of exergame research.

Power analysis is the ability to detect a significant effect (a relationship between the variables), where one exists. When a pilot study is conducted, power analysis can help to make sure that the procedures are working well enough to encourage the researchers to consider a larger scale research. On the other hand, participants might be a minority population (e.g. children with unusual health problems) who in this case, are often hard to study in a large number of participants.

One method for determining sample size is to use sample size calculators that are widely available on the internet. They are often available as free resources. Some of them are provided below:

1. **Creative Research Systems:** www.surveysystem.com/sscalc.htm.
2. **Raosoft:** www.raosoft.com/samplesize.html.
3. **National Statistics Service (Australia):** www.nss.gov.au/nss/home.NSF (access via statistical references).

Another program is called G*Power which has been available for several years. It's a tool to calculate power analyses for many statistics tests. It can also calculate effect sizes and display the results graphically (Faul et al., 2007). It is important to consider power, effect size, number of participants, and type of design/statistics in order to increase chances of finding an effect.

Pilot Study: Muscle Activation during Swimming Exergame

In the following part, we will take a look at an experiment we are conducting and a part of which was published in the XII international symposium on biomechanics and medicine in swimming (Soltani, Figueiredo, Fernandes, Fonseca, & Vilas-Boas, 2014). Our main aim was to provide a muscle activation profile for a swimming exergame and to compare level of activation in different conditions.

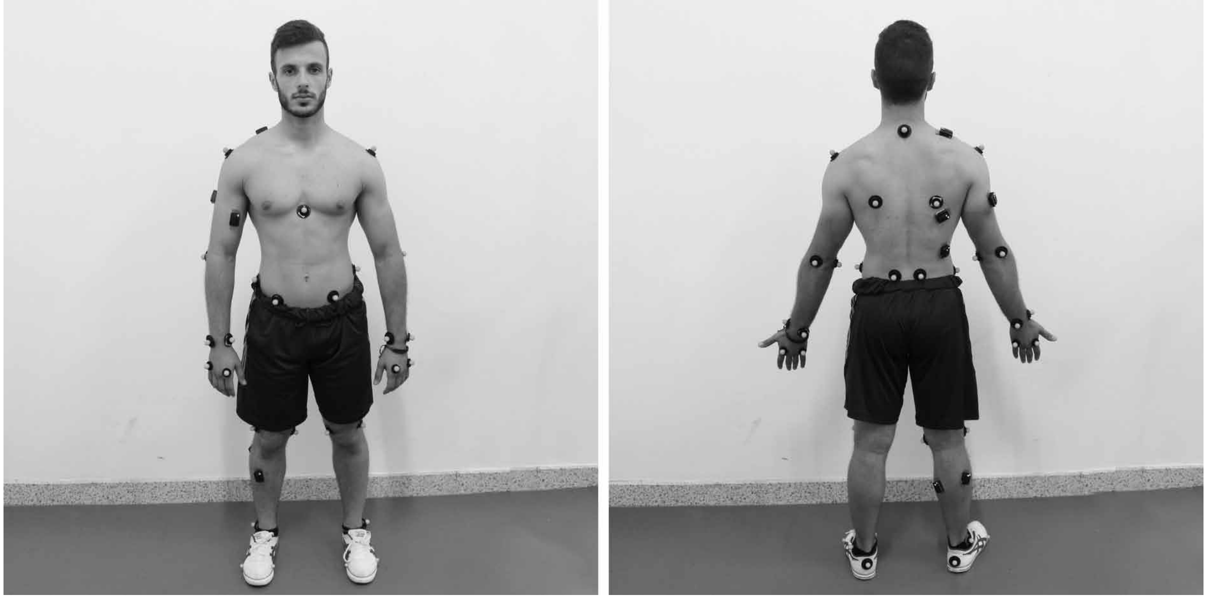
Procedures

10 male subjects (age 24.1±3.3 yr; body mass 71.7±6.1 Kg; height 175.1±7.2 cm) played bouts of swimming exergame. Anthropometric measures were taken and the participants were familiarized with the equipment and the procedure. Wireless EMG sensors were placed on dominant upper limb/side of players. Five muscles of interest (*biceps brachii* (BB), *triceps brachii* (TB), *latissimus dorsi* (LD), *upper trapezius* (UT)) for this study were employed. These muscles were frequently used in swimming (McLeod, 2010). We also monitored the activity of *erector spinae* (ES) as it was used in this particular game. Placement of electrodes was according to SENIAM recommendation (Freriks et al. 1999) and EMG was recorded using a Trigno Wireless system (Delsys Inc., USA) at sampling rate of 2000 Hz.

In order to relate EMG and kinematics, spherical reflective markers (size: 20 mm) were placed over the skin on the anatomical landmarks based on a custom links segment model as follows: 7th cervical vertebrae, acromio-clavicular joints, lateral and medial epicondyles approximating elbow joints, wrist bar thumb side and pinkie side (radial styloid and ulnar styloid), dorsum of the hand just below the head of the second and fifth metacarpal, inferior lower border of scapula bones, sacrum, sternum, and mid-superior, anterior superior aspect of iliac crest. The setup was in accordance with commonly used model (Rab, Petuskey, & Bagley, 2002).

3D position of each marker was simultaneously recorded at 200 Hz using a 12-camera opto-electronic motion capture system (Qualisys AB, Gothenburg, Sweden) within acquisition software (Qualisys Track Manager, Qualisys AB, Gothenburg, Sweden). Figure 7 shows a subject with the reflective markers and wireless EMG sensors placed on his body. For this study we considered only the upper limb kinematics.

Figure 7. A sample setup for EMG sensors and reflective markers placement



A dynamometer (Biodex 4, Biodex Medical Systems, Shirley, NY) was used to obtain MVIC. Three MVIC attempts were obtained, each lasted 10 s (3 seconds of rest in the beginning, 4 seconds of contraction, and 3 more seconds to reduce gradually) with one minute rest between the attempts. The MVIC values were chosen from the highest value of the three attempts to normalize the trial data. During MVIC, verbal encouragement was provided.

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, which connects to the Xbox via a USB cable allowing users to interact physically with the game.

After arriving at the laboratory, participants got familiar with the device through navigating the menus and exploring different options. As part of the game, they watched a brief instructional video from the game in which playing with the game was demonstrated. The game was divided into two phases of normal and fast swimming. Four different swimming techniques were randomly played during this study. Each event consisted of 100-meters of virtual swimming. In the beginning of the game, players can cheer the audience by moving their arms up and down and get extra energy (Figure 8A). Subjects had to stand in front of Kinect and slightly bend forward (Figure 8B) and as soon as they saw “Go!” command, they had to return back to normal standing position (Figure 8C). After that, they have to swing their arms according to the technique (no leg movement) to move the avatar in the game (Figure 8D-8K). When they finished one lap of the pull, they have to push their hand forward in order to return back (Figure 8L). At the end of the event, they had to drop both arms (Figure 8M) and then raise one arm to finish the race (Figure 8N). To prevent players from swimming too fast or too slow, there is a spectrum on the screen which indicated if the cycle frequency is at 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 can save energy on a so called energy bar and reuse it in the push the limit phase.

Figure 8. Position of the body during front crawl

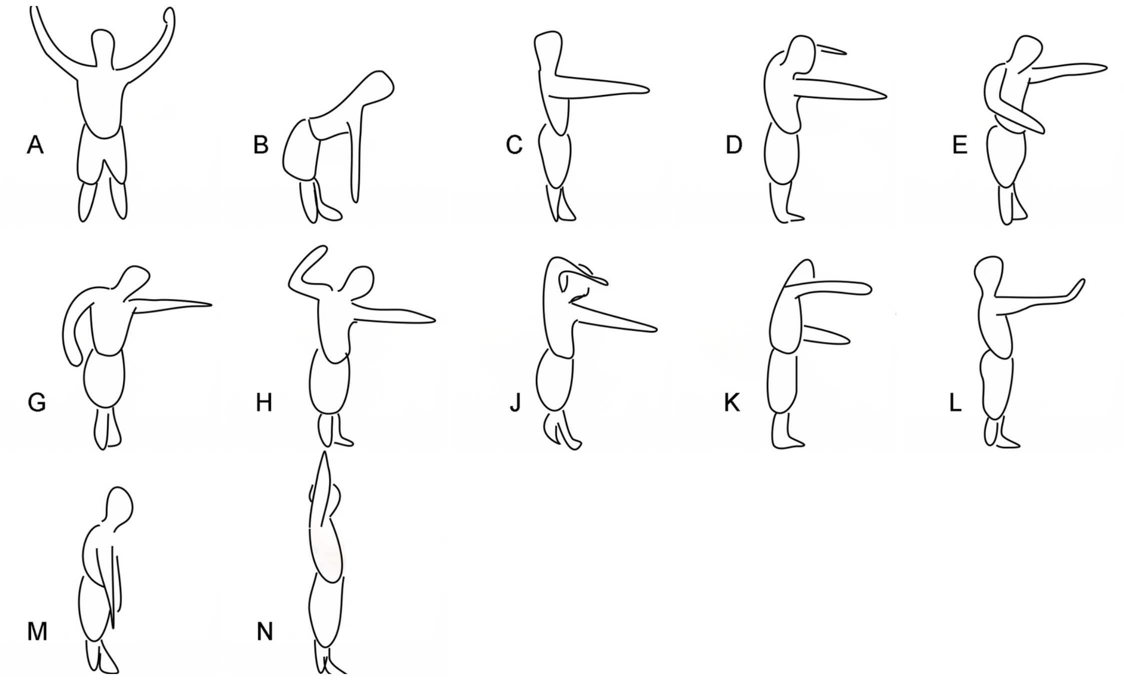
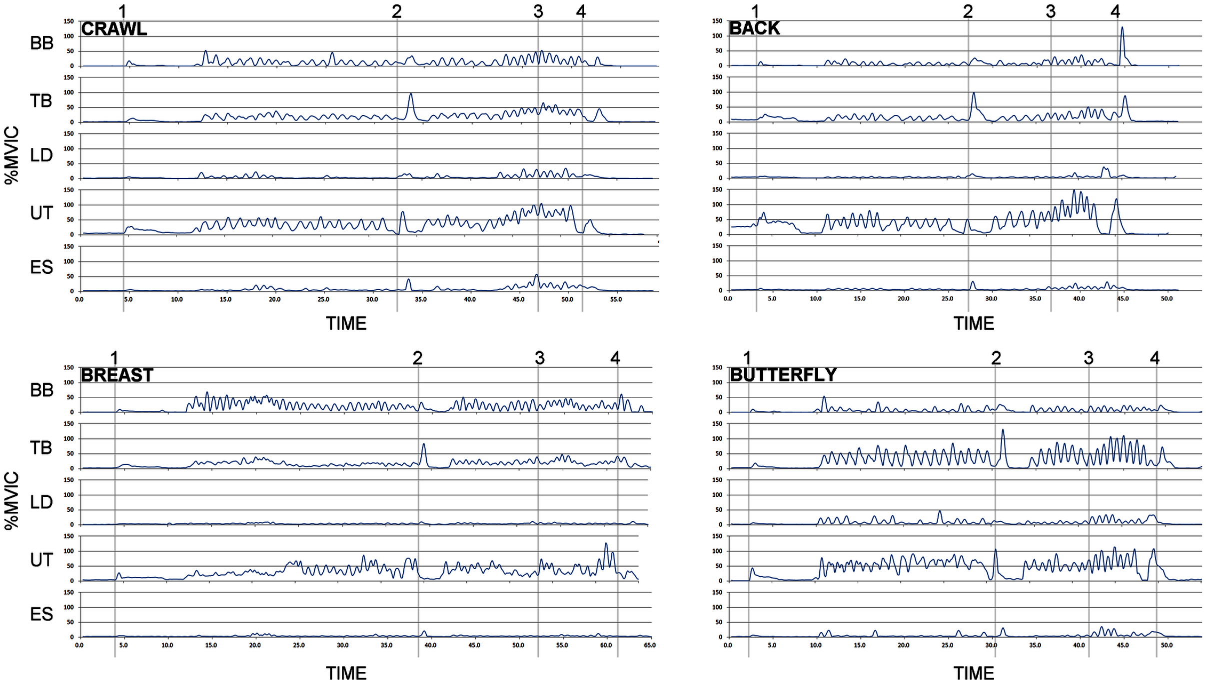


Figure 9. Time sequencing of muscle activation in different technique; 1: Start, 2: Return phase, 3: Push the Limit (fast swimming) phase, 4: End; BB: biceps brachii, TB: triceps brachii, LD: latissimus dorsi, UT: upper trapezius, ES: erector spinae; Values of %MVIC ranges from 0 to 150% (each line is 50% of muscle activation).



EMG data was processed using EMG Works Analysis 4.0 (Delsys Inc, USA), and it included signal filtering between 20-450 Hz, full-wave rectification and 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-test was run on each technique ($p < 0.05$).

Preliminary Results

Table 1 presents RMS EMG mean±SD data expressed as a percentage of MVIC, recorded during "normal" and "fast" phases of swimming. The pair t-test showed a 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).

Figure 9 presents a visual time sequencing of muscle activation for different techniques.

Figure 10 shows a sample movement pattern of a player in front crawl along with the behavior of the signal according to the position of the player.

DISCUSSION

Preliminary results show higher contributions of UT in all techniques. This is probably because players always have to hold their upper limbs up/front (flexed shoulder). Particularly high values were obtained for back crawl, where expressive shoulder flexion/rotation is required. In addition, as players were focused on the game and television, they avoided rotating their bodies which may justify why there were not any significant changes between normal and fast swimming as players

Figure 10. Behavior of the signal according to the position of the body in front crawl; BB: biceps brachii, TB: triceps brachii, LD: latissimus dorsi, UT: upper trapezius, ES: erector spinae ; Values of %MVIC ranges from 0 to 150% (each line is 50% of muscle activation).

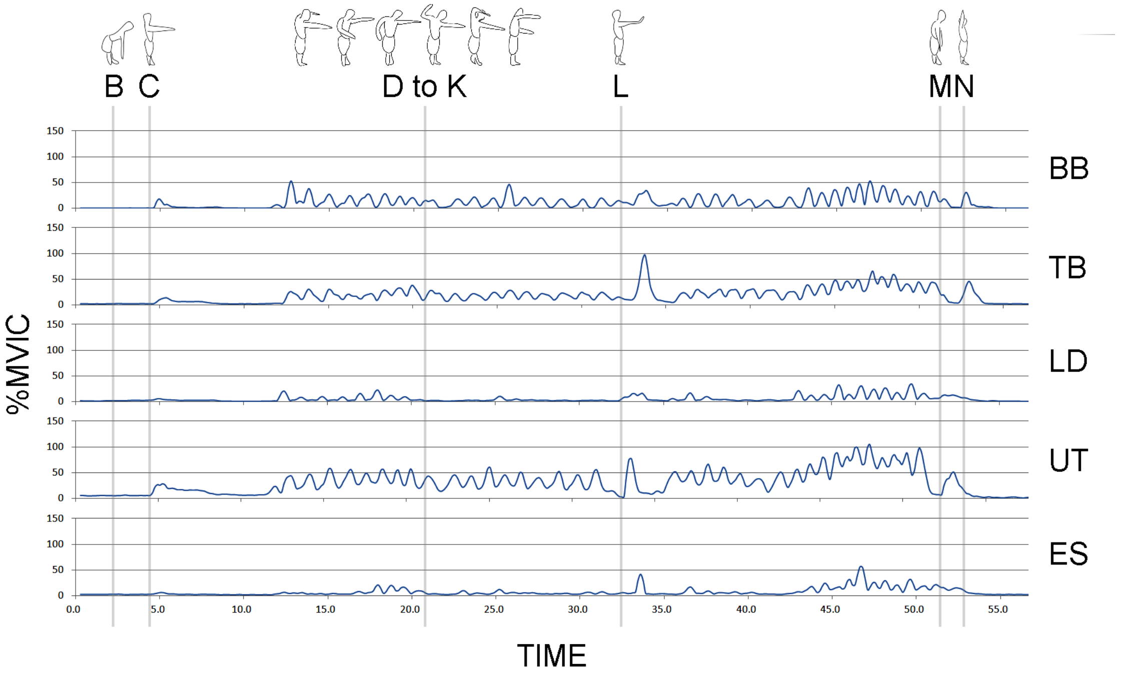


Table 1. Muscle activation levels (normalized to % MVIC) during swimming exergame for all muscle groups in two virtual swimming phases

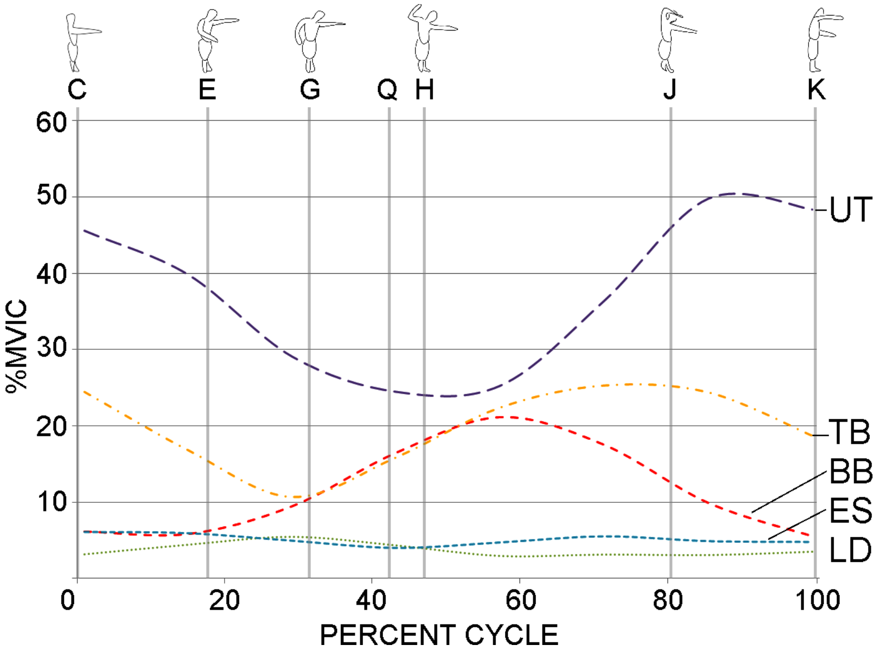
		Bi	Tri	LD	UT	ES
Back Crawl	Normal	4.9±2.4	17.0±16.2	15.4±10.4	47.0±15.5	6.8±4.1
	Fast	8.2±5.0	23.7±22.1	21.7±18.1	69.3±18.6	13.4±7.3
Breaststroke*	Normal	10.0±5.5	19.0±18.2	11.1±6.7	29.0±19.3	5.0±2.6
	Fast	18.3±7.2	28.8±31.7	20.6±12.4	46.1±40.8	8.1±4.5
Butterfly*	Normal	5.6±2.0	23.4±21.3	24.4±32.7	43.8±19.0	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*

had to exert a lot during both phases. When players perform the movements of swimming out of water, gravity is the only relevant resistance they confront and it will affect the movement as the subjects want to lift their upper limb (i.e. in the so called recovery phase and in the last part of pull).

The investigation of muscular coordination can be performed using kinematics while the EMG signals are cut into cycles (Figure 11). Typically, most important muscles around a joint or most muscles within a group could be measured. The cycle begins when the dominant hand is completely

Figure 11. Muscle activation pattern in one cycle during front crawl based on the position of the dominant arm; BB: biceps brachii, TB: triceps brachii, LD: latissimus dorsi, UT: upper trapezius, ES: erector spinae.



extended in front (Figure 11C). The level of UT activation is close to the maximum. This is happening due to upward rotation of the shoulders. LD quickly joins other muscles to assist this phase (similar to the first propulsive phase of real swimming). At the elbow and during (Figure 11E), BB (one of the elbow flexors) begins to contract as the player rotates the hand inward and gradually into a flexed position. This happens as ES and LD is helping rotating the body.

Following that, TB activity, which was reduced to the minimum while the hand in the lowest position (Figure 11G), starts to increase again extending the elbow which brings the hand backward and up (Figure 11Q). In the real swimming, this phase is called recovery in which deltoid and rotator cuff are assisting TB in removing the hand from water to start a new phase. As in swimming exergame, players tend not to rotate their trunk due to facing the television, they would compensate by flexing the elbow. That's why there an increase in BB activity from Figure 11E to Figure 11Q.

TB is the main stabilizer muscle as the activity of UT decreases in this phase. When the hand is completely in the back (Figure 11Q), player flexes his arm to return the arm in order to start a new phase. Once again, as the player did not rotate his body completely, during Figure 11H, the hand is not fully extended in the back, causing UT not to be active much, and ES acts as a core stabilizer. From that point, the activity of BB starts to decrease again but TB starts to extend the arm again. When arm is in the highest position (Figure 11J), the activity of UT is almost maximum as it is stabilizing the arm too. As the arm is extended too, the activity of UT reaches maximum. From that point the activity of TB starts to decrease again while LD accompanies the gravity in lowering the arm (Figure 11K).

SOLUTIONS AND RECOMMENDATIONS

Problems

EMG data collection is generally not a fast process. Straker et al. (2009) measured energy expenditure and EMG in different exergame platforms but did not normalize their results in order to reduce the time burden on their participants (children). Although wireless EMG sensors are easy to apply but the preparation phase (preparing subjects) and MVIC recordings for each muscle are time consuming. Our data collection took approximately one hour per subject (participation in game and recording MVIC for five muscles) which might not be tolerable for children and elderly. In such cases, normalization can also be performed using a standardized reference contraction, and the muscle activation is expressed as a percentage of reference voluntary electrical activity (%RVE). Of course, time issues vary for different groups of participants and different approaches. The limitations on time highlight the importance of planning, scheduling, and piloting the EMG study.

We were using the standard adhesive tapes for our EMG sensors. However, after the MVIC recording and as the subjects start to sweat, there was a chance for the sensors not have proper contact with the body. This is important to keep the recording time as short as possible for having proper signal. We were using securing nets for UT and ES in order to make sure that the sensors are not moving during the game play. Because of the rectangular shapes of the sensors and by using nets, we made sure that the sensors are in place especially for rotational movements of the arms.

Exergame researchers should know what each sensor type measure. During these kinds of experiments, we should keep in mind that human body might be influenced by other parameters such as room temperature, supervision of investigators, noise, and many more that could affect our interpretation of muscular activity. By controlling unwanted factors, we can improve signal-to-noise ratio while measuring muscle activation.

Application of EMG

Muscle activation profile may allow adapting the activity according to the needs of participants. In terms of exergame design, profiling makes the game closer to the real activity. In case of virtual swimming, it might be a method to compare the activation pattern of the muscles with the real swimming. If proved similar, it could be used as an alternative; especially when measuring the real activity is practically hard (Marion, Guillaume, Pascale, Charlie, & Anton, 2010), albeit feasible.

During repetitive movements which involve fatigue and changes in temperature, EMG-force relationship could be useful (Dowling, 1997) and a fast Fourier transform (FFT) analysis of the frequency response can be used to identify the occurrence of fatigue. Creating EMG profile in each activity may allow full program/game design guidelines and decisions. It does provide details on how each activity can benefit or harm the subject. If you decide to use exergames in your practice and if you would like to target one specific muscle, EMG profiles can give you useful insights.

However, we should be aware of several considerations while applying exergames. The repetitive nature of most exergames might develop muscle imbalances and fatigue. Some muscles might face overload while others may not even be used. These muscle imbalances may also create secondary postural imbalances.

As exergames might be used in other domains such as rehabilitation and in an unsupervised and self-directed setting, such understandings are crucial for prescription and secure training session. The changes that we observed in our study may be appropriate for healthy population. We should note that training and games should be specific to the population. As mentioned in a systematic review by Barry, Galna, & Lynn Rochester (2014), using exergames in rehabilitation is still very novel. Concerns regarding safety, feasibility, effectiveness should be address before implementing them in clinical practice. Dogan-Aslan, Nakipoglu-Yüzer, Dogan, Karabay, & Özgirgin (2012) also suggested that combinations of EMG and conventional therapies are more successful.

Finding the suitable exergame for certain groups is a challenge. The commercial exergame titles and platforms are cheap and it might provide opportunities to promote physical activity for elderly and disabled patients (Higgins, Horton, Hodgkinson, & Muggleton, 2010). On the other hand, specific exergames that meet certain needs of the patients might be expensive as they are not mass produced.

Applying EMG in Game Design

Depending on the type of platform and game title, some muscle groups might be more active than others. In some platforms such as Nintendo Wii, players have to hold a sensor while playing which gives extra activation on wrist extensors. All exergame platforms have advantages and disadvantages for clinical research. Inaccurate sensors might cause the players to repeat the movements or might generate frustration which leads to decrease adherence.

By using wireless EMG sensors and kinematics, muscle activity signal can be recorded during the gaming session and could be used to modify the games before final release, which seem to be a better approach than subjective methods (i.e. using questionnaires during or after gameplay) of evaluation.

Sport exergames might be used as a tool for training real sports. Therefore, proper exergame exercises need to be selected carefully. Two concepts of transference and isolation can help in choosing the exercises. Transference is the ability of an exercise in strengthening muscles in a way that helps a skill. Isolation is selecting a specific activity that targets one muscle or muscle group in order to make that muscle stronger.

Soltani & Vilas-Boas (2013) considered learning during a sport exergame. They asked real swimmers and expert exergame player to play bouts of swimming exergame. They concluded that real swimmer applied the real swimming mechanics during playing while expert players were swimming technically (not mimicking real swimming or emotionally) in order to win the game. In their study, the authors used kinematics of movement as a result of learning. Therefore, the swimming exergame may not be used in transference as most of the players tend to use technically rather than emotionally (correctly). However, it might be a good tool in teaching basic concepts of real swimming to children and those who don't know how to swim at all.

As mentioned by Lui, Szeto, & Jones (2011), one third of players experience some sort of body pain during playing with video games. Among reported areas, neck pain is commonly occurring. Our results confirm this as UT was the most active muscle during the game play. This justifies the importance of warm-up routines and adapting the games according to the needs of players. By using small EMG sensors, muscle activation can be recorded without interrupting the game play. This information can be used to modify different events of the game.

Exergame Ergonomics

Repetitive stress injuries are becoming a concern in biomechanics, ergonomics, and rehabilitation. Researchers can use many EMG tools to identify tasks that could potentially be dangerous to the body. In case of exergames, even low-intensity activities could be fatiguing if conducted for a long time. As many games consist of repetitive tasks, the site of fatigue could be determined using EMG techniques and EMG analysis could be a useful tool in redesigning and reducing fatigue.

FUTURE RESEARCH DIRECTIONS

Future research should investigate exergames qualitatively and quantitatively. Future studies could incorporate real world practices (such as warm up, stretching, instructions, and feedback) and analyze their effects on exergame performance. Dividing the movements into different phases using kinematics, and comparing the EMG levels in different phases, could possibly show in what part of the movement the incidence of injury is more probable. As exergames consist of lots of repetitive movement, such approaches could be beneficial in designing games avoiding extreme movements that could potentially harm the body.

EMG could be used to compare the game play behavior of different players. After playing for some time, most of the players tend to switch the way they play in order to spend less energy. EMG and kinematics could be used to identify these points and adapt the game levels for a more meaningful experience. Adding a virtual competitor (computer or another peer) increases the exercise effort among competitive tasks for both normal (Anderson-Hanley, Snyder, Nimon, & Arciero, 2011) and stroke patients (Chuang, Sung, Chang, & Wang, 2006). Future studies should compare muscle activation with the presence of peer pressure.

CONCLUSION

In this chapter one possible way to analyze exergames has been outlined. We introduced different challenges using EMG for the game analysis, describing the process from obtaining raw data to interpretable signal. We covered the sufficient recommendations of SENIAM and the equipment used in recording EMG. EMG profiling could predict user's effort and measure their results. This can affect the development of a game, and will allow developers to gather data from real world users to improve the game using an objective process.

Evaluating exergames from different aspects proves their applications and their types of measurements and how to measure them are the main areas. Measuring performance is one of the categories of the impact of the exergames and includes the factors in the person's ability to finish a task. Profiling exergames using muscle activation might prolong game play, especially when lots of repetitive movements are involved.

Injury biomechanics research applied to exergames is trying to prevent trauma through game modification. To do so, it is necessary to clearly understand what the mechanisms of injury are, and to have an understanding of human tolerance to game impact. EMG research might help in identifying and defining the mechanisms of injury and it quantifies the responses of human muscles to these mechanisms.

The individual's playing experience is important in exergaming as it might be used to foster fitness goal or to be used in other contexts. For a better exergame, the game should have a good user experience (based on the purpose of user evaluation). Active video games are gaining popularity in different populations and game developers might use emerging technologies to design better games. Game user research and human computer interaction can offer better understating of player's experience with active video games.

Making decision to use an active video game in other contexts (such as rehabilitation or teaching) is based on clinical reasoning (Schenkman, Deutsch, & Gill-Body, 2006). Using patient-centered focus and detailed analysis, makes the decision on inclusion of games in practice easier. More research to characterize and showing the efficacy of games will help incorporating exergames into practice.

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KEY TERMS AND DEFINITIONS

Electromyography: Electromyography is a technique for recording and evaluating the electrical activity produced by skeletal muscles.

Exergame User Research: It focuses on understanding user behaviors, needs, and motivations through observation techniques, task analysis, and other feedback methodologies.

Exergame: A portmanteau of “exercise” and “game” is a term used for video games that are also a form of exercise.

Isometric Exercise: Muscle action in which tension is developed but there are not any changes in joint position.

Kinematics: Kinematics involves the study of the size, sequencing, and timing of movement, without reference to the forces that cause or result from the motion.

Microsoft Xbox 360: The second video game console developed by and produced for Microsoft and the successor to the Xbox, a seventh generation videogame console which integrates Kinect, which allows the players to interact with the Xbox 360 without the need to touch a game controller, through a natural user interface using gestures and spoken commands.

Power Analysis: A process that allows to decide: (a) how large a sample is needed to enable accurate statistical judgment and (b) calculate the minimum effect size that is likely to be detected in a study using a given sample size.