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Original Research

Upper Limb Muscles Activity during Punches in Virtual Reality Exergame on Standing and Sitting Position

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ABSTRACT

Background: Physical activity (PA) provides various health benefits. Unfortunately, individuals with disabilities may experience health problems and greater obstacles to PA participation. Boxing exergame (EXG) based on virtual reality (VR) can be an alternative option to increase physical activity level because it is fun, relatively affordable and accessible. Punching in boxing requires complex movements, wherein the lower limbs are contributor for effective punches. An understanding of muscles activity is important to uncover the potential benefits of VR EXG.

Aim: To evaluate the differences in upper limb muscles activity of the dominant side in standing compared to sitting position during punches.

Material and methods: This was a cross-sectional study involving 15 healthy adult men. Surface electromyography examinations was performed on four upper limb muscles of the dominant side (upper trapezius, anterior deltoid, biceps, triceps) when delivering straight, hook and uppercut punches while playing VR EXG "Fitness Boxing" Nintendo Switch™ in standing and sitting position.

Results: Fifteen healthy men (age 31.87±3.14 years old, BMI 23.77±2.47 kg.m-2) were participated in this study. No significant difference found in the percentage of maximum voluntary isometric contraction (%MVIC) values of the upper trapezius, anterior deltoid, biceps and triceps muscles of the dominant sides when the subjects delivered straight, hook and uppercut punches (p>0.05), except for upper trapezius muscle during uppercut punch in standing compared to sitting position (p=0.041).

Conclusion: The VR EXG "Fitness Boxing" Nintendo Switch™ can be done in a standing or sitting position to get similar effect on the upper limb muscles.

Keywords: *boxing, electromyography, exergame, muscle activity, nintendo switch, playing position, virtual reality*

Introduction

Physical activity provides benefits such as improving physical function, mental health, cognition, sleep quality, quality of life, reducing risk of various diseases, obesity, depression and anxiety.[1-3] Unfortunately, individuals with disabilities are twice physically inactive and may experience health problems and greater barriers to physical activity participation compared to general population.[4] They also may have difficulty in maintaining work skills, recreational activities participation, self-care and various social activities. These problems require efforts to facilitate individuals with disabilities to have greater participation in all aspects and obtain better life satisfaction.[5] Regarding disabled person with lower limb problems, activation of upper limb muscles is crucial to meet the needs of daily physical activity.

Virtual reality exergaming (VR EXG) is an alternative option to help individuals with special conditions to increase their physical activity because the technology needed is relatively easy to access and at an affordable cost through popular commercial video-game devices (Nintendo Wii™, Xbox® Kinect).[6-8] Virtual reality (VR) is an interactive computer simulation that gives users the opportunity to participate in environments that look and feel like real-world condition.[9] Exergame is defined as a video-game that uses or requires the player's physical movement beyond sedentary conditions which consist of strength, balance, and flexibility components.[10] VR EXG can be used in various places (hospitals, homes, schools), for various age groups, conditions and goals.[11-18] Boxing is known as empty-handed martial arts and one of the most popular sports today, which requires strength, endurance, stamina, agility, speed, coordination and high concentration.[19] Punching is the main component and it requires complex movements of the arms, trunk, and legs, which the lower body is the contributor of effective punch. There are several basic types of punches in boxing, such as straight, hook and uppercut.[20,21] Thus, using punching movements in Boxing VR EXG activates the upper limb muscles.

Electromyography (EMG) measures electrical signals related to muscle-neural activity and provides real-time information about what happens in nerves and muscles in general, also muscle activity sequence or timing, which also allows us to examine skill related parameters during exercise and learning process.[22] A complete and comprehensive understanding of muscle activity involved is important to assess the potential benefits of VR EXG.[23] In boxing punches, the muscles recruitment order gives us hints regarding the importance of lower body/lower limbs, which begin from lower body to upper body and sequentially to upper extremity.[24]Using EMG, we try to objectively describe the upper limb muscle activations in sitting, diminishing lower limb movement and thus, lower limb muscle activation, compared to standing or normal playing position.

Various VR EXG studies around the world use popular commercial video-game consoles such as the Nintendo Wii™, Xbox® Kinect®.[6,7,11,13,14,16,18] Nintendo Switch™ is the latest generation video-game console from Nintendo and "Fitness Boxing" is an exclusive exergame for Nintendo Switch™.[25-26] There were still few studies that explored muscle activity while playing VR EXG and to the best of authors' knowledge, there has not been any study based on the Nintendo Switch™ console.

Several studies report differences in energy expenditure during exergame in standing position compared to sitting, which may be influenced by large lower limb muscle activity which is limited in sitting position. However, it is uncertain whether upper body muscle activity will decline or increase as compensation for the lack of involvement of the lower body. This study aims to evaluate the differences in upper limb muscle activity of the dominant side in standing and sitting position when delivering punches in VR EXG "Fitness Boxing" Nintendo Switch™, which could give us the idea of using the Boxing VR EXG to individual who only could move upper limb because of lower limb problems

Material and Method

Fifteen healthy adult men were recruited for this study using consecutive sampling from the Department of Physical Medicine and Rehabilitation Dr. Soetomo Academic General Hospital, Surabaya, through the broadcast message of instant messaging application. Inclusion criteria were: (1) aged 21- 39 years old; (2) body mass index (BMI) 18.5 - 29.9 kg/m^2. Exclusion criteria were: (1) "yes" responses to at least one item of Physical Activity Readiness Questionnaire (PAR-Q)[27]; (2) suffering from a disease or condition that causes difficulty in playing or affects the safety of participants during data collection. General health checks were performed on all participants. This study was approved by the ethics committee of Dr. Soetomo Academic General hospital, Surabaya (1834/KEPK/II/ 2020) and all participants have received an explanation and signed a written informed consent.

This study used a pretest-posttest repeated measurement design. All participants played the VR EXG "Fitness Boxing" using Nintendo Switch™ console with the same order of playing menu, position and punches. This console was chosen because it is one of the latest video- game consoles and the successor to the Nintendo Wii console which has been used widely in various fields of rehabilitation research. Output parameters were maximal isometric voluntary contraction (MVIC) and muscle activity (% MVIC) of the four upper body muscles (dominant side): upper trapezius, anterior deltoid, biceps and triceps (measured using a surface electromyography (sEMG) MESPEC 4000 HW-SYSTEM 8CH, Mega Electronics Ltd. Finland) when delivering straight, hook and uppercut punches according to the examples and instructions of the virtual trainer in standing and sitting positions. Standing position is the normal playing position, while the sitting position was used to eliminate or at least minimize lower limb muscles activity (see figure 1). The aim of sitting position was to get a similar condition on individuals with disorders or paralysis of the lower body/limbs.

Figure 1. Participants delivering straight punches while playing "Fitness Boxing" using Nintendo Switch™ with electrode attached on four upper limb muscles in standing and sitting position

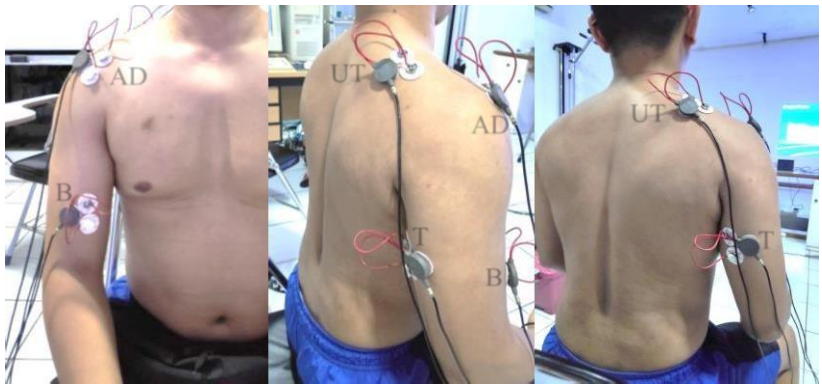

Figure 2. Electrodes placement on four upper limb muscles of the dominant side. UT: upper trapezius, AD: anterior deltoid, B: biceps, T: triceps

Stretching and familiarization to an accuracy score of 80% was done after undergoing a general health examination, anthropometric data collection, a brief explanation and demonstration of how to play the game. Participants were asked to wear comfortable pants and shoes when playing, while the shirt was removed for attachment of the electrodes to the four muscles examined (see figure 2).[28] Participants underwent a maximal isometric voluntary contraction (MVIC) examination first, then were given a 5 minute break.[29] Participants did straight, hook and uppercut punches in standing position and were repeated in sitting position while playing VR EXG "Fitness Boxing" Nintendo Switch™. In each change of punch type, participants were given a 1-2 minute rest interval and washout period of 5-10 minutes when changing position from standing to sitting. The raw signals data from the surface EMG device (mV) were processed to obtain root mean square (RMS) value, then normalized by dividing with the same muscle MVIC data, so that the final data is obtained in percentage (%MVIC).

The data distribution normality test was done using the Shapiro-Wilk test. Data analysis by comparing the results of the mean %MVIC activity of the four upper limb muscles in standing and sitting position was done using paired t-test if the data were normally distributed and the Wilcoxon signed rank test was used if the data were not normally distributed. All data analysis was performed with the SPSS version 23.0.

Result

Fifteen healthy adult male participants met the criteria. Table 1 shows the patient characteristic. In this study, participants underwent the treatment sequence with the same play menu, position and three types of punches. The results of this study showed no significant difference in %MVIC value of upper trapezius (UT), anterior deltoid (AD), biceps (B) and triceps (T) of the dominant side when participants delivered straight, hook or uppercut punch in standing position compared to the sitting position, except for the upper trapezius muscle during the uppercut punch (p value = 0.041) as shown in Table 2.

Table 1. Participants Characteristic

Characteristic	Mean ± Standard Deviation	Range
Age (years)	31.87 ± 3.14	26-36
Height (cm)	168.37 ± 8.06	156-183
Body mass (kg)	67.71 ± 11.18	51.5-88.3
Body mass index ($kg.m^{-2}$)	23.77 ± 2.47	19.62-28.34

Table 2. Upper limb muscles %MVIC values in standing and sitting position

Punch type	Muscle	Standing	Sitting	*p*-value
Straight (%)	Upper trapezius	91.60 ± 38.26	86.33 ± 50.57	0.465[a]
	Anterior deltoid	94.07 ± 37.67	92.93 ± 49.55	0.904[a]
	Biceps	43.47 ± 21.94	50.47 ± 48.57	0.865[b]
	Triceps	68.60 ± 47.46	61.87 ± 40.49	0.319[b]
Hook (%)	Upper trapezius	96.87 ± 44.91	97.73 ± 47.31	0.866[a]
	Anterior deltoid	104.40 ± 63.31	104.53 ± 44.64	0.753[b]
	Biceps	53.67 ± 36.29	54.20 ± 37.11	0.509[b]
	Triceps	57.07 ± 59.71	51.40 ± 34.48	0.801[b]
Uppercut (%)	Upper trapezius	77.27 ± 40.73	87.80 ± 43.22	0.041[a]*
	Anterior deltoid	108.73 ± 60.69	114.27 ± 52.26	0.776[b]
	Biceps	79.20 ± 52.36	68.87 ± 44.72	0.478[b]
	Triceps	50.60 ± 27.51	67.47 ± 78.68	0.733[b]

Note: Data in mean ± standard deviation. [a]paired t-test; [b]Wilcoxon signed ranks test.

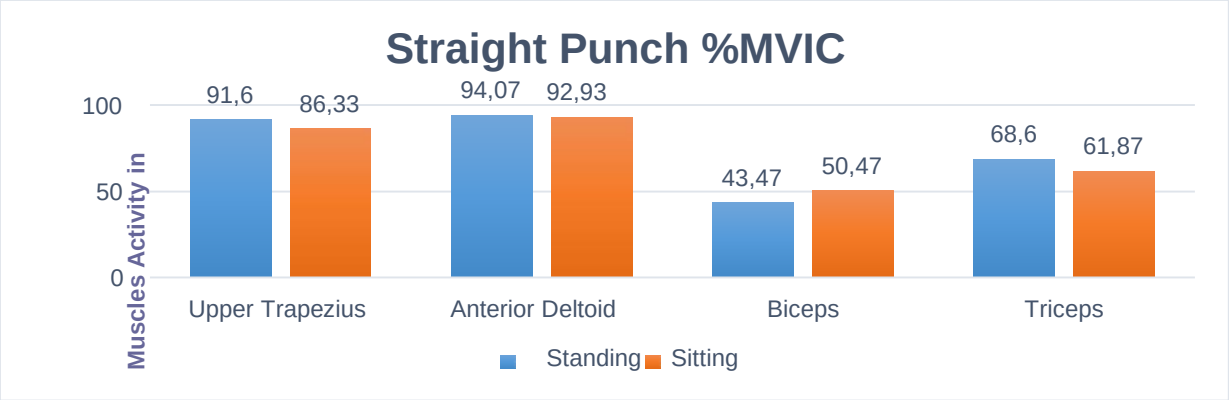

Figure 3. Upper limb muscles activity in %MVIC during straight punch

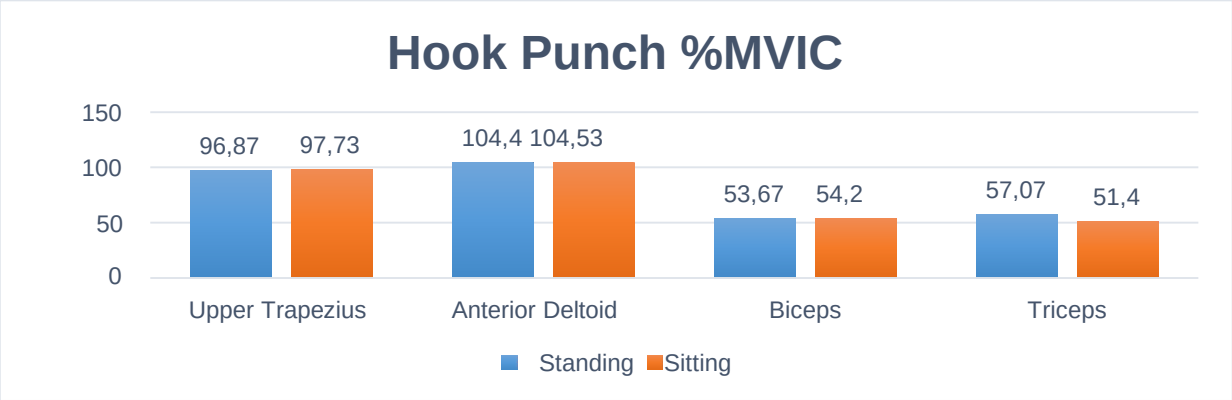

Figure 4. Upper limb muscles activity in %MVIC during hook punch.

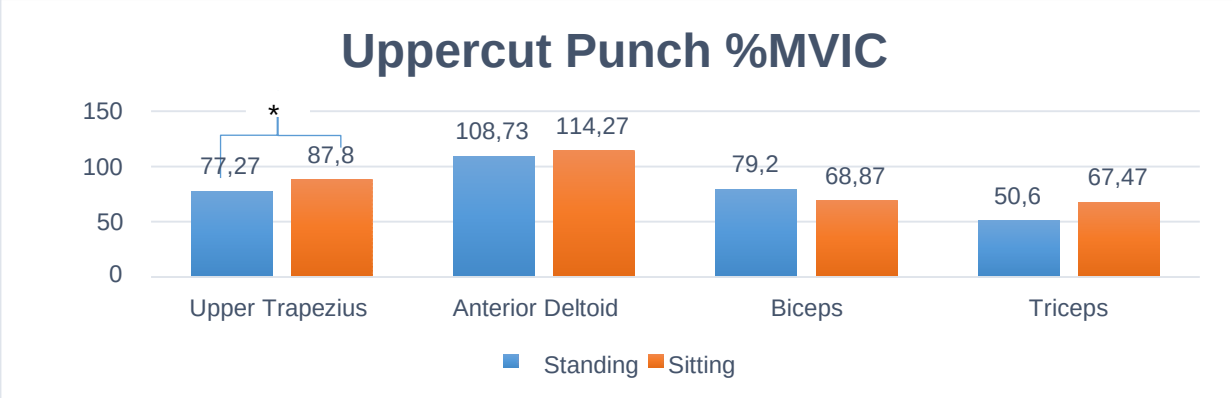

Figure 5. Upper limb muscles activity in %MVIC during uppercut punch. *$p < 0.05$

Discussion

To the best of authors' knowledge, this study is the first to determine whether there are differences in upper limb muscles activity of the dominant side, namely the upper trapezius (UT), anterior deltoid (AD), biceps (B) and triceps (T) when performing boxing punches in VR EXG "Fitness Boxing" using the Nintendo Switch™ commercial video-game console in a standing compared to sitting position.

When doing a straight punch while standing, the muscles activity were higher than sitting position in the upper trapezius, anterior deltoid and triceps muscles, while the biceps muscle had higher muscle activity in the sitting position than standing. This difference could be connected by the fact that in order to be able to perform effective punches, linear recruitment of muscles is required, starting from the legs, trunks, shoulders and arms where in this study, sitting position was aimed to eliminate the lower limb contribution.[24] Sitting position eliminates the trunk rotation when the return phase after a straight punch is back to its original position, which causes the biceps to work harder pulling the forearm back to the initial partial flexion position.

When doing a hook punch, the muscles activity in sitting position were higher than standing position in the upper trapezius, anterior deltoid and biceps muscles, while the triceps muscle activity was higher in the standing position than sitting. This can be caused by the movement of the hook punch from the outside inwards, basically a rotating motion of the upper extremity in a horizontal plane with an axis at the shoulder joint. In the normal playing position (standing), this rotational movement is assisted and influenced by trunk rotation, so that the activity of the upper trapezius, anterior deltoid, and biceps muscles were higher in the sitting position as a form of compensation. The triceps muscle had lower muscle activity in the hook punch sitting position than the straight punch which can be caused by the participants trying to make the hook punch stronger so that the triceps muscle becomes less activated as observed from the angle of elbow flexion which is smaller in the sitting than the standing position.

When performing uppercut punch, sitting position had higher muscle activity than standing position in the upper trapezius, anterior deltoid and triceps muscles, while the biceps muscle activity was higher in standing than sitting position. Significant differences were only found in the upper trapezius muscle. This may be caused when seated, the area to make uppercut, which is a punch from the bottom up is more limited than when doing this punch in standing position. Another possibility is the loss of the lower limb contribution and trunk rotation, causing the upper body muscles (especially the upper trapezius) to compensate by increasing its effort. Lower biceps muscle activity in the sitting position may be caused by the angle of flexion of the elbow that was observed to be smaller (elbows almost in full flexion position) than when performing an uppercut in a standing position. This can be caused by limited space in the sitting position causing the

subject to compensate by modification in that position.

There were no muscles activity differences in standing compared to sitting position in this study which was not in accordance with the hypothesis. This might be because the participant delivered the punches in accordance with instructions and examples from the virtual trainers, but with styles or habits that could be different one to another, although there was a requirement that the participant must meet the hit score in VR EXG with an accuracy of at least 80%. No differences meant that the upper body muscle activity of the dominant side, when delivering punches in VR EXG between standing and sitting positions was similar in terms of the level of muscle activity, so it should have the same effect on individuals who need increased physical activity but have conditions that make them unable to do it in a normal (standing) position.

Playing VR EXG using popular video-game consoles such as Xbox® Kinect® and Nintendo Wii was shown to increase energy expenditure in healthy individuals and special conditions such as individuals with disabilities and healthy elderly people and with balance problems. The intensity of exercise while playing Wii games was shown to be in mild to moderate levels.[8,30] Kafri et al conducted a study with post-stroke patients subjects who played boxing on the Nintendo Wii which mainly used upper limbs in standing and sitting positions, where standing positions showed higher METs and %HRmax values compared to sitting.[8] This finding is similar to research by Taylor et al in which higher VO_2 and METs were found in standing position compared to sitting position when playing Wii games "bowling" or "boxing".[31] This difference is likely influenced by the large lower limb muscles activity which is limited in sitting conditions. In this study, it can be said that there was no difference in standing and sitting muscle activity, so that the possibility of differences in the level of energy expenditure which is higher in standing position than sitting position was directly related to the loss of lower limb muscles contribution, but without any changes in muscle activity in the upper body which was originally thought to compensate in higher muscles activity in sitting position. Soltani et al stated that VR EXG does not produce as much muscle activity when compared to doing the actual sports.[32]

This study is a basic study of muscle activity when playing VR boxing exergame, and had several limitations, including: (1) the study samples were healthy adult men, the results of which are not yet known in other population groups; (2) electrodes attachment and surface electromyography examination on moving subjects could cause movement artifacts due to abrupt arm movement and trunk rotation; (3) the adjustable chair used did not facilitate complete lower limb fixation because the soles of the feet could still touch and press the floor, so it could slightly affect the punching motion and effectiveness; (4) there were no measurements of standing and sitting oxygen consumption to complement the muscle activity data; (5) the subject punched according to the instructions and examples given by the virtual trainer, where there could be differences in style and habits in making punches; (6) kinematic analysis (joint position and movement, stroke speed) was not carried out using a motion analysis system to evaluate the sequence and categorization of movements in a better and more detailed way.

Conclusion

This research concludes that playing the VR EXG "Fitness Boxing" Nintendo Switch™ provides similar upper limb muscle activity when delivering straight, hook and uppercut punches in standing and sitting position.

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