

Effects of Exergaming in Cancer Related Fatigue in the Quality of Life and Electromyography of the Middle Deltoid of People with Cancer in Treatment: A Controlled Trial

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Abstract

Objective: In the present study, we aimed to evaluate the effects an exergaming protocol for cancer patients who undergo or have already undergone cancer treatment. We sought to evaluate changes in cancer-related fatigue, function, and ability to perform daily activities, in addition to changes in the electromyographic pattern of the middle deltoid muscle. **Methods:** We conducted a controlled trial. Nineteen volunteers in the cancer group (aged 61 ± 9 years; body mass index 28 ± 5) and 19 in the control group (aged 58 ± 8 years; body mass index 28 ± 4) participated in the study. They were evaluated by means of a sociodemographic and clinical questionnaire, the Functional Assessment of Chronic Therapy-Fatigue (FACIT-F) questionnaire, and surface electromyography in the deltoid muscle at three moments: before the beginning of the exergaming protocol, after 10 training sessions, and after 20 sessions. The protocol consisted of practicing exergaming using Xbox 360[®] (Microsoft, Redmond, USA) with Kinect[®]. The game “Your Shape Fitness Evolved” (Ubisoft, Rennes, France) was used. **Results:** Total FACIT-F scores, fatigue subscale scores, and median frequency values observed in the cancer group were lower than those in the control group. These values improved in relation to the initial evaluation in the cancer group after the practice of the exergaming protocol. **Conclusion:** The exergaming protocol used in this study was effective for reducing reported symptoms of fatigue, increasing perceived quality of life, and improving the pattern of deltoid muscle contraction in cancer patients.

Keywords: Fatigue- exergaming- quality of life- eletromiography- rehabilitation

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Introduction

Cancer is the second leading cause of death in developed countries and the third in developing countries (WHO, 2003). The most prevalent side effect of cancer treatment is fatigue (Jones et al., 2015; Shapiro and Recht, 2001). Fatigue affects cancer patients from the beginning to the end of treatment, persisting for years and negatively impacting quality of life (Jones et al., 2015; Hampson et al., 2015).

The definition of cancer-related fatigue (CRF), according to the National Comprehensive Cancer Network, is the “persistent and distressing physical, emotional, and/or cognitive exhaustion or fatigue related to cancer or its treatment that is not proportional the recent activities performed and interfere in their normal function” (Mock et al., 2000).

Fatigue is present at the time of diagnosis in 50–75% of cancer patients. Among patients undergoing

chemotherapy, this prevalence increases to 80–96%, and the rate is 60–93% among patients undergoing radiotherapy (Stasi et al., 2003).

Treatments for CRF include psychotherapy, physiotherapy, therapy for sleep disturbances, nutritional adequacy, and pharmacological treatment (Franc et al., 2014). Research has found that regular physical activity (measured weekly) is positively associated with reduction in CRF symptoms in individuals with cancer (Huang et al., 2010; Spence et al., 2010; Cramp and Byron-Daniel, 2012). Physical activity should be light at first, and individuals’ reactions should guide increases in intensity to maintain patient safety (Wollin et al., 2012; Schimitz et al., 2010).

Performing exercises using videogames, or exergaming, demands attention and motivation, and it promotes a feeling of task accomplishment in users. Therefore, it is used as a form of entertainment that can assist patients in adhering to CRF treatment protocols (Kuys et al., 2011;

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Chang et al., 2013). Exergaming is a physical activity of mild to moderate intensity, requiring coordinated movement of all body parts, thus using different muscle groups (Peng et al., 2011). Therefore, because it is also a pleasant activity, exergaming is a viable alternative for CRF treatment (Harvard Health Publishing, 2012).

Therefore, this study evaluated an exergaming protocol for cancer patients who undergo or have already undergone treatment. The aim was to determine whether patients' self-reported fatigue, function, and ability to perform daily activities changed after the exergaming protocol. The study also examined whether the exergaming protocol was followed by changes the electromyographic pattern of the middle deltoid muscle.

Materials and Methods

This is a controlled study conducted between June, 2015, and October, 2016. The study was approved by the Research Ethics Committee of the Federal University of Alfenas (Protocols numbers 923.589; 1.366.215) and registered in the Registration Platform of Clinical Trials (RBR-9t48g5).

For convenience, participants were assigned to two groups: a cancer group (n =19) and a control group (n = 19). The cancer group was recruited in the Oncology department of the Santa Casa de Alfenas hospital, and the control group at the Physiotherapy Clinic of the Federal University of Alfenas - Minas Gerais State (MG).

The inclusion criteria for the cancer group were: age between 18 and 80 years, good ability to understand the methods of evaluation and training, clinical diagnosis of any type of cancer in stage 0 to III, undergoing or having previously undergone radiotherapy or chemotherapy, and medically cleared for the practice of physical activity. The control group had the same inclusion criteria, but could not have had a medical diagnosis of cancer until the end of the study.

Exclusion criteria were as follows: presence of orthopedic lesion in the shoulder with signs and symptoms active in the last six months, presence of nerve damage that impairs upper limb motility, reduction limb activity that prevents participation in the exergaming protocol, presence of infectious disease, presence of cutaneous lesions that make evaluation impossible, incapable of voluntary movement of the upper limbs, and incapable of performing isotonic exercises. Those who, for any reason, refused to sign the free and informed consent form were also excluded.

All the evaluations were performed by a different evaluator that didn't participate in the interventions and did not know which group the volunteer participated in. The interventions were realized by the other researchers. All the researchers were physiotherapists very experienced in rehabilitation of cancer patients. This study was carried out at the Human Movement Analysis Laboratory of the Federal University of Alfenas - MG. A preliminary evaluation was carried out by means of a sociodemographic and clinical questionnaire. Then, an inspection and palpation was performed on the upper limb, anterior trunk, and posterior trunk in order to observe

changes such as hyperemia, cyanosis, spots, fibrosis, feverish state, or any other dermal alteration.

CRF and the quality of life were evaluated using the full score and the fatigue subscale of a Portuguese translation of the Functional Assessment of Chronic Therapy-Fatigue (FACIT-F) questionnaire, which is a validated instrument designed to evaluate fatigue and the quality of life of cancer patients. The questionnaire covers five domains: physical well-being (7 items), social and family well-being (7 items), emotional well-being (6 items), functional well-being (7 items), and additional concerns or fatigue subscale (13 items). The fatigue subscale is used as an evaluator of the presence of the symptoms, and higher scores indicate lower self-perception of symptoms. The overall FACIT-F score consists of the sum of the scores of the five domains and evaluates patients' quality of life, where a higher score indicates better quality-of-life indices (Ishikawa et al., 2010).

A Trigno 8 Channel Wireless electromyograph (Delsys Inc., Natick, USA) and EMG Works Acquisition software (Delsys Inc., Natick, USA) were used for muscle fatigue analysis. The median frequency data were analyzed during the isometric contraction test.

The electrode was positioned on an imaginary line between the acromion and the lateral epicondyle, in the region of greater muscle belly of the deltoid muscle, after tricotomy (if necessary) and skin cleaning with 70% alcohol, as recommended by Surface-EMG for The Non Invasive Assessment of Muscle (SENIAM 8, 2015).

For the test, participants were seated in a rigid chair, with the upper limb to be tested at approximately 90°, where the middle deltoid muscle is highly activated (Witte et al., 2014). Patients were encouraged to perform an abduction of the shoulder against a load cell, maintaining maximum force throughout the test. The test was terminated if the patient could not maintain maximum voluntary isometric contraction (MVIC) for 60 seconds from the start of the test (Grange and Houston, 1991). This test was performed three times, with a 5-minute interval between tests (De Luca et al., 1983). Prior to the test, participants were verbally and visually instructed in the correct manner of performing the test, using a demonstration by the assessor. The volunteer was verbally encouraged to achieve maximum strength through the command ("Force, Force").

Muscle contraction patterns were graphically analyzed through the evaluation of the median frequency during the test. The first and the last 5 seconds were excluded in order to minimize the effects of the verbal command on the muscular contraction, resulting in 50-second tests for evaluation. The mean of the three trials was considered for MVIC analysis (Heinonen et al., 1994).

After the first evaluation, participants completed 10 exergaming sessions, followed by a second evaluation, then a further 10 sessions of the proposed exergaming protocol, and, finally, a third evaluation using the same evaluation instruments.

Initially, the volunteers were positioned in front of a 42" LED television equipped with the Xbox 360® (Microsoft, Redmond) console with Kinect®. The game "Your Shape Fitness Evolved" was used, with the

subgames called “Stomp It” and “Wall Breaker”. The subgame “Wall Breaker” has the objective of breaking blocks with the upper limbs. Players are scored as a function of execution time, with higher scores being obtained with faster execution. The initial duration is 1.5 minutes, and 10 seconds are added for each group of broken blocks. The average game duration is 2 minutes, and the protocol asked participants to repeat the game 9 times. The subgame “Stomp It” has the objective of executing a movement with the lower limbs, indicated by lights on the screen demonstrating different positions. The resulting movement resembles a dance. Again, the average game duration is 2 minutes, and the protocol asked participants to repeat the game 9 times. These exercises were chosen because they encourage aerobic exercise, which is effective in reducing fatigue in cancer patients (Cramp and Byron-Daniel, 2012). Participants performed 20 sessions each, with progressive game duration according to their tolerance to the exercise, reaching a maximum of 50 minutes, including the duration of the games and the rest time between games. Participants performed the exergaming protocol two or three times per week, for a total study duration of 8–10 weeks. Before the study began, all participants were briefed on the games and console handling.

The Statistical Package for Social Sciences (SPSS) (IBM Corp., Chicago, USA), version 20.0 was used for statistical analysis of the data. The variables were analyzed by means of the intention-to-treat (ITT) method, demonstrated through a flow chart of the study design (Figure 1). Initially, the data were analyzed using descriptive statistical methods, obtaining the values of mean, standard deviation, and confidence intervals. Then, all datasets were tested for their normality using the Shapiro-Wilk test, using a significance level of 5%. To analyze differences in the variables (a) age and (b) body mass index (BMI), the independent t test was used, and for the variables (c) sex, (d) practice of physical activity, (e) smoking, and (f) alcoholism, the chi-squared test was used.

For the independent variables, when the normal distribution criterion was met, Student’s t tests were carried out for independent samples; if the statistical assumption criteria were not met, the corresponding non-parametric alternative, the Mann-Whitney U test, was used for intergroup comparison. For both tests, a significance level of 5% was used.

Regarding the dependent variables, when both criteria were met (normal distribution and homoscedasticity), a Student’s t test was performed for dependent samples and, when any criterion was not met, the non-parametric alternative, Wilcoxon test, was used for the intragroup comparison, using a significance level of 5% for both tests.

The effect of the intervention was compared between the groups by means of a two-factor analysis of variance (ANOVA) model when the criterion of normality was met. When normality was not met, the corresponding nonparametric alternative, Friedman test with two factors (group and evaluations), was used, with a significance level of 5% for both tests. The comparisons for the variables which is normal were performed using the

Bonferroni test.

For the normal variables, the statistical power of the results given the sample size was calculated, with a high power defined as 0.8 or above.

Results

The sociodemographic and clinical characteristics of the sample of the present study are presented in Table 1. The independent t test revealed no significant differences between the groups with respect to age ($p = 0.301$) or body mass index ($p = 0.707$). The chi-squared test revealed no significant differences with respect to sex ($p = 0.426$), physical activity ($p = 0.721$), smoking ($p = 0.146$), or

Table 1. Socio- Demographic Characteristics of Study Participants

Characteristics	Cancer Group (n = 19)	Control Group (n = 19)
Age (years)	61.46 ± 8.79	57.62 ± 7.57
Body Mass Index	28.36 ± 4.94	28.06 ± 3.74
Sex		
Male- n (%)	3 (15.79)	5 (26.32)
Female- n (%)	16 (84.21)	14 (73.68)
Cancer diagnosis (months)	49.78 ± 39.40	
Performs physical activity- n(%)	5 (26.32)	6 (31.58)
Smoking- n (%)	0	2 (10.52)
Alcoholism- n (%)	0	1 (5.26)
Cancer diagnosis site- n (%)		
Gastrointestinal tract	2 (10.52)	
Breast	9 (47.37)	
Abdomino-pelvic	1 (5.26)	
Ovary	2 (10.52)	
Uterus	2 (10.52)	
Prostate	2 (10.52)	
Oropharynx	2 (10.52)	
Stage- n (%)		
0	0	
I	3 (15.79)	
II	9 (47.37)	
III	2 (10.52)	
IV	0	
No data	5 (26.32)	
Chemotherapeutic drug- n (%)		
Antibiotics	1 (11.1)	
Platinum	2 (22.2)	
Taxanes	6 (66.7)	
Types of treatment performed-n (%)		
Just surgery	1 (5.26)	
Just chemotherapy	0	
Just radiotherapy	2 (10.52)	
Surgery and chemotherapy	4 (21.05)	
Surgery and radiotherapy	1 (5.26)	
Chamotherapy and radiotherapy	1 (5.26)	
All	10 (52.65)	

Mean ± standard deviation; % , percentages; n, number of members.

Table 2. Comparative Analysis of Scores (mean ± Standard Deviation) Obtained in the Fatigue Subscale and FACIT-F Questionnaire of Cancer and Control Groups at the Moments of Evaluation

Variables	Groups	Evaluation 1	Evaluation 2	Evaluation 3	P (G*E)	P (E)
Fatigue Subscale	Cancer	40.26 ± 6.69 ^{&}	44.10 ± 7.75 [*]	44.36 ± 8.13 [*]	0.003	0.001
	Control	48.05 ± 4.45	48.05 ± 4.33	48.10 ± 4.34		
FACIT-F	Cancer	117.04 ± 23.74 ^{&}	124.58 ± 27.36 ^{&*}	127.45 ± 28.02 ^{&#}	0.001	0.001
	Control	145.31 ± 10.58	146.94 ± 9.47	146.68 ± 9.30		

Intragroups: Wilcoxon test – *vs. evaluation 1; # vs. evaluation 2; p < 0.05; Intergroups, Mann Whitney U test – & vs. control; p < 0.05; G*E, Friedman test two factors (groups and evaluations); E, Friedman test with evaluation factor

Table 3. Comparative Analysis of the Median Frequency Values (Hz) (Mean ± Standard Deviation) of the Mean of Deltoid Muscles of the Cancer and Control Groups at the Moments of Evaluation

Groups	Evaluation 1	Evaluation 2	Evaluation 3	P (G*E)	Power	P (E)	Power	P (G)	Power
R Cancer	59.12 ± 14.07 ^{&} (52.34–65.91)	59.61 ± 14.07 ^{&} (53.10–66.12)	62.38 ± 13.29 ^{&#} (55.97–68.79)	0.523	0.156	0.013	0.765	0.005	0.825
	Control	69.41 ± 8.27 (65.42–73.40)	70.82 ± 7.64 (67.13–74.50)						
L Cancer	60.98 ± 13.89 ^{&} (54.28–67.68)	63.57 ± 14.09 (56.77–70.36)	64.48 ± 12.92 ^{&} (58.26–70.71)	0.204	0.332	0.198	0.338	0.017	0.684
	Control	71.85 ± 8.45 (67.78–75.92)	70.68 ± 8.21 (66.72–74.64)						

R, Right; L, Left; G*E, ANOVA groups and evaluation factors; E, ANOVA evaluation factor; G, ANOVA group factor; Bonferroni – # vs. Evaluation 2; & vs. control; p < 0.05

alcoholism (p = 0.311).

The fatigue subscale scores and the FACIT-F scores are described in Table 2. The cancer group obtained lower fatigue subscale scores relative to the control during the initial evaluation (p = 0.001). There was a statistically significant increase in the cancer group for the fatigue subscale, when the scores between the first evaluation and the two subsequent ones were compared (evaluation 1 vs. 2: p = 0.003; evaluation 1 vs. 3: p = 0.003). For the FACIT-F score, the cancer group had statistically lower values than those in the control group in all evaluations (evaluation 1: p = 0.001; evaluation 2: p = 0.002; evaluation 3: p = 0.007), although the FACIT-F score of the cancer group increased from the first to the two following evaluations (evaluation 1 vs. 2: p = 0.005; evaluation 1 vs. 3: p = 0.003) and from the second to the last evaluation (evaluation 2 vs. 3: p = 0.04).

Table 3 shows the mean values and standard deviations of bilateral middle deltoid muscle performance of the cancer and control groups at the evaluation moments. Among the groups, it is possible to observe lower values of the median frequency of the cancer group compared with the control group in all evaluations for the right upper limb, and in the first and last evaluation for the upper left limb. In addition, for the cancer group, an increase in the median frequency from the second to the last evaluation was observed in the right upper limb.

Discussion

Perceived fatigue and quality of life are important for comparative analysis of the effects of treatments on cancer patients. These factors can help in making decisions about

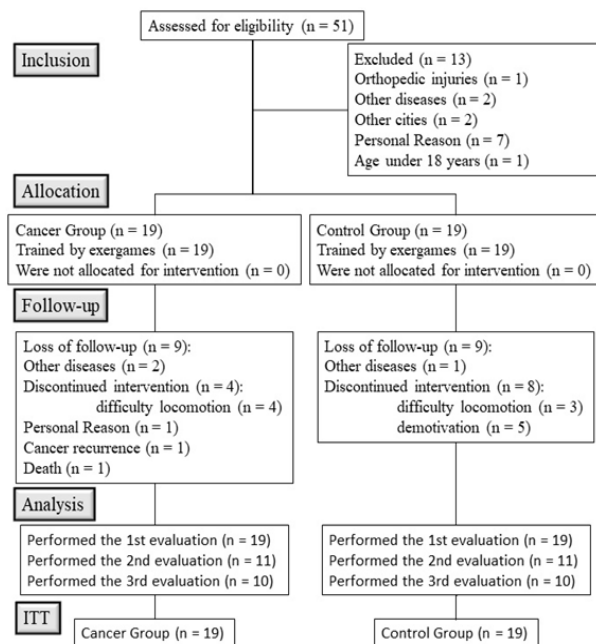


Figure 1. Study design

continuity and future treatments, in addition to possible palliative care (Yellen et al., 1997).

People diagnosed with cancer who undergo chemotherapy, radiotherapy, and/or surgery have higher rates of perceived fatigue during and after treatment (Curt et al., 2000; Rubin et al., 2004). In the present study, most of the participants with cancer underwent these procedures together and initially presented a lower score for the fatigue subscale and for the FACIT-F questionnaire,

demonstrating a higher level of fatigue, lower level of function and ability to perform activities of daily living in this group.

In general, aging results in deterioration of the physiological systems. In a study involving young women affected by cancer, they show a greater presence of fatigue when compared to older women regardless of the type of cancer (Smith et al., 2013, Sekse et al., 2015).

In another study, women surviving from breast cancer have a correlation between age and the presence of fatigue. In our study, these variables were not correlated, since it was not the purpose of the study (Tabrizi, Alizadeh, 2017). However, we believe that due to the fact that the volunteers have adult characteristics, they could even report a greater presence of fatigue independently from the presence of cancer, but this would not influence the results of the study since the age profile between the groups does not show a significant statistical difference.

After the exergaming protocol, the FACIT-F scores increased significantly at the end of the evaluations, suggesting an improvement in the symptoms of fatigue and in the function and activities of daily living. These findings are similar to those of other authors, who demonstrate an increase in FACIT-F score after aerobic exercise in people with cancer diagnosis (Cramp and Byron-Daniel, 2012; Meneses-Echávez et al., 2015). However, previous studies did not use devices that encourage physical activity in a virtual way. It was also observed that the volunteers with cancer had significantly lower mean bilateral frequency values than the control, also consistent with the literature (Yavuzsen et al., 2009), which demonstrates the influence of the peripheral nervous system on the fatigue mechanism as evaluated in another muscle group (Alves et al., 2017). The pattern of muscle fiber distribution of the deltoid also makes it more susceptible to metabolic changes derived from a constant muscle contraction period, contributing to changes in the electromyographic signal spectrum (Bouissou et al., 1985; Stallknecht et al., 1998; Komi and Tesch, 1979).

There was an increase in the median frequency values of the last evaluation of the right middle deltoid muscle in relation to the previous evaluation, a fact that did not occur in the other limbs. One factor that may have influenced this response is muscle memory. Muscle cells maintain their nuclei even after disuse atrophy, favoring muscle recovery according to its previous characteristics after the resumption of stimulus (Bruusgaard and Gundersen, 2008; Bruusgaard et al., 2010; Bruusgaard et al., 2012). This could correspond to a faster response of the muscles of the dominant limb to the activity promoted by the exergame; the non-dominant limb could require more stimulation to obtain the same result. However, dominance was not measured in the present study. Perelle and Ehrman (1994) showed that the majority of the population had right-side dominance.

Exergaming consists of controlled physical activity that motivates patients and promotes increased intensity without perceived exertion (Kho et al., 2012; Schneider and Hood, 2007). With improved physical abilities and reduced fatigue symptoms, quality of life tends to improve among the cancer group in this study (Cramp and

Byron-Daniel, 2012). However, despite the improvement in the FACIT-F result, the cancer group did not reach scores similar to those in the control group. It is possible that the offered stimulus may not produce effects similar to the practice of other physical activity modalities (Comello et al., 2016).

Therapy with the use of videogames has the advantage of distracting the patient, thus reducing anxiety and pain levels and encouraging greater treatment adherence (Leutwyler et al., 2014; Chirico et al., 2016). Because exergaming is pleasurable, there is less perception of effort and time required for task accomplishment. In addition, exergaming incentivizes users to increase the intensity of the exercise to achieve higher scores in the game (Kho et al., 2012; Schneider and Hood, 2007). The improvement in the variables evaluated after the exergaming protocol demonstrates that this is a valid way to improve deltoid muscle activation, as well as to reduce self-reported fatigue and improve quality of life in cancer patients, suggesting that the practice of exergaming may be a viable and reliable alternative in the clinical setting.

The study has some limitations, among them the fact that we did not control for possible etiology of fatigue symptoms, such as changes in hematological factors.

Because the study did not take place in a center for the treatment of cancer, there was great difficulty in obtaining a satisfactory sample, which could influence the results. This explains the heterogeneity of cancers obtained in the cancer group, as well as the types of treatment that participants underwent.

In addition, an analysis of intensity of physical activity during exergaming practice could have been used to monitor volunteers' responses to the effort. Future studies will be needed to better elucidate these still-obscure issues.

The protocol of 20 exergaming sessions used in this study changed the perception of reported symptoms of fatigue, increasing the perceived quality of life, and improving the MDF values in cancer patients, regardless of the stage of the treatment. This therapeutic tool was effective to restore the differences initially found in the perception of fatigue and the patterns of the deltoid muscle contraction between cancer and control groups. This is important because the practice of exergames is relatively inexpensive and easy to use and may be a valid alternative for the treatment of CRF.

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Trial registration

Registry of Clinical Trials Platform (RBR-9t48g5).

Statement conflict of Interest

The authors declare that they have no competing interests.

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