Rehabilitacja Medyczna (Med Rehabil) 2017; 21 (2): 10-18 DOI: 10.5604/01.3001.0010.5003 eISSN 1896-3250

Comparative effects of burst mode alternating current and resisted exercise on physical function, pain intensity and quadriceps strength among patients with primary knee osteoarthritis

Porównanie wpływu prądów Kotza oraz ćwiczeń oporowych na sprawność fizyczną, intensywność bólu i siłę mięśnia czworogłowego uda u pacjentów cierpiących na osteoartrozę pierwotną stawu kolanowego

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Key words
primary knee osteoarthritis, burst mode alternating current, resisted exercise

Abstract
Background and objective: The beneficial effect of Resisted Exercise (RE) in Knee Osteoarthritis (OA) rehabilitation is often hamstrung by the presence of other comorbidities affecting exercise implementation, hence the need for comparative alternative therapies. This study compared the effect of Burst Mode Alternating Current (BMAC) and RE in the management of patients with knee OA.
Methods: Forty-seven consenting patients with primary knee OA participated in this study. The participants were recruited from the outpatient physiotherapy department of a Nigerian teaching hospital. The participants were randomly assigned into either RE plus BMAC (RBMAC) or RE Only (REO) groups. The effects of intervention were assessed in terms of physical function, pain intensity and quadriceps strength at the 4th and 8th week of intervention. Descriptive and inferential statistics were used to analyze data at $p<0.05$ alpha level.
Result: RBMAC and REO led to significant mean changes in physical function (RBMAC – $p=0.001$: REO – $p=0.001$), pain intensity (RBMAC – $p=0.001$: REO – $p=0.001$), and muscle strength (RBMAC – $p=0.001$: REO – $p=0.001$) scores. However, there was no significant difference in the mean change in physical function, pain intensity or muscle strength scores between RE plus BMAC and RE only groups ($p>0.05$).
Conclusion: In conclusion, resisted exercise alone had significant effects on physical function, pain intensity and quadriceps strength in patients with knee osteoarthritis. However, burst mode alternating current did not show additional effects.

Słowa kluczowe
osteoartroza pierwotna stawu kolanowego, prądy Kotza, ćwiczenia oporowe

Streszczenie
Cel pracy: Pozytywny wpływ ćwiczeń oporowych (ang. *Resisted Exercise*, RE) w przypadkach rehabilitacji osteoartrozy stawu kolanowego (ang. *Knee Osteoarthritis*, OA) bywa często ograniczany przez choroby współistniejące, które wywierają wpływ na wykonanie ćwiczeń, stąd potrzeba stosowania porównywalnych alternatywnych terapii. W niniejszej pracy porównano wpływ prądów Kotza (ang. *Burst Mode Alternating Current*, BMAC) i ćwiczeń oporowych na leczenie pacjentów cierpiących na osteoartrozę stawu kolanowego.

The individual authors contributed to this paper in the following way: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

Received: 20.03.2017; accepted: 10.09. 2017

Please cite: Omole J.O., Egwu M.O., Mbada Ch.E., Awotidebe T.O., Onigbinde A.T. Comparative effects of burst mode alternating current and resisted exercise on physical function, pain intensity and quadriceps strength among patients with primary knee osteoarthritis. Med Rehabil 2017; 21 (2): 10-18. DOI: 10.5604/01.3001.0010.5003

Internet version (original): www.rehmed.pl

Metody: W badaniu wzięło udział czterdziestu siedmiu pacjentów z pierwotną postacią OA. Uczestnicy zostali wybrani spośród osób leczonych ambulatoryjnie na oddziale fizjoterapii nigeryjskiego szpitala klinicznego. Zostali oni losowo przydzieleni do jednej z grup, której: 1) zalecono ćwiczenia oporowe plus prądy Kotza (RE + BMAC, RBMAC) lub 2) aplikowano jedynie ćwiczenia oporowe (RE Only, REO). Efekty interwencji oceniane były ze względu na sprawność fizyczną badanych, intensywność bólu oraz siłę mięśnia czworogłowego uda w 4. i 8. tygodniu badania. Za pomocą narzędzi statystyki opisowej i inferencyjnej dokonano analizy danych na poziomie $p<0,05$ α.
Wyniki: Terapie RBMAC oraz REO doprowadziły do znaczących średnich zmian w wynikach sprawności fizycznej (RBMAC $p=0,001$; REO $p=0,001$), intensywności bólu (RBMAC $p=0,001$; REO $p=0,001$), i siły mięśni (RBMAC $p=0,001$; REO $p=0,001$). Odnotowano jednak brak znaczącej różnicy w zakresie średniej zmiany wyników sprawności fizycznej, intensywności bólu i siły mięśni pomiędzy grupami RBMAC i REO ($p>0,05$).
Wnioski: Stwierdzono znaczący wpływ ćwiczeń oporowych na sprawność fizyczną, intensywność bólu i siłę mięśnia czworogłowego uda u pacjentów cierpiących na osteoartrozę stawu kolanowego. Działanie prądami Kotza nie wykazało natomiast żadnych dodatkowych efektów.

INTRODUCTION

Osteoarthritis (OA) is a debilitating, progressive disease which is characterized by the degeneration of normal cartilage resulting from a change in matrix composition comprising of collagen and other matrix molecules which leads to a decrease in joint strength and eventually, pathologic changes[1]. The classification of Knee OA is mainly divided into primary or secondary classes[2]. Primary Knee OA, although common, is idiopathic[3]. Identified risk factors include aging and heredity, while secondary OA is caused by other diseases or conditions that trigger the joint degeneration such as trauma, infection, congenital deformity or repetitive motion seen in certain occupations like farming or soccer[3,4]. The frequency of Knee OA increases with age. Females over the age of 50 are more predisposed to knee osteoarthritis than their male counterparts[5]. Thus, the presence of knee OA in individuals usually results in a higher rate of disability and medical services[6].

The earliest symptom of knee OA is pain, which is primarily an intermittent dull aching pain after periods of rest, which later becomes a continuous and cramp like pain occurring after activity[7]. Pain progresses from an acute to a chronic form resulting in reduced range of motion and muscle weakness particularly in the quadriceps muscles that results in disabilities, especially in the older age group[8]. Quadriceps weakness places an undue stress across the knee joint and has been confirmed to be related to both etiology and progression of the disease[9].

Many treatment measures have been suggested for an osteoarthritic knee, which includes non-invasive means such as pharmacotherapy and physiotherapy or invasive means like surgery[10]. Physiotherapy has been found to be effective in the management of patients with knee OA[11-13]. Physiotherapy management is aimed at pain reduction, muscle strengthening, increasing joint range of motion, restoration of function, prevention of deformities, to mention but a few[14]. The used approaches range from exercise therapy, electrotherapy, tapping, manual therapy, cryotherapy, foot orthosis, bracing and education on self-care[8,12].

Resisted Exercise (RE) has been reported to significantly reduce pain[15,16], improve physical function[17] and strengthen weak muscles, especially the quadriceps[18,19] in patients with knee OA. RE to the quadriceps has been reported to be beneficial in not just improving muscle strength and reducing pain but also in enhancing physical function and quality of life[20]. This was supported by a systematic review done by Øiestad et al[21]. They concluded that weakness in the knee extensor was associated with an increased risk of developing knee osteoarthritis in both men and women that resulted in decreased lifestyle and physical function. Quadriceps RE of 10 to 15 repetitions, performed five days per week for a length of two weeks has been proven to be effective in muscle strength gain[22].

Despite studies supporting the efficacy of RE in the management of knee OA, controversies on its effectiveness still linger[23,24]. The rigor and safety of the RE training program are discouraging factors for uptaking exercise in OA. Improper execution and negligence of appropriate precaution could also result in injury[25]. Furthermore, most patients are unable to perform the resisted type exercises to a point of benefit due to co-morbidities like high blood pressure or even cardiac disease[26]. Consequently, the inclusion of other interventions as an adjunct to strengthening exercises has been recommended[27,28].

Some authors have advocated for the use of Electrical Muscular Stimulation (EMS) in lieu of RE especially in the face of limiting factors to undertaking resisted exercises[25,28,29,30]. Burst Mode Alternating Current (BMAC) was first used by Kots in 1976 to strengthen the muscles of athletes, and he reported a 40% increase in force gain in the quadriceps. BMAC has been reported to be effective in pain control[29,31] and improving physical function[32,33]. However, not many studies have been conducted on BMAC in the management of patients with knee OA, while the available results present varying conclusions[28,34,35,36].

Therefore, the objective of this study was to compare the effect of BMAC and RE in the management of patients with knee OA.

MATERIALS AND METHOD

Participants

The participants of this study were 47 patients referred from the orthopaedic clinic to the physiotherapy department of the Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC), Ile-Ife and Ilesha Units, with a physician diagnosis of primary OA of the knee joint. Eligibility for inclusion were

having a grade III knee OA according to the Kellgren and Lawrence classification; unilateral or bilateral knee OA (as for patients with bilateral knee OA, the more symptomatic knee was included) and being within the age of 40 and 75. Exclusion criteria were: patients with Knee OA resulting from traumatic injury or infection; and those with any recent surgical interventions, metallic implants, any current severe neuromuscular disorders, absolute or uncontrolled cardiovascular contraindications to exercise and patients who have had intra-articular steroid injections to the knee within three months prior to the study.

Instruments

The Western Ontario and McMaster Universities Osteoarthritis Index Physical Function subscale questionnaire (WOMAC-PF), which is a self-administered, valid and reliable questionnaire, was used to assess limitations in physical function. Each item was scored as follows: 0 – none, 1 – mild, 2 – moderate, 3 – severe and 4 – extreme; with the total score ranging from 0 to 68, where higher scores indicate higher level of functional disability[37,38]. The Visual Analogue Scale (VAS) which is a 100 mm straight and horizontal line drawn with the left extreme (mark zero) indicating "no pain" and the right extreme indicating "unbearable pain" was used to assess pain intensity of the participant with knee OA. Participants were requested to mark the line to indicate their level of pain. The VAS is then determined by measuring (in millimeters) from the left extreme of the line to the point marked by the patient. Higher values suggest more intense dull-aching pain. The VAS is a one-dimensional, applicable and dependable instrument[39]. The Pocket Spring Balance Scale, which is a valid and reliable instrument[40,41], is a 100 kg capacity pocket spring balance scale made in China with the model number: NOPS PK-100, and was used to assess isometric quadriceps strength of participants with knee OA in kilogram force. This value was converted to Newtons (N) to have a grade of 0 – 980.665N, (1 kgf = 9.80665N). The stadiometer made by Leaidal Medical Ltd, United Kingdom with the model number: RGZ-160 was used to measure the weight and height of each participant in kilograms and meters, respectively.

Procedure

Ethical approval for the study was obtained from the Ethics and Research Committee of the OAUTHC, Ile-Ife, Nigeria (ERC/2016/09/08). Administrative approval was obtained from the head of Physiotherapy Department, OAUTHC. An informed consent form was used to elicit willingness of the participants in the study.

Participants were consecutively recruited and were randomly assigned into two different treatment groups using a random permuted block of a block size of four using an online program[42]. The first group received standardized RE protocol to the quadriceps of the affected knee joint. The participants in the second group received RE plus BMAC, also to the quadriceps of the affected knee. Treatment was applied twice a week for eight (8) weeks, totaling 16 sessions.

Measurement of physical characteristics

Height – The height was measured in meters (m) to the nearest 0.01 m with the participants standing erect on the stadiometer with their shoes off and the occiput touching the meter rod. The measuring rod was placed at the highest point of the participant's head which is perpendicular to the height meter[43].

Weight – Participant's weight was measured in kilograms (kg) to the nearest 0.1 kg. Participants stood on the stadiometer with their shoes off while wearing light apparel. The reading was recorded while the participant looked forward[43].

Body Mass Index – Participant's body mass index was calculated in kilograms per meter squared (kg/m^2). The participant's appropriate weight in kilograms was divided by the square of the appropriate height in meters. Participants were then classified according to WHO (2000) classifications of BMI values[44,45]. The BMI values are as follows:

- Underweight
  < 18.50 kg/m^2
- Normal
  18.50-24.99 kg/m^2
- Overweight
  25.00-29.99 kg/m^2
- Class I Obesity
  30.00-34.99 kg/m^2
- Class II Obesity
  35.00-39.99 kg/m^2
- Class III Obesity
  40 and above kg/m^2

Resisted exercise intervention

Participants in each group completed three specific non-weight bearing or open chain RE using ankle free weights with the osteoarthritic leg (unilateral knee OA) or the most symptomatic leg (bilateral knee OA). The exercises were:

- Knee extension from a high sitting position – starting position sitting with knee at 90° flexion. The patient was verbally instructed to fully extend the affected leg against the resistance of ankle weights.
- Knee extension with hold at 30° knee flexion from a high sitting position – starting position sitting with knee at 90° flexion, the patient was verbally instructed to extend the affected leg to 30° flexion against the resistance of ankle weights.
- Straight Leg Raise (SLR) – Starting position supine with the affected leg raised to 30° hip flexion against the resistance of ankle weights[46].

The amount of free ankle weights used for each participant was determined using the progressive resistance exercise program based on ten Repetition Maximum (RM) as proposed by Thomas Delorme[47]. A RM is defined as "the greatest amount of weight or load a muscle can move through the full, available range of motion with control a specific number of times before fatigue sets in"[48]. Participants ten RM was determined, recorded and were each instructed

to come back in one week time to commence strength training. Before commencement of the resisted exercises, each participant performed a warm-up exercise by riding on a bicycle ergometer for five minutes. There was no resistance applied to the bicycle ergometer. Participants began their exercise by initially carrying out the first set of 10 repetition at 50% of 10RM, a second set of 10 at 75% of 10RM, and a third set of 10 at 100% of 10RM[47]. The three sets were performed with a rest interval of 120 seconds in-between each set. Each set contained 10 repetitions that were carried out slowly and in a systematic manner. At every possible end range, the position was maintained for five seconds but later increased to 10 seconds. The Valsalva maneuver was discouraged by constantly instructing the participants to continue breathing throughout the phase of the exercise[46,49]. The RE was carried out within tolerable levels of pain[46]. Free ankle weights were progressively increased once it was observed that the quadriceps had adapted to the weights or loads[48].

Burst mode alternating current intervention

In addition to RE, participants in the second group received BMAC stimulation (RE + BMAC) to the quadriceps of the affected or most symptomatic knee joint after resting for a period of 10 minutes following the RE intervention. A Sonopuls 692 electrical stimulation machine made by Enraf-Nonius Company, The Netherlands, with model number: 1600945; was used to stimulate the quadriceps muscles of participants with knee OA in this group. Participants were positioned in a supine lying position during the application of BMAC to the quadriceps muscle of the osteoarthritic or affected knee. Equal paired sized carbon rubber electrodes (8 x 12 cm) were placed on the rectus femoris and vastus medialis muscles, and held with fixation straps. The carbon rubber electrodes were first placed in a moist pad (8 x 12) before placed on the quadriceps. The labile method (also called the bipolar method) of electrode placement was used to stimulate the quadriceps. The stimulation was applied for a duration of 10 minutes using the 10/50/10 regimen – 10 seconds "on" followed by 50 seconds "off" with this sequence repeated for 10min[28,34,50]. A carrier frequency of 2.5kHz alternating sinusoidal waveform current with a burst frequency at 50Hz was used. Participants in the RE + BMAC group had their quadriceps stimulated for 10 minutes twice a week for 8 weeks. The intensity was gradually increased until there was a maximal but tolerable strong contraction of the quadriceps muscles. Any time neural accommodation occurred, the amplitude was further increased to produce a strong contraction but at a comfortable sensory level for each participant[25].

MEASUREMENTS

Physical function

The participants' limitations in physical function were assessed using the WOMAC-PF questionnaire. Each participant was required to fill in the questionnaire (all the three subscales – pain, joint stiffness and physical function) three times: before the treatment intervention began (baseline), at the end of the fourth and eighth week, respectively. Data from the physical function subscale was analyzed.

Pain intensity

The participants' pain intensity was assessed using the Visual Analog Scale (VAS). Participants were asked to objectively rate the severity of their pain (by performing activities that reproduce their pain) and by marking a point on a 100mm straight horizontal line, after explaining to them that the left extreme indicates "no pain at all" and the right extreme indicates "the worst pain ever".

Quadriceps strength

The participants' isometric quadriceps strength was assessed using a pocket spring balance scale. Following the procedure described by Balogun and Onigbinde[40], participants were instructed to sit on a testing table with an adjustable backrest. The participants maintained hip joint at 120° flexion and the knee joint at 60° flexion. An ankle cuff was affixed to the participant's lower leg while the pocket spring balance scale was attached to the base of the testing table so that it (the scale) was perpendicular to the lower leg. Each participant was motivated with the word "PULL" during knee extension. Three trials were carried out but the highest reading was used for data analysis. Maintenance of knee joint angle during the test procedure was achieved by instructing the patient to hold onto the table firmly and not to lift their pelvis off the table[51]. Adequate rest intervals were allowed in between each measurement. Readings from the pocket spring balance scale were measured in kilogram force but this value was converted to Newtons (N) to have a grade of 0 – 980.665N (i.e. 1 kgf = 9.80665N).

Data analysis

Data analysis was performed using the Statistical Program for Social Sciences for Windows version 22 (SPSS Inc., Chicago, Illinois, United States). Testing the normality of data using the Shapiro-Wilk test was executed to isolate outliers. The results of the Shapiro-Wilk test suggested that the dependent variables were normally distributed. Descriptive statistics of means, frequency, standard deviation and percentages were used to summarize data. Inferential statistics of repeated measure of Analysis of Variance (ANOVA) was used to compare physical function, pain intensity and quadriceps strength of each of the two groups across baseline, as well as the 4th and 8th week. Post hoc analysis of Fisher's Least Significant Difference (LSD) was used to identify which pair of means of physical function, pain intensity and quadriceps strength was statistically different in each of the two groups at baseline and the 4th

and 8th week. The Student t-test was used to compare the mean changes in physical function, pain intensity and quadriceps strength between the RE only and the RE + BMAC groups. Alpha level was set at 0.05.

RESULTS

Forty-seven patients with primary knee OA participated in this study. They comprised of 11 males (23.4%) and 36 females (76.6%) with a male to female ratio of 1:3.3. The mean age, weight, height and body mass index of all the participants were the following: 61.34 ±10.60 years, 82.00 ±11.04 kg, 1.60 ±0.08m and 32.81 ±4.91 kg/m^2, respectively. Table 1 shows the independent t-test comparison of the general characteristics of the participants by group. The comparison of the age and anthropometric parameters between the two groups were comparable. Repeated measure of Analysis of Variance (ANOVA) was used to compare the effects of RE only and RE + BMAC on physical function, pain intensity and quadriceps strength across the three time periods (at baseline, 4th and 8th week) as presented in Tables 2-3. The results showed that the RE only group had significant improvement in both physical function (F=111.92; p=0.001) and quadriceps strength (F=100.66; p=0.001), as well as reduction in pain intensity (F=77.79; p=0.001). The results of the RE + BMAC group also showed significant improvement in physical function (F=35.83; p=0.001), quadriceps strength (F=58.63; p=0.001) and reduction in pain intensity (F=168.47; p=0.001). The independent t-test comparison of the effects of the RE only and RE + BMAC groups on physical function, pain intensity and quadriceps strength in the 4th and 8th weeks showed no significant differences between groups in physical function (p>0.05), pain intensity (p>0.05) and quadriceps strength (p>0.05). This is shown in Table 4. Fisher's least significant difference (LSD) post-hoc analysis was used to clarify where the significance values in the F-ratio lie.

DISCUSSION

This study compared the effects of Burst Mode Alternating Current (BMAC) and Resisted Exercise (RE) on physical function, pain intensity and quadriceps strength among patients with primary knee osteoarthritis (OA). The mean age of the study participants was 61.34 ±10.60 years. The age category of participants in this study fell within the age bracket of 40–75 years within which knee OA is prevalent[52,53]. In addition, comparison of the mean ages and anthropometric parameters of the two groups showed no significant differences.

This study showed that Resisted Exercise plus Burst Mode Alternating Current (RE + BMAC) caused significant improvements in both physical function and quadriceps strength, with reduction in pain intensity in participants with knee OA post treatment. These findings are in agreement with previous reports[28,35,54-56]. The inter-group comparison of participants in the RE + BMAC group across the three time periods of this study revealed significant differences in physical function, pain intensity and quadriceps strength. These findings are similar to studies conducted by Heggannavar et al.[28], and Kocaman et al.[55]. BMAC stimulation has been reported to cause an increase in the excitability of spinal routes, changes in the cortical activation pattern and improve the recruitment of fast twitch (fatigable) muscle fibers which are responsible for strength[57,58,59]. In addition, there seem to be some neural adaptations that increase the capacity of voluntary muscle contraction that was impaired in patients with knee OA[60].

The result of this study showed that participants in the Resisted Exercise Group (REG) also had significant improvement in both physical function and quadriceps strength, with reduction in pain intensity post treatment. These findings were in agreement with previous reports[15,18,20]. The inter-group comparison of participants in REG across the three time periods of the study revealed that resisted exercise had significant positive effects on physical function, pain intensity and quadriceps strength. These findings are consistent with previous reports that demonstrated evidence for use of the resisted exercise protocol[16,17,19,61]. This may be explained due to the evidence that joint cartilage positively responds to the stimulation of moderate physical activity[62,63] and that physical activity increases interleukin-10 levels, an anti-inflammatory cytokine, and also

Table 1

Comparison of the general characteristics of the participants in the resisted exercise and resisted exercise plus BMAC groups

Variable	Resisted Exercise Group (n=23)	RE + BMAC Group (n=24)		
	Mean ±*SD*	Mean ±*SD*	*t*-test	*p*-value
Age (years)	63.43 ±10.24	59.33 ±10.77	1.337	0.188
Weight (kg)	83.43 ±11.64	80.63 ±10.50	0.870	0.389
Height (m)	1.58 ±0.08	1.61 ±0.07	1.317	0.194
BMI (kg/m^2)	33.33 ±4.53	31.18 ±4.90	1.550	0.129

Significance level = p<0.05; BMAC – Burst Mode Alternating Current; RE – Resisted Exercise; *SD* – Standard deviation; BMI – Body Mass Index

Table 2

Repeated measure ANOVA comparison of the effects of RE only on physical function, pain intensity and quadriceps strength across the three time periods

Variable	Baseline	4th week	8th week		
	Mean ±*SD*	Mean ±*SD*	Mean ±*SD*	*F*-ratio	*p*-value
P. Function	54.73 ±23.45[a]	39.77 ±26.45[b]	29.75 ±25.06[c]	111.92	0.001*
Pain Intensity	5.96 ±2.03[a]	3.87 ±2.07[b]	2.39 ±1.53[c]	77.79	0.001*
Q. Strength	114.69 ±42.69[a]	141.13 ±44.99[b]	209.08 ±69.42[c]	100.66	0.001*

* Significance level – $p<0.05$; RE – Resisted Exercise; *SD* – Standard Deviation; P. Function – Physical Function; Q. Strength – Quadriceps Strength
Superscripts (a, b, c).
For a particular variable, mode means with different superscript are significantly ($p<0.05$) different. Mode means with the same superscript are not significantly ($p>0.05$) different. In each column, a maximum of three contrasts is possible, when only one contrast is significant, one of the three cell means has no superscript attached. The pair of cell means that is significant, has different superscript.

Table 3

Repeated measure ANOVA comparison of the effects of RE + BMAC on physical function, pain intensity and quadriceps strength across the three time periods

Variable	Baseline	4th week	8th week		
	Mean ±*SD*	Mean ±*SD*	Mean ±*SD*	*F*-ratio	*p*-value
P. Function	51.92 ±24.13[a]	36.33 ±23.10[b]	27.37 ±19.12[c]	35.83	0.001*
Pain Intensity	6.50 ±1.79[a]	4.04 ±1.55[b]	2.33 ±1.34[c]	168.47	0.001*
Q. Strength	93.03 ±32.25[a]	122.00 ±39.86[b]	169.40 ±61.29[c]	58.63	0.001*

* Significance level – $p<0.05$; RE – Resisted Exercise; BMAC – Burst Mode Alternating Current; *SD* – Standard Deviation; P. Function – Physical Function; Q. Strength – Quadriceps Strength
Superscripts (a, b, c).
For a particular variable, mode means with different superscript are significantly ($p<0.05$) different. Mode means with the same superscript are not significantly ($p>0.05$) different. In each column, a maximum of three contrasts is possible, when only one contrast is significant, one of the three cell means has no superscript attached. The pair of cell means that is significant, has different superscript.

Table 4

Independent t-test comparison of physical function, pain intensity and quadriceps strength between RE only and RE + BMAC groups in the 4th week and 8th week

Variable	Resisted Exercise Group (n=23)	Resisted Exercise plus BMAC (n=24)		
	Mean ±*SD*	Mean ±*SD*	*t*-test	*p*-value
		4th week		
P. Function	-14.96 ±6.98	-15.60 ±6.38	0.328	0.744
Pain Intensity	-2.09 ±1.24	-2.46 ±0.78	1.240	0.223
Q. Strength	26.43 ±11.24	26.79 ± 26.47	-0.610	0.952
		8th week		
P. Function	-24.97 ±10.18	-24.55 ±18.28	-0.097	0.923
Pain Intensity	-3.57 ±1.65	-4.17 ±1.49	1.321	0.196
Q. Strength	94.39 ±43.23	77.52 ±57.36	1.135	0.262

* Significance level – $p<0.05$; RE – Resisted Exercise; BMAC – Burst Mode Alternating Current; *SD* – Standard deviation; P. Function – Physical Function; Q. Strength – Quadriceps Strength

reduces levels of the oligomeric protein, a protective marker of cartilage metabolism in the synovial fluid[64,65].

Patients with knee OA usually experience quadriceps weakness which could be due to reflex inhibition in response to pain and joint effusion, disuse, impaired proprioception or loss of mechanical integrity around the knee joint[26]. The increase in pain intensity and loss of physical function usually results in disability, especially in the elderly population. Systematic reviews have shown that resisted exercises not only strengthen the weak quadriceps but also reduce pain intensity and improve physical function[21,66]. Amin et al.[67], reported

that participants having stronger quadriceps have less knee pain and better physical function as compared with those with lesser strength.

The inter-group comparison of participants in the RE + BMACG and REG groups in the 4th week and 8th week post treatment of this study revealed no significant differences in physical function, pain intensity or quadriceps strength. In their studies, Porcari et al.[68], Dehail et al.[69], Taspinar et al.[70] and Vaz et al.[71] concluded that BMAC (electrical stimulation) had no significant or additional effect on muscle strength. Reasons were given for their findings which included insufficient electrically generated contractive force, a quicker rate of muscle fatigue and high levels of discomfort.

In order for the quadriceps to attain an electrically generated contractive force, it must be stimulated above a critical threshold[68]. An electrically induced contraction must be at least 25% to 60% of Maximum Voluntary Isometric Contraction (MVIC) to cause improvement in muscle strength[72,73]. Studies have shown that a 2.5kHz alternating sinusoidal waveform current delivers a higher stimulation frequency than other current types which is responsible for the production of less Maximum Voluntary Isometric Torque (MVIT)[72,74].

Both resisted exercise and burst mode alternating current seems to have the same order of muscle recruitment. Fast glycolytic muscle fibers, which are also large diameter muscle fibers, are recruited first, before the recruitment of the slow oxidative (smaller diameter) muscle fibers[68]. This means that the muscle fatigues more quickly as compared to aerobic or endurance exercise. Despite this, there seems to be a difference in the rate at which muscle fibers become fatigued in both treatment protocols. In resisted exercise, muscle fibers are given ample time to rest and hence, motor units are able to recover and replace used adenosine triphosphate (ATP). In this study, a 120 second rest period in-between resisted exercise was observed. As for the electrically induced muscle contraction, there seems to be evidence that muscle fibers in the RE + BMACG fatigued quicker than those in the REG. This may be due to the selective recruitment of fatigable muscle fiber synchronous stimulation of the same muscle fibers over and over again[68]. Normally, fatigue via the use of BMAC is minimized by using the on:off ratio protocol which was 1:5, that is 10 second contraction, 50 second rest intervals[34]. The fifty seconds of rest period for the muscle fiber to recover may still be small as compared to the 120-second rest period observed during the resisted exercise regime before another round of contraction.

In an attempt to achieve a 10% MIVC, Vaz et al.[71] discovered that BMAC generated a higher discomfort level than the Low-Frequency Pulse Current (LFPC). Hence, a sustained forceful muscle contraction is only possible when patients feel less discomfort during electrically generated contractive force. Laufer and Elboim[75] had reported that maximal discomfort level was achieved between 30% to 38% MIVC. This simply implies that most patients will not yet be able to attain the electrically generated contractive force which is usually 25%-60% MIVC[72,73] needed for effective improvement in muscle strength before unbearable discomfort occurs. Thus, when considering strength, fatigue and comfort together, BMAC seems to be at a disadvantage[75]. Participants in the RE + BMACG complained of discomfort, and most were unwilling to allow any further increase in intensity despite accommodation or adaptation.

CONCLUSION

In conclusion, resisted exercise (using the DeLorme resisted exercise protocol) alone had significant effects on physical function, pain intensity and quadriceps strength in patients with knee osteoarthritis. However, burst mode alternating current did not show additional effects.

Funding: None
Conflict of interest: None declared

Acknowledgments

The authors gratefully acknowledge Prof. Adedoyin R.A. (Head of Department, Medical Rehabilitation, OAU) for his invaluable intellectual contribution to this study. We are also indebted to Dr. Oyelese O.B. (Head of Department, Physiotherapy Department, OAUTHC) for granting us support. Special thanks to Mr. Afolabi O.O and Mrs Arilewola O.A for their assistance in this study.

References

1. Bronner F., Farach-Carson M.C. Bone and Osteoarthritis. 4th ed. Springer. 2007: 5-8.
2. Michael J.W.P., Schluter-Brust K.U., Peer E. The Epidemiology, Etiology, Diagnosis and Treatment of Osteoarthritis of the Knee. Dtsch Arztebl Int 2010; 107(9): 152-162.
3. Clement N.D. Is Osteoarthritis of the knee hereditary? A review of literature. Hereditary Genet 2013; S1:004.
4. Blagojevic M., Jinks C., Jeffery A., Jordan K.P. Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. Osteoarthritis Cartilage 2010; 18(1): 24-33.
5. Heidari B. Knee osteoarthritis prevalence, risk factors, pathogenesis and features: Part 1. Caspian J Intern Med 2011; 2(2): 205-212.
6. Verbrugge L.M. Women, men, and osteoarthritis. Arthritis Care Res 1995; 8(4): 212-220.
7. Maheshwari J. Essential Orthopedics. 4th ed. Jaypee Brothers 2011: 287-289.
8. Nath J. Knee osteoarthritis with special emphasis to physiotherapy treatment focusing various stimulation technique. Int J Sci Res 2015; 5(3): 2250-3153.
9. Heidari B. Knee osteoarthritis diagnosis, treatment and associated factors of progression: part II. Caspian J Intern Med 2011; 2(3): 249-255.
10. Shekhar S.A. The effect of short term dynamic and isometric resistance training in knee osteoarthritis. Indian J Physiothera Occup Ther 2011; 5(1): 5-8.
11. Adegoke B.O.A., Gbeminiyi M.O. Efficacy of ice and shortwave diathermy in the management of osteoarthritis of the knee. Afr J Biomed Res 2004; 7: 107-111.
12. Page C.J., Hinman R.S., Bennell K.L. Physiotherapy management of knee osteoarthritis. Int J Rheum Dis 2011; 14(2): 145-151.
13. Olagbegi O.M., Adegoke B.O.A., Odole A.C. Effectiveness of combined chain exercises on pain and function in patients with knee osteoarthritis. Bangladesh J Med Sci 2016; 15(2): 178.
14. Holtgrefe K., Kisner C. Joint, Connective Tissue and Bone Disorders and management. [In:] Kisner C., Colby LA. Therapeutic Exercises, Foundations and Techniques. 6th Ed. F.A. Davis 2012; 330-350.
15. Burrows N.J., Booth J., Sturnieks D.I., Barry B.K. Acute resistance exercise and pressure pain sensitivity in knee osteoarthritis: a randomized crossover trial. Osteoarthritis Cartilage 2014; 22: 407-414.
16. Henriksen M., Klokker L., Graven-Nielsen T., Bartholdy C., Schjodt J.T., Bandak E., et al. Association of exercise therapy and reduction of pain sensitivity in patient with knee osteoarthritis: a randomized controlled trial. Arthritis Care Res; 2014; 66(12): 1836-1843.
17. Vincent K.R., Vincent H.K. Resistance Exercise for knee Osteoarthritis. PM R 2012; 4(5 Suppl): S45-S52.
18. Bennell K.L., Hinman R.S. A review of the clinical evidence for exercise in osteoarthritis of the hip and knee. J Sci Med Sport 2011; 14(1): 4-9.

19. McQuade K.J., Oliveira A.S. Effects of progressive resistance strength training on knee biomechanics during single leg step-up in persons with mild knee osteoarthritis. Clin Biomech, 2011; 26: 741-748.
20. Pelland L., Brosseau L., Wells G., Macleay L., Lambert J., Lamothe C et al. Efficacy of strengthening exercises for osteoarthritis (part 1): a meta-analysis. Phys Ther 2004; 9(2): 77-108.
21. Øiestad B.E., Juhl C.B., Eitzen I., Thorlund J.B. Knee extensor muscle weakness is a risk factor for development of knee osteoarthritis. A systematic review and meta-analysis. Osteoarthritis Cartilage 2015; 23(2): 171-177.
22. Iwamoto J., Sato Y., Takeda T., Matsumoto J. Effectiveness of exercise for osteoarthritis of the knee: A review of the literature. World J Orthop 2011; 2(5): 37-42.
23. Blackham J., Garry J.P., Cummings D.M., Russell R.G. Does regular exercise reduce the pain and stiffness of osteoarthritis? J Fam Pract 2008; 57(7): 476-477.
24. Villadsen A., Overgaard S., Holmgaard-Larsen A., Christensen R., Roos E.M. Postoperative effects of neuromuscular exercise prior to hip or knee arthroplasty: a randomized controlled trial. Ann Rheum Dis 2014; 73: 1130-1137.
25. Onigbinde A.T., Adeloye O.O., Akindoyin O., Nesto T. Effects of motor-level transcutaneous electrical nerve stimulation on ipsilateral and un-stimulated contralateral. quadriceps femoris. Technol Health Care 2014; 22(5): 759-766.
26. Iversen M.D., Westby M.D. Arthritis. [In:] O'Sullivan S.B., Schmitz T.J., Fulk G.D. (eds.). Physical Rehabilitation. 6th edition. F.A. Davis Company, Philadelphia 2014: 1031-1089.
27. Awotidebe T.O., Babalola J.F., Oladipo O.I., Abass A.O., Mbada C.E., Onigbinde A.T., et al. Comparative efficacy of open kinetic-chain exercise and short-wave diathermy in the management of patients with knee osteoarthritis. Med Sport 2011; 7(3): 1635-1642.
28. Heggannavar A.B., Dharmaya S.R., Nerurkar S.S., Kamble S. Effect of Russian current on quadriceps muscle strength in subjects with primary osteoarthritis of knee: a randomized control trial. Int J Physiother Res 2014; 2(3): 555-560.
29. Ward A.R., Oliver W.G. Comparison of the hypoalgesic efficacy of low-frequency and burst modulated kilohertz frequency currents. Phys Ther 2007; 87(8): 1056-1063.
30. Shapiro S., Ocelnik M. Introduction to Electrical Current. [In:] Cameron M.H. (ed.). Physical Agents in Rehabilitation. Missouri. Saunders-Elsevier 2013: 223-239.
31. Ward A.R., Lucas-Toumbourou S., McCarthy B. A comparison of the analgesic efficacy of medium frequency alternating current and TENS. Physiother 2009; 95: 280-288.
32. Petterson S.C., Mizner R.L., Stevens J.E., Raisis L., Bodenstab A., Newcomb W., et al. Improved function from progressive strengthening interventions after total knee arthroplasty: A randomized clinical trial with an imbedded prospective cohort. Arthritis Rheum 2009; 61(2): 174-183.
33. Avramidis K., Karachalios T., Popotonasios K., Sacorafas D., Papathanasiades A.A., Malizos K.N. Does electric stimulation of the vastus medialis muscle influence rehabilitation after total knee replacement? Orthopedics 2011; 34(3): 175-185.
34. Ward A.R., Shkuratova N. Russian Electrical Stimulation: The early experiments. Phys Ther 2002; 82: 1019-1030.
35. Park S.H., Hwangbo G. Effects of combined application of progressive resistance training and Russian electrical stimulation on quadriceps femoris muscle strength in elderly women with knee osteoarthritis. J Phys Ther Sci 2015; 27(3): 729-731.
36. Zeng C., Li H., Yang T., Deng Z.H., Yang Y., Zhang Y., et al. Electrical stimulation for pain relief in knee osteoarthritis: systematic review and network meta-analysis. Osteoarthritis Cartilage 2015; 23(2): 189-202.
37. Konstantinidis G.A., Aletras V.H., Kanakari K.A., Natsis K., Bellamy N., Niakas D. Comparative validation of the WOMAC osteoarthritis and Lequesne algofunctional indices in Greek patients with hip or knee osteoarthritis. Qual Life Res 2014; 23(2): 539-548.
38. Mahler E., Cuperus N., Bijlsma J., Vliet V.T., Van-den Hoogen F., Den Broeder A.A., et al. Responsiveness of four patient-reported outcome measures to assess physical function in patients with knee osteoarthritis. Scand J Rheumatol 2016; 45(6): 518-527.
39. Olaogun M.O.B., Adedoyin R.A., Anifaloba R.O. Reliability and Concurrent Validity of Visual Analogue Scale and Modified Verbal Rating Scale of Pain Assessment in Adult Patients with Knee Osteoarthritis in Nigeria. S Afr J Physiother 2003; 59(2): 12-15.
40. Balogun J.A., Onigbinde A.T. Hand and leg dominance: Do they really affect limb muscle strength. Physiother Theory Pract 1992; 8: 89-96.
41. Onigbinde A.T., Ajiboye R.A., Bada A.I., Isaac S.O. Inter-limb effects of isometric quadriceps strengthening on untrained contra-lateral homologous muscle of patients with knee osteoarthritis. Technol Health Care 2017; 25(1): 19-27.
42. Sealed Envelope Ltd (2016). Create a block randomization list. Available from: https://www.sealedenvelope.com/simple-Randomizer/v1/list. Accessed on the 30th of October, 2015.
43. Pérez A., GabrielK.P., Nehme E.K., Mandell D.J., Hoelscher D.M. Measuring the bias, precision, accuracy, and validity of self-reported height and weight in assessing overweight and obesity status among adolescents using a surveillance system. Int J Behav Nutr Phys Act, 2015; 12(Suppl 1):S2
44. WHO. Obesity: preventing and managing the global epidemic. Report of a WHO Consultation. WHO Technical Report Series 894. Geneva: World Health Organization, 2000.
45. Al-Shammari S.A., Khoja T., Gad A. Community-based study of obesity among children and adults in Riyadh, Saudi Arabia. Food Nutr Bull 2001; 22(2): 178-183.
46. Bennell K.L., Egerton T., Wrigley T.V., Hodges P.W., Hunt M., Ross E.M., et al. Comparison of neuromuscular and quadriceps strengthening exercise in the treatment of varus misaligned knees with medial knee osteoarthritis: a randomized controlled trial protocol. BMC Musculoskelet Disord 2011; 12: 276.
47. Da Silva D.P., Curty V.M., Areas J.M., Souza S.C., Hackney A.C., Machado M. Comparison of Delorme with Oxford resistance training techniques: Effects of training on muscle damage markers. Biol Sport 2010; 27(2): 77-81.
48. Kisner C., Colby L.A. Resistance Exercise for Impaired Muscle Performance: Therapeutic Exercise – Foundations and Techniques. 6th edition. Davis-Plus 2012: 157-240.
49. Soucek M., Frana P., Kara T., Sitar J., Halamek J., Jurak P., et al. The Effect of Short-term Isometric Muscle Contraction and the Valsalva Maneuver on Systemic and Pulmonary Hemodynamics in Patients with Severe Heart Failure. Clin Cardiol 2009; 32(6): E32-E39.
50. Ward A.R. Electrical stimulation using kilohertz-frequency alternating current. Phys Ther 2009; 89(2): 181-190.
51. Pham H.M., Nguyen N.D., Center J.R., Eisman J.A., Nguyen T.V. Contribution of Quadriceps Weakness to Fragility Fracture: A Prospective Study. J Bone Miner Res 2016; 31(1): 208-214.
52. Zhang Y., Jordan J.M. Epidemiology of osteoarthritis. Clin Geriatr Med 2010; 26: 355-69.
53. Guillemin F., Rat A.C., Mazieres B., Pouchot J., Fautrel B., Euller-Ziegler L., et al. Prevalence of symptomatic hip and knee osteoarthritis: a two-phase population-based survey. Osteoarthritis Cartilage 2011; 19(11): 1314-1322.
54. Talbot L.A., Gaines J.M., Ling S.M., Metter E.J. A home-based protocol of electrical muscle stimulation for quadriceps muscle strength in older adults with osteoarthritis of the knee. J Rheumatol 2003; 30(7): 1571-1578.
55. Kocaman Ö., Koyuncu H., Dinç A., Toros H., Karamehmetolu S. The Comparison of the Effects of Electrical Stimulation and Exercise in the Treatment of Knee Osteoarthritis. Turk J Phys Med Rehab 2008; 54: 54-58.
56. Ahmed A.F. Effect of Modulated Kilohertz Frequency Current on Quadriceps Muscle Activation in Subjects with Knee Osteoarthritis. Bull Fac Ph Th Cairo Univ 2009; 14(2): 45-53.
57. Gondin J., Brocca L., Bellinzona E., D'Antona G., Maffiuletti N.A., Miotti D. et al. Neuromuscular electrical stimulation training induces atypical adaptations of the human skeletal muscle phenotype: a functional and proteomic analysis. J Appl Physiol 2011; 110(2): 433-450.
58. Mang C., Clair J., Collins D. Neuromuscular electrical stimulation has a global effect on corticospinal excitability for leg muscles and a focused effect for hand muscles. Exp Brain Res 2011; 209(3): 355-363.
59. Shin H.K., Cho S.H., Jeon H.S., Lee Y.H., Song J.C., Jang S.H. et al. Cortical effect and functional recovery by the electromyography-triggered neuromuscular stimulation in chronic stroke patients. Neurosci Lett 2008; 442(3): 174-179.
60. Petterson S.C., Barrance P., Buchanan T., Binder-Macleod S., Snyder-Mackler L. Mechanisms underlying quadriceps weakness in knee osteoarthritis. Med Sci Sports Exerc 2008; 40(3): 422-427.
61. Mikesky A.E., Mazzuca S.A., Brandt K.D., Perkins S.M., Damush T., Lane K.A. Effects of strength training on the incidence and progression of knee osteoarthritis. Arthritis Rheum, 2006; 55(5): 690-699.
62. Foley S., Ding C., Cicuttini F., Jones G. Physical activity and knee structural change: a longitudinal study using MRI. Med Sci Sports Exerc, 2007; 39(3): 426-434.
63. Roos E.M., Dahlberg L. Physical activity as medication against arthrosis – training has a positive effect on the cartilage. Lakartidningen 2004; 101(25): 2178-2181.
64. Helmark I.C., Mikkelsen U.R., Borglum J., Rothe A., Petersen M.C.H., Andersen O. Exercise increases interleukin-10 levels both intra-articularly and peri-synovially in patients with knee osteoarthritis: a randomized controlled trial. Arthritis Res Ther 2010; 12(4): R126.
65. Helmark I.C., Petersen M.C., Christensen H.E., Kjaer M., Langberg H. Moderate loading of the human osteoarthritic knee joint leads to lowering of intra-articular cartilage oligomeric matrix protein. Rheumatol Int 2012; 32(4): 1009-1014.
66. Roddy E., Zhang W., Doherty M. Aerobic walking or strengthening exercise for osteoarthritis of the knee? A systematic review. Ann Rheum Dis 2005; 64(4): 544-548.
67. Amin S., Baker K., Niu J., Clancy M., Goggins J., Guermazi A., et al. Quadriceps strength and the risk of cartilage loss and symptom progression in knee osteoarthritis. Arthritis Rheum 2009; 60(1): 189-198.
68. Porcari, J.P., McLean K.P., Foster C., Kernozek T., Crenshaw B., Swenson C. Effects of electrical muscle stimulation on body composition, muscle strength, and physical appearance. J Strength Cond Res 2002; 16(2): 165-172.
69. Dehail P., Duclos C., Barat M. Electrical stimulation and muscle strengthening. Electrostimulation et gain de force musculaire. Ann Readapt Med Phys 2008; 51(6): 441-451.
70. Taspinar F., Aslan U.B., Taspinar B. Evaluating the effects of different strength training techniques on anthropometric structure and endurance of healthy quadriceps femoris muscle. J Med Sci 2011; 11: 274-279.

71. Vaz M.A., Aragão F.A., Boschi E.S., Fortuna R. Melo M.O. Effects of Russian current and low-frequency pulsed current on discomfort level and current amplitude at 10% maximal knee extensor torque. Physiother Theory Pract 2012; 28(8): 617-623.
72. Currier D.P., Mann R. Muscular strength development by electrical stimulation in healthy individuals. Phys Ther 1983; 63(6): 915-921.
73. Alon G., Smith G.V. Tolerance and Conditioning to Neuro-Muscular Electrical Stimulation Within and Between Sessions and Gender. Sports Sci Med 2005; 4(4): 395-405.
74. Stefanovska A., Vodovnik L. Change in muscle force following electrical stimulation. Dependence on stimulation waveform and frequency. Scand J Rehabil Med 1985; 17(3): 141-146.
75. Laufer Y., Elboim M. Effect of burst frequency and duration of kilohertz-frequency alternating currents and of low-frequency pulsed currents on strength of contraction, muscle fatigue, and perceived discomfort. Phys Ther 2008; 88(10): 1167-1176.

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