Original article

Effectiveness of combined chain exercises on pain and function in patients with knee osteoarthritis

Olagbegi OM[1], Adegoke BOA[2], Odole A[2]

Abstract

Objective: This randomized controlled trial was designed to investigate and compare the effectiveness of twelve-week open, closed and combined kinetic-chain exercises (OKCEs, CKCEs and CCEs) on pain and physical function (PF) in the management of knee osteoarthritis. ***Method***: Ninety-six consecutive patients with knee OA were randomly assigned to one of OKCE, CKCE and CCE groups. Participants' average daily pain (ADP), pain before and after walking (PBW and PAW), were evaluated using Visual Analogue Scale while PF was assessed using Ibadan Knee/Hip Osteoarthritis Outcome Measure. ***Results***: Seventy-nine participants completed the study but data of another 4 participants who completed only 8-week treatment were included in data analysis (total=83; mean age = 61.10±13.75 years). The groups' demographic and dependent variables were comparable at baseline but CCE group demonstrated significantly more reductions ($p < 0.05$) in ADP, PBW and PAW than OKCE and CKCE groups at weeks 4, 8 and 12 of the study. However, there were significant within group improvements ($p < 0.05$) in all four variables for the three groups. ***Conclusion***: CCEs are better than OKCEs and CKCEs for pain reduction in though all three exercise regimens are singly effective. CCEs are recommended for improving treatment outcome for pain in patients with knee osteoarthritis.

Keywords: knee osteoarthritis; kinetic-chain exercises; pain; physical function

Bangladesh Journal of Medical Science Vol. 15 No. 02 April'16. Page : 178-188

Introduction

Knee osteoarthritis (OA) is a major public health issue because it causes chronic pain, reduces physical function and diminishes quality of life [1]. Ageing of the population and increased global prevalence of obesity are anticipated to dramatically increase the prevalence of knee OA and its associated impairments[1, 2].The disease imposes a significant healthcare burden and accounts for high annual hospitalizations in the developed world[2, 3, 4, 5].Ultimately, chronic OA of the lower limb joints leads to reduced physical fitness with resultant increased risk of cardio metabolic co-morbidity[6, 7, 8]and early mortality[9].

Osteoarthritis (OA) is characterized by complex multifactorial joint pathology[10]and is the most common form of joint disorder in the world [4].It has been estimated that about 40% to 80% of people with radiographic changes will have symptomatic knee OA which is highly prevalent among older people worldwide (10% to 30%), especially in rural regions, where people are involved in heavy occupational tasks[11]. The prevalence of OA increases with age and majority of individuals over the age of 65 have radiographic and/or clinical evidence of OA[12, 13, 14, 15]. Reports from community and hospital based studies conducted in some geographical sections of Nigeria also suggest considerable number of adult in the country are affected OA[16, 17, 18]although data on general prevalence of OA in Nigeria is scarce.

The knee is the most frequently involved joint in OA[19]. It has been demonstrated that muscle strength and functional capacity are reduced in patients suffering from this disease[20, 21],and the functional consequences of knee OA are associated with lower extremity mobility limitations [22, 23]. Deterioration in quadriceps function may cause impaired balance

1. Oladapo M. Olagbegi, Principal Physiotherapist,
Department of Physiotherapy, Federal Medical Centre, Owo, Ondo State, Nigeria
2. Babatunde O. A.Adegoke
3. AdesolaC. Odole,
Department of Physiotherapy, College of Medicine, University of Ibadan, Nigeria.

Corresponds to: Oladapo Michael Olagbegi, Principal Physiotherapist, Federal Medical Centre, Owo, Ondo State, Nigeria**, E-mail:** olagbegioladapo@yahoo.com

and gait, thus reducing mobility and function in patients with knee OA[24]. Though, pain is the most important symptom that often makes individuals with OA to seek medical attention [25, 26,27],the patient may present with such symptoms as limitation of joint motion, muscle atrophy and weakness, joint instability, progressive functional limitation and associated disability, depending on the severity and stage of the disease[28].

There is no known cure for knee OA but exercise therapy is among the dominant non-pharmacological interventions recommended by international guidelinesfor amelioration of symptoms [1]. Evidence from systematic reviews and meta-analyses of randomized controlled trials have shown that muscle strengthening and aerobic exercises are effective in reducing pain and disability, improving quality of life in patients with mild to moderate OA of the knee[5, 29, 3031, 32, 33].A systematicreview by Lange et al[34]particularly reported that resistance training for patients with knee OAimproved muscle strength and self-reported measures of pain and physical function in over 50–75%of the studies reviewed.

Quadriceps muscle weakness and atrophy have been reported to contribute to functional impairment and pain in patients with knee OA [35]and quadriceps strengthening can be achieved through closed kinetic chain or open kinetic chain exercises (OKCEs or CKCEs)[13, 36]. CKCEs are modeled as closed linkages, in which a movement in a joint simultaneously produces movements in other joints of the extremity while OKCEsisolate one link of the kinetic chain and the distal segment is free to move[13, 37].The two forms of exercises have been shown to be individually effective for improving pain and function in patients with knee OA[38, 39, 40, 41]and there seems no consensus on the comparative efficacy of OKCEs and CKCEs.On the other hand, combined chain exercises (CCEs) have been anecdotally used among physiotherapists but their effects on knee OA have not been reported in literature.This study was hence designed to evaluate and compare the effects of quadriceps strengthening twelve-week OKCEs, CKCEs and CCEs on pain and physical functionin patients with OA of the knee and the following questions were answered:

(1) What would be the effects of a12-week each of open and closed kinetic chain quadriceps strengthening exercises (OKCE) on average daily pain and pain associated with walkingin patients with knee OA?

(2) Would the effects of 12-week OKCEs, CKCEs and CCEs on average daily pain, pain associatedwith walking and physical functionin patients with knee OA be comparable?

Materials and Methods

A-single-blind randomized controlled trial involving patients with knee OA was performed. The study was approved by the Health Research Ethics Committee of the University of Ibadan and University College Hospital (Ref no: UI/EC/13/0013), the permission of the management of the Federal Medical Centre (FMC), Owo, Nigeria was also sought and obtained before the commencement of the study. All participants gave their informed consent before being included. The participants were patients with mild to moderate knee OA attending the Physiotherapy Department, FMC, Owo between January 2013 and December 2014; they have been diagnosed according to the radiographic assessment of their knee joints by the orthopaedic surgeons and family physicians. They were male and females with knee OA of one or both knees with grade IIKell gren and Lawrence classification system based on plain x-rays[42].They also satisfied the American College of Rheumatology Criteria for classification of knee OA [10] and were placed on 3000mg Paracetamol daily.

Patients with knee OA who also had neurological diseases of the lower limb (such as post stroke muscle weakness and poliomyelitis), severe systemic disease such as hypertension, kidney failure and severe diabetic condition, psychiatric disorder, and those unable to walk were excluded from the study [10]

Computer generated random numbers were used to assign participants to one of three intervention groups: Open Kinetic Chain Exercise (OKCE), Closed Kinetic Chain Exercise (CKCE) and Combined Chain Exercise (CCE) Groups (by a physiotherapist who did not partake in assessment and treatment).A minimum sample size of 78 (26 per group was estimated for the study at $\alpha = 0.05$, power = 80% and effect size = 0.8 using the Cohen's table [43]. A total of 105 patients were enrolled in this study. Of these, 9 subjects did not meet the inclusion criteria. The remaining 96 participants were randomly assigned into the three intervention groups. Thirteen participants did not complete the first four weeks of intervention and their data were not included in final analysis. Seventy-nine participants (OKCE = 26, CKCE = 26 and CCE = 27) completed the study; however,

four participants who completed 8weeks of the exercise programmes but dropped out at the ninth week had their data included in the analysis making a total of 83 participants (OKCE = 28, CKCE = 27, CCE = 28). A total of 17.7% (OKCE = 6.25%, CKCE = 6.25%, CCE = 5.20%), attrition rate was hence observed in the study.

Assessment of average daily pain and pain during walking

Visual Analogue Scale (VAS) was used for assessment of pain. Average daily pain (ADP) was assessed by asking the participant to mark the point on the VAS that corresponded to the intensity of the average pain he/she felt every day which was recorded as the participant's average daily pain (ADP)[44, 45]. Pain before walking(PBW)was assessed using VAS at rest before the participants commenced waking on a 50- foot walkway [10]. Pain after walking (PBW) was assessed using VAS immediately after the participant completed walking the 50- foot distance [10].The validated Yoruba version was administered on participants who only understood the local language[46].

Assessment of Physical Function (PF)

The participants completed the self-administered part of Ibadan Knee/Hip Osteoarthritis Outcome Measure (IKHOAM) while the researcher filled the clinician administered section after the participants performed the required physical tasks. The IKHOAM is a scale that assesses PF and treatment outcomes in patients with knee and/or hip OA. It was developed to reflect the Nigerian environment and culture [47] and is a three-part 33 items questionnaire that is both patient (self) and clinician administered, taking approximately 15 minutes to complete. The score range is 0-232; a higher score indicates higher functioning. The sum of scores in all three parts of the questionnaire was converted to a value over 100 using appropriate formula. The IKHOAM is available in English and three main Nigerian languages (Yoruba, Igbo and Hausa), along with evidence of psychometric properties. The Yoruba version which was administered to Yoruba speaking participants was developed and validated to encourage the use of the IKHOAM in Southwestern region of Nigeria[48]. The instrument has been shown to have high validity, reliability and responsiveness in measuring function in Nigerians with knee/hip OA[48, 49, 50, 51].

ADP, PBW, PAW and PF were assessed at baseline and at the end of weeks 4, 8 and 12 of study.

Intervention

Participants were required not to alter their normal activities of daily living or take part in any additional form of physical activity or physiotherapywhile the study lasted.

(1) Open Kinetic Chain Exercise(OKCE) Group

Participants in this group were treated individually and performed the following exercises:

Quadriceps setting

The participant in a supine position isometrically contracted the quadriceps muscle of the affected lower extremity by drawing up his patella while maintaining the knee in extension. He held the contraction for a count of 10, relaxed and repeated the exercise 10 times [13, 52]. This exercise was carried out by the participants throughout the duration of the study.

Straight leg raising (SLR)

The participant in a supine position isometrically contracted his quadriceps (quadriceps setting) and lifted the lower extremity up to achieve about 45° of hip flexion while maintaining the knee in extension. He held the position to a count of 10, and then lowered the limb; repeating the exercise 10 times. The contralateral knee and hip were flexed to about 90^0 and 45° respectively to avoid undue stress on the low back [13]. From third week *SLR with weight* was commenced by strapping an ankle weight equivalent to his/her 10RM to the ankle region, the Participant then lifted the lower extremity to about 45° of hip flexion while maintaining the knee in extension. The contralateral knee and hip were also each flexed to 45°[13, 52].

Full-arc extension

The participant in a high sitting position had a weight corresponding to his 10RM strapped to the leg of the affected lower extremity just above the ankle. The popliteal space was protected with a roll of towel. He then lifted the load slowly through the range of 90° to 0° of knee flexion (full extension). He held the position for a count of 5 and then lowered the load [13]. He/she performed three bouts of ten repetitions of this exercise per session but the foot was rested on a stool between the bouts [13, 52]. This exercise was carried out from the fourth week to the end of the study.

Cycling in the air

The participant in supine lying position on the gym mat raised his legs with the hip joints flexed to about 90 degrees and knees bent to about 90^0 in the air. With slow and steady balance, he then performed the cycling movements of the lower limbs in the air

continuously for a period of two minutes [53]. During the air cycling of the legs, the hands were placed along the sides of the body and resting on the gym mat. This exercise was for the entire twelve week.

(2) Closed Chain Kinetic Chain Exercise Group

Participants in CKCE Group individually underwent the following exercises:

Quadriceps Setting Exercise

The participant sat on a chair with his back supported, knee extended and heel on the floor. The participants then pressed their heel against the floor and thigh against the seat of the chair. The position was held for a count of 10 after which the participant relaxed. The exercise was repeated ten times [13]. This exercise was performed throughout the duration of the study.

Wall slides

In a standing position, the participant positioned his back up against the wall with hips and knees flexed to about 60^0as if he was preparing to sit on a chair[13, 54]. The position was held for 10 seconds, after which the participant returned to the starting position and relaxed for 5 seconds. Ten repetitions of wall slides were carried out per exercise session [55]. From week 3, participants commenced *wall slides with weight* by holding dumbbells in both hands. This was initiated with a weight equivalent to his 10RM and progressed by determining a new 10RM at the beginning of each week of study [52]

Step-up and step-down

The participant performed forward, backward and lateral step-ups and step-downs using a 5cm – high sturdy wooden box [52]. The participant's trunk was kept upright and he/she ensured that his/her heel was the last to leave the floor and the last to return in order to emphasize the activities of the quadriceps muscle [13]. The participant performed 10 repetitions of each component of the exercise. This exercise was carried out during the sixth week of the study only [52]. From week 7, ankle weight was strapped to participants' ankle region for *step-ups and step-downs with weight*[52]

(3) CCE Group

Participants in this group had their exercises individually and went through the following combination of open and closed kinetic chain exercises:

(i) Open kinetic chain exercises: Straight leg raising (SLR) and Full-arc extension.

(ii) Closed kinetic chain exercises: Quadriceps setting and Wall slides

The intensity and progression of exercises for the participants in this group were the same as for OKCE and CKCE groups.

Participants in all three groups progressed weekly by determining a new 10RM at beginning of each week as new weight [52].Exercise training took place thrice weekly for all participants.

Data Analyses

The data were analyzed using SPSS 16.0 version software (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics, repeated measures and one-way ANOVA were used for within and across group comparisons respectively of participants' ADP, PBW, PAW and PF; Paired t test with Bonferroni adjustment of alpha and LSD were respectively used for post-hoc analysis. Level of significance was set at $p = 0.05$ and 0.0125 for across group comparisons and for post-hoc analysis of Repeated Measures ANOVA respectively.

Results

Fifty-one (61.4%) of the participants were females. Their mean age, height, weight and BMI of all the participants were 61.10 $\pm$13.75 years, 1.60 $\pm$ 0.07m, 78.43$\pm$18.34 Kg and 30.62 $\pm$ 8.23 kg/m2 respectively. One way ANOVA indicated that the groups were comparable in their baseline anthropometric and clinical parameters (table 1). Repeated measures ANOVA showed significant difference in ADP, PBW, PAW and PF across the four time points of the study for participants in the OKCE ($p < 0.001$), CKCE ($p < 0.001$), and CCE ($p < 0.01$) groups (table 2). Post hoc analysis using paired t-test with the α-level set at 0.0125 by Bonferroni adjustment indicated significant reduction in ADP among participants in the three groups at all the time frames of the study; however, PBW and PAW were not significantly different for the OKCE group at week0/week4 interval (table 2).One-way ANOVA and Least Significant Difference post-hoc multiple comparison of the participants' treatment outcomes at the four points of the study are presented in table 3.The result indicated that there were significant differences in the groups' mean ADP, PBW and PAW at the end of weeks 4, 8 and 12 of study while the groups' mean PF were comparable at the time points.CKCE group had significantly lower mean PBW than OKCE group at the end of week 8 whileCKCE and CCE groups had significantly lower mean PAW than the OKCE group at the end of week 4 and 8 of study. At the end of week 12, participants in the CCE groups had significantly lower mean PAW than those in either OKCE or CKCE groups while

the CKCE group also had significantly lower mean PAW than OKCE group.The trends of ADP, PBW, PAW and PF across the four time points of the study are presented in figures 1-4.

Discussion

Effects of open, closed and combined chain exercises on average daily pain, pain during gait and function in knee ostearthritis

The significant effects of the three exercise programmes on ADP is consistent with reports from previous studies regarding the effect of muscle strengthening exercise regimens on pain in patients with knee OA [10, 53, 56, 57]. Reduction in pain and consequent improvement in function following quadriceps strengthening exercise have been attributed to increased stability of the knee joint which is enhanced by improvement in quadriceps muscle strength[58, 59].Evidence from literature also suggests that quadriceps strengthening may activate the pain- suppressing β- endorphin system[60], favourably alter sensory input to the central nervous system and the gate control mechanism (regulating pain perception) [61]and as well improve blood flow and cartilage nutrition [62].In a more recent study by Anwer and Alghadir[59], a five -week isometric quadriceps exercise programme brought about a significant reduction in knee pain and improvement in function in the of patients with knee OA; the finding seems to compare favourably with the results of the present study as the three intervention groups in this study had significant reduction in pain as early as fourth week of treatment.

The within-group comparisons conducted revealed that 12 -week OKCEs, CKCEs and CCEs) had significant effects on PBW and PAW from the fourth week of the study. The findings are in agreement with the reports of previous related randomized controlled trials on the effects of strengthening exercises on pain associated with walking in knee OA [10, 63]. Silva et al [10]found a significant reduction in pain before and after 50 –feet walk test for participants who had 18-week water or land based exercises. Jan et al [63]compared eight-week high and low resistance training exercises and observed significant improvements in both groups on pain associated with five activities, namely: walking on level ground, walking up and down stairs, sleeping, sitting and standing. Increase in quadriceps muscle strength induced by quadriceps muscle strengthening exercises and aforementioned resulting improvement in stability of the knee joint might have helped the participants to walk with reduced pain as evidence by the findings of this study.

The three exercise regimens also demonstrated significant effects on physical function scores from the fourth week of the study. Stability of the knee joint which is enhanced by increased quadriceps muscle strength following resistance exercises has been opined to improve function in patients with OA [59]. Similarly, Alnahdi et al [64] in a review of literature also identified muscle strength especially quadriceps as a major determinant of both performance –based and self- reported physical function and further submitted that exercise therapy, including global and targeted resistance training, is

Table 1: Baseline comparison of participants' demographic and clinical variables

	Groups				
	OKCE (n=28)	CKCE (n=27)	CCE (n=28)		
Variable	Mean ± SD	Mean ± SD	Mean ± SD	F-value	p-value
Age (Years)	63.57±14.33	61.19±3.29	58.54±13.62	0.938	0.396
Height (m)	1.61±0.07	1.60±0.08	1.62±0.07	0.774	0.465
Weight (kg)	79.68±21.42	78.93±18.35	76.71±15.29	0.193	0.825
BMI (kg/m^2)	31.13±9.21	31.26±8.54	29.49±6.98	0.396	0.675
ADP	5.05±0.73	5.11±0.83	5.12±0.87	0.047	0.954
PBW	3.54±0.93	3.32±1.10	3.15±1.07	1.016	0.367
PAW	3.54±0.93	3.33±1.10	3.14±1.06	1.015	0.368
PF (%)	75.47±13.07	76.78±14.32	80.96±13.07	1.261	0.289

$p < 0.05$

ADP – average daily pain, PBW – pain before walking, PAW – pain after walking, PF- physical function

Table 2: Repeated measures ANOVA and paired t-test post-hoc multiple comparison of participants' pain intensity and pain before walking, pain after walking and physical function scores across the four time frames of the study.

		Groups		
		OKCE (n=28)	CKCE (n=27)	CCE (n=28)
Variable	Time Frame	Mean±SD	Mean±SD	Mean±SD
ADP	Week 0	5.05 ± 0.73[a]	5.11 ± 0.83[a]	5.12 ± 0.87[a]
	Week 4	4.45 ± 0 .75[b]	4.46 ± 0.90[b]	3.63 ± 1.07[b]
	Week 8	3.99 ± 0.83[c]	3.89 ± 0.97[c]	3.34 ± 0.89[c]
	Week 12	3.34 ± 0.79[d]	3.30 ± 0.83[d]	1.94 ± 1.11[d]
F-ratio		143.074	134.146	182.274
p-value		< 0.001*	< 0.001*	< 0.001*
PBW	Week 0	3.54 ± 0.93[a]	3.32 ± 1.10[a]	3.15 ± 1.07[a]
	Week 4	2.54 ± 0.93[a]	2.32 ± 1.10[b]	1.70 ± 0.96[b]
	Week 8	2.15 ± 0.89[b]	1.49 ± 0.97[c]	0.84 ± 0.75[c]
	Week 12	1.69± 0.88[c]	1.43±0.97[d]	0.48 ± 0.61[d]
F-ratio		232.300	931.198	430.782
p-value		< 0.001*	< 0.001*	< 0.001*
PAW	Week 0	3.54 ± 0.93[a]	3.33 ± 1.10[a]	3.14 ± 1.06[a]
	Week 4	2.64 ± 0.93[a]	2.33± 1.10[b]	1.88±1.00[b]
	Week 8	2.35 ± 0.91[b]	1.49 ± 0.97[c]	1.06 ± 0.74[c]
	Week 12	1.97±0.94[c]	1.44 ± 0.98[d]	0.74 ± 0.65[d]
F-ratio		232.200	931.198	371.952
p-value		< 0.001*	< 0.001*	< 0.001*
PF(%)	Week 0	75.47 ± 13.07[a]	76.78 ± 14.32[a]	80.96 ± 13.07[a]
	Week 4	80.23 ± 12.54[b]	81.24 ± 13.39[b]	83.40 ± 12.47[b]
	Week 8	82.82 ± 12.18[c]	83.98 ± 12.78[c]	86.95 ± 10.92[c]
	Week 12	85.25 ±11.99[d]	86.27 ± 12.29[d]	89.08 ± 10.53[d]
F-ratio		78.000	78.000	78.000
p-value		< 0.001*	< 0.001*	< 0.001*

*indicates significant time point difference at α=0.05

Superscripts (a,b,c,d). For a particular variable, mean values with different superscript are significantly (p<0.05) different. Mean values with same superscripts are not significantly (p>0.05) different.

ADP= pain intensity, PBW = pain before walking, PAW = pain after walking, PF – physical function

effective in reducing pain and improving function in individuals with knee OA. The observed improvement in physical function demonstrated by OKCE, CKCE and CCE groups in this study is in line with the reports of authors who conducted related clinical trials [40, 53, 65, 66]. The similarity between the findings of these researchers and that of the present study may be attributed to significant pain reduction observed in present study which was also reported by these authors; a significant inverse relationship between pain and physical function has been previously reported in literature [67]. Despite differences in sample sizes and duration of treatment among the aforementioned studies; the strength training protocols were commonly progressive in nature as in the present study.

Comparative effectiveness of open, closed and combined chain exercises on average daily pain, pain during walking and function

The three groups were comparable at baseline in their anthropometric and clinical variables; hence, any subsequent difference between them can be attributed to the difference in the effects of the interventions. The combined chain exercise (CCE)

Table 3:Across groupcomparison of participants' pain and physical function scores at baseline and at the end of weeks 4, 8 and 12 of the study

Variable	Time Frame	Groups OKCE (n=28) Mean±SD	CKCE (n=27) Mean±SD	CCE (n=28) Mean±SD	p-value
ADP	Baseline	5.05 ± 0.73	5.11 ± 0.83	5.12 ± 0.87	0.954
	Week 4	4.45 ± 0 .75[a]	4.46 ± 0.90[a]	3.63 ± 1.07[b]	0.001*
	Week 8	3.99 ± 0.83[a]	3.89 ± 0.97[a]	3.34 ± 0.89[b]	0.017*
	Week 12	3.34 ± 0.79[a]	3.30 ± 0.83[a]	1.94 ± 1.11[b]	< 0.001*
PBW	Baseline	3.54 ± 0.93	3.32 ± 1.10	3.15 ± 1.07	0.367
	Week 4	2.54 ± 0 .93[a]	2.32 ± 1.10[a]	1.70 ± 0.96[b]	0.007*
	Week 8	2.15 ± 0.89[a]	1.49 ± 0.97[a]	0.84 ± 0.75[b]	0.001*
	Week 12	1.69± 0.88[a]	1.43±0.97[a]	0.48 ± 0.61[b]	< 0.001*
PAW	Baseline	3.54 ± 0.93	3.33 ± 1.10	3.14 ± 1.06	0.368
	Week 4	2.64 ± 0.93[a]	2.33± 1.10[b]	1.88±1.00[b]	0.022*
	Week 8	2.35 ± 0.91[a]	1.49 ± 0.97[b]	1.06 ± 0.74[b]	0.001*
	Week 12	1.97±0.94[a]	1.44 ± 0.98[b]	0.74 ± 0.65[c]	< 0.001*
PF(%)	Baseline	75.47 ± 13.07	76.78 ± 14.32	80.96 ± 13.07	0.289
	Week 4	80.23 ± 12.54	81.24 ± 13.39	83.40 ± 12.47	0.642
	Week 8	82.82 ± 12.18	83.98 ± 12.78	86.95 ± 10.92	0.418
	Week 12	85.25 ±11.99	86.27 ± 12.29	89.08 ± 10.53	0.498

SD – standard deviation
*indicates significant difference at α=0.05
Superscripts (a,b,c).
For a particular variable, mean values with different superscript are significantly ($p<0.05$) different.
Mean values with same superscripts are not significantly ($p>0.05$) different.
ADP - average daily pain, PBW - pain before walking, PAW - pain after walking, PF – physical funct

group had significantly more reduction in ADP, PBW and PAW at the end of the fourth, eighth, and twelfth weeks of the study.

From this result, it seems CCEs are more effective than either OKCEs or CKCEs for pain relief in patients with knee OA. Alghamdi et al [68] in a review of literature advocated for the use of CCEs submitting that clinicians should not discard CKCEs in the management of knee OA because of the concerns of the possibility that CKCEs induce wear and tear of joint cartilage which might accelerate disease progression.

Alghamdi and his colleagues [68]submitted further that the use of OKCEs alone in managing knee OA compromises the specificity and selectivity principles of training which state that optimal gains in a motor activity are made when the exercise most closely resembles the activity [13,68]. Some other researchers have earlier opined that exercise intervention for OA should involve considerations of joint stability, joint motion, joint effusion, synovial fluid level, position sense, balance, and conduct of daily activities [69, 70, 71]. Improvements in daily function would be best served by exercise resembling the daily activity [68]. The specificity of such exercises (OKCE) must also be geared toward mainly strengthening instead of improving a specific functional activity; while issues relating to exercise extend beyond simple consideration of cartilage wear and tear. The superiority of combined CCE exercises over CKCE and OKCE exercises in terms of reduction of average daily pain and pain associated with walking of participants in this present study may be evidence in support of such viewpoints.

Studies on the effectiveness of CCEs in the management of knee OA are rather scarce, though they have been anecdotally used among

Nigerian Physiotherapists, the effectiveness of such intervention in some related knee pathologies such as post anterior cruciate ligament (ACL) reconstruction [72] and patellofemoral pain syndrome (PPS) [73] have been reported in literature. The findings of this study regarding significantly more reduction in pain for the CCE group appears consistent with the reports of Minoonejad et al [73] who also reported significantly more reduction in pain intensity for participants with PPS in the CCE group than the controls although the extent to which their findings can be compared with the results of this study is limited because the controlsdid not undergo any exercise training. Mikkelsen et al [72] found that addition of isokinetic OKCEs to CKCEs for one study group at the sixth week after both groups commenced CKCEs produced significantly higher isokinetic quadriceps strength than the group that had CKCEs alone; their finding are not really comparable with that of this study because pain was not assessed by Mikkelsen et al[72]

Unlike CCEs, the comparative effects of OKCE and CKCE exercises on pain in knee OA have been largely studied in the past two decades [38, 39, 40, 41, 52, 63, 65]although some of the authors did not report significant difference in the effect s of OKCEs and CKCEs. The result of this study on ADP is hence consistent with the reports of this aforementioned authors. CKCE group had significantly lower PAW than OKCE group at the end of weeks 4, 8 and 12 of this study. It has been opined that CKCEs resemble functional activities [13, 37] and constitute about 65% of human gait[74], this may have accounted for the observed difference since walking a form of functional activity.

Clinical Implication of Study

The study's outcome indicated that OKCEs, CKCEs and CCEs are all effective for improving treatment outcomes for average daily pain and pain during walking and physical function in patients with knee OA. However, CCEs are more effective than OKCEs and CKCEs on three of the four tested variables. Addition of CKCEs to the more popular OKCEs in the management of patients with knee OA may help physiotherapists to achieve better treatment outcome for pain and consequent reduction in disability. Specifically, the study has demonstrated the effectiveness of CCEs for pain reduction in patients with knee OA and pain has been identified as the major reason why

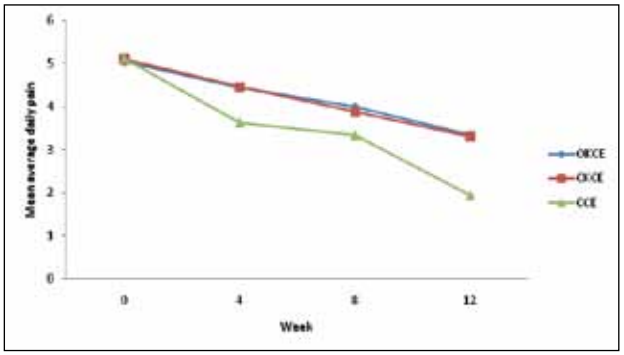

Figure 1: Trends of average daily pain for the OKCE, CKCE and CCE groups at the 4 time points of the study.

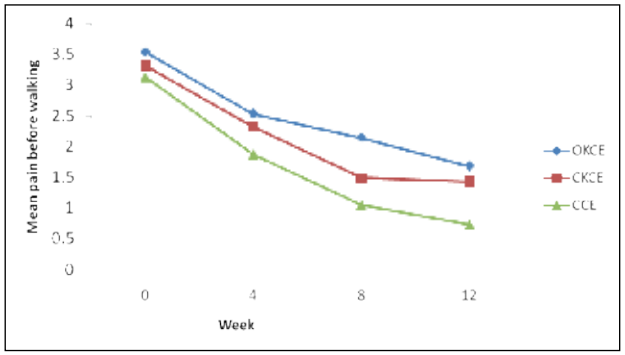

Figure 2: Trends of pain before walking for the OKCE, CKCE and CCE groups at the 4 time points of the study.

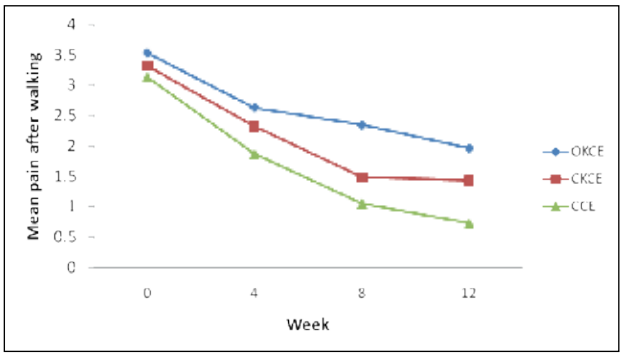

Figure 3: Trends of pain after walking for the OKCE, CKCE and CCE groups at the 4 time points of the study.

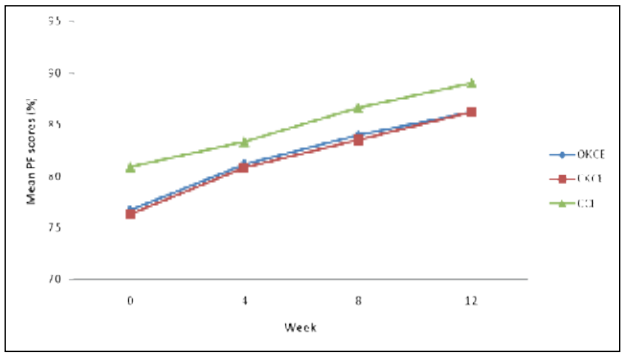

Figure 4: Trends of physical function scores for the OKCE, CKCE and CCE groups at the 4 time points of the study.

this category of patients seek medical assistance[27].

Conclusion

The findings of this study have shown that OKCEs, CKCEs and CCEs are all effective for reducing painand disability in patients with knee OA but CCEs are more effective than either CKCEs or OKCEs for pain relief while CKCEs are more effective than OKCEs for reducing pain during walking.Physiotherapists are encouraged by the findings from this study to combine open and closed kinetic chain exercises for pain relief and improvement of function in patients with mild to moderate OA. Future studies should investigate the effects of combined chain exercises on other clinical and psychosocial variables in knee OA.The efficacy of CCEs in osteoarthritis of other joints such as the hip may also be investigated.

Authors' contributions

O.M.O. and B.O.A.A. were involved in the acquisition of the data, conceptualisation of the study, statistical analyses, and drafting ofthe manuscript; A.C.O reviewed the data analysis results, drafted the manuscript, and critically revised the manuscript. All authors read and approved the final version of the manuscript.

Conflicts of interest

The authors declare that they have no competing interests.

Funding/support

This project was fully funded by the authors.

Acknowledgements

The authors acknowledge the technical support received from postgraduate lecturers at the Department of Physiotherapy, University of Ibadan, Ibadan, Nigeria. The authors also acknowledge all the staff of the Department of Physiotherapy, Federal Medical Centre, Owo, OndoState, Nigeria. They also acknowledge the physicians at the Department of Family Medicine, Federal Medical Centre, Owo for their role in recruiting of participants for the study.

References

1. Fransen M, McConnell S, Harmer AR, Van der Esch M, Simic M, Bennell KL. Exercise for osteoarthritis of the knee. *Cochrane Database of Systematic Reviews*.2015: Issue 1. Art. No: CD004376. DOI: 10.1002/14651858. CD004376.pub3.

2. Zhang Y,Jordan JM.Epidemiology of Osteoarthritis. *ClinGeriatr Med*.2010**: 26(**3): 355–369

3. Roddy E, Zhang W, Doherty M, Arden NK, Barlow J, Birrell F, Carr A, Chakravarty K, Dickson J, Hay E, Hosie G, Hurley M, Jordan KM, McCarthy C, McMurdo M, Mocket TS, O'Reilly S, PeatG, Pendleton A, Richards S. Evidence based recommendations for the role of exercise in the management of osteoarthritis of the hip or knee- the MOVE consensus. *Rheumatology* 2005:**44**(1): 67-73

4. Arden N,Nevitt MC. Osteoarthritis epidemiology. *Best Pract Res ClinRheumatol*.2006: **20**(1):3-25.

5. Bennell KL,Hinman RS. The role of resistance training in the management of knee osteoarthritis. *EurMusculoskelet Rev*.2011: 6.1: 10-3.

6. Minor MA, Hewett JE, Webel RR, Dreisinger TE, Kay DR. Exercise tolerance and disease related measures in patients with rheumatoid arthritis and osteoarthritis. *J Rheumatol*.1988: **15**:905–11.

7. Philbin EF, Groff GD, Ries MD, Miller TE. Cardiovascular fitness and health in patients with end-stage osteoarthritis. *Arthritis Rheum*.1995:**38**:799–805.

8. Nielen MM, van Sijl AM, Peters MJ, Verheij RA, Schellevis FG, Nurmohamed MT. Cardiovascular disease prevalence in patients with inflammatory arthritis, diabetes mellitus and osteoarthritis: a cross-sectional study in primary care. *BMC MusculoskeletDisord*.2013: **13**: 150.

9. Hochberg MC. Mortality in osteoarthritis. *ClinExpRheumatol*. 2008: **26**:S120–4.

10. Silva LE, Valim V, Pessanha APC, Oliveira LM, Myamoto S, Jones A,Natour J. Hydrotherapy versus conventional land-based exercise for the management of patients with osteoarthritis of the knee: A randomized clinical trial. *PhysTher*.2008: **88**: 12-21

11. Busija L, Bridgett L, Williams S, Osborne R, Buchbinder R, March L, et al.Burden of musculoskeletal conditions: osteoarthritis. *Best Pract Res ClinRheumatol* 2010: 24:757–69.

12. Goldring SR,Goldring, MB.Clinical aspects, pathology and pathophysiology of osteoarthritis. *JMusculoskelet Neuronal Interact* 2006: 6(4): 376-378.

13. Kisner C, Colby LA. *Therapeutic Exercises: Foundations and Techniques*. Philadelphia, F.A. Davis Company 2007: pp314-316, 475-476.

14. Cooper C. Osteoarthritis: epidemiology and classification. In Hochberg M (ed). *Rheumatology* 2003: 3rd ed. Mosby pp1781-1783

15. Hasan M. and Shuckett R. Clinical features and pathogenetic mechanisms of osteoarthritis of the hip and knee. *BCMJ* 2010;***52****(8): 393-398*

16. Akinpelu AO, Alonge OO,Adekanla BA,Odole AC.Pattern of osteoarthritis seen in Physiotherapy facilities in Ibadan and Lagos, Nigeria. *Afr J Biomed Res.*2007: **10:** 111 – 115.

17. Akinpelu AO, Alonge TO,Adekanla BA,Odole AC. Prevalence and pattern of symptomatic knee osteoarthritis in Nigeria. A community-based study. *IJAHSP* 2009: **7** (3): 1-7.

18. Akinpelu AO, Maduagwu SM, Odole AC,Alonge TO. Prevalence and pattern of knee osteoarthritis in a North Eastern Nigerian rural community. *EAOJ*. 2011 (5): 5-11.

19. Diracoglu D, Baskent A, Celik A, Issever H, AydinR. Long-term effects of kinesthesia/balance and strengthening exercises on patients with knee osteoarthritis. A one-year follow-up study. *JBack MusculoskeletRehabil.* 2008: 21:253-62.

20. O'Reilly SC, Jones A, Muir KR, Doherty M. Quadriceps weakness in knee osteoarthritis: the effect on pain and disability. *Ann of Rheum Dis*. 1998: **57:**588-94.

21.Gür H, Cakin N, Akova B, Okay E, Küçükoğlu S. Concentric versus combined concentric-eccentric isokinetic training: effects on functional capacity and symptoms in patients with osteoarthrosis of the knee. *ArchPhys MedRehabil*. 2002: **83**:308-16.

22. Guccione AA, Felson DT, Anderson JJ, Anthony JM, Zhang Y, Wilson PW, et al. The effects of specific medical conditions on the functional limitations of elders in the Framingham Study. *Am JPublic Health* 1994: **84:** 351-8.

23.Maly MR, Costigan PA, Olney SJ. Contribution of psychosocial and mechanical variables to physical performance measures in knee osteoarthritis. *PhysTher*. 2005: **85**: 1318-28.

24. Hurley MV, Scott DL, Rees J, Newham DJ. Sensorimotor changes and functional performance in patients with knee osteoarthritis. *Ann of Rheum Dis*. 1997: **56**:641- 8

25. Rubinow A.Pain in osteoarthritis and its management. In Rheumatic pain. *Newsletter of theIASPS Special Interest Group on Rheumatic Pain.*1998:(July) 1-5.

26. Creamer P.Osteoarthristis pain and its treatment. *CurrOpinRheumatol.*2000: **12:** 450-455.

27. Chan KKW, Wu RWK. Symptoms, signs and quality of life in osteoarthritis. 2012: Retrieved Dec 26, 2014 from *www.intechopen.com* at 1.45 pm.

28. Fransen M,Margioth E,Hessenler T, Edmonds J. Group exercise in subjectswith osteoarthritis of the knee. *AustJ Physiother.*1995; **41**: 253- 259

29. Van Bar ME, Assendelft WJ, Dekker J, Oostendorp RA,Bijisma JW. Effectiveness of exercise therapy in patients with osteoarthritis of the hip or knee: A systematic review of randomized clinical trials. *Arthritis Rheum.*1999; **42**:1361-1369

30. Deyle GD, Henderson NE, Matekel RL, Ryder MG, Garber, MB and Allison, S.C. Effectiveness of manual Physical Therapy and exercise in osteoarthritis of the knee. *Ann Intern Med.*2000; **132:**173-181.

31. Fransen M, McConnell S. Exercise for osteoarthritis of the knee. 2008: *Cochrane Database System Review CD004376.*

32. Fransen M. and McConnell S. Land-based exercise for osteoarthritis of the knee: a meta-analysis of randomized controlled trials. *J Rheumatol.*2009;**36**:1109-1117.

33. Iwamoto J, Sato Y, Takeda T, Matsumoto H.Effectiveness of exercise for osteoarthritis of the knee: A review of the literature. *World Journal of Orthopedics* 2011: 2.5: 37-42.

34. Lange AK, Vanwanseele B. and Singh, M.A.F. Strength training for treatment of osteoarthritis of the knee: A Systematic Review.*Arthritis Rheum.*2008**;59**(10):1488–1494 DOI 10.1002/art.24118

35. Creamer P, Hochberg MC. Management of Osteoarthritis. In Hazzard, WR, Blass JP, Ettinger WH, Halter JB,OuslanderJG. eds. *Principles of Geriatric Medicine and Gerontology*. 1999: 4th edition. Washington, McGraw-Hill Companies: 1155-1161.

36. Tagesson S, Oberg B, Good L,Kvist J**A.** Comprehensive Rehabilitation Program With Quadriceps Strengthening in Closed Versus Open Kinetic Chain Exercise in Patients With Anterior Cruciate Ligament Deficiency. A Randomized Clinical Trial Evaluating Dynamic Tibial Translation and Muscle Function. *Am J Sports Med.* 2008; **36**(2): 299-308 DOI: 10.1177/0363546507307867

37. McGinty G, Irrgang JJ,Pezzullo D. Biomechanical considerations for rehabilitation of the knee. *ClinBiomech.*2000;**15**:160-166.

38. Lim BW. A comparative study of open and closed kinetic chain exercise regimes in patients with knee osteoarthritis. *Physiother Singapore* 2002; **2**:34-40.

39. Jan M, Lin C, Lin Y, Lin J, Lin D. Effects of Weight-Bearing Versus Nonweight-Bearing Exercise on Function, Walking Speed, and Position Sense in Participants With Knee Osteoarthritis: A Randomized Controlled Trial. *Arch Phys Med Rehabil.*2009; 90:897-904.

40. Verma S. Comparing open kinetic chain with closed kinetic chain exercise on quadriceps strength and functional status of women with osteoarthritic knees. *MedicinaSportiva)* 2012;**8**(4):1989-1996

41. Gbiri CA, Okafor UAC,Alade MT. Comparative efficacy of open chain and close-chain kinematics on Proprioception, Muscles' Strength andFunctional Performances in Individual with Knee Osteoarthritis. *Occup Med Health Aff.* 1 2013:**104**. doi:10.4172/2329-6879.1000104

42. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis* 1957;**16:**494-502.

43. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 1988: 2nd ed. New York. Academic Press: 55.

44. Reading AE, Testing Pain Mechanism in Persons. In Wall, P.D. and Melzack, R. eds. *Textbook of Pain*1989: 2nd ed. Churchill Livingstone.

45. Soyannwo OA, Amanor-BoaduSD, Sanya AO, Gureje O. Pain assessment in Nigerians-visual analogue scale and verbal rating scale compared. *West Afr J Med.*2000;**19**:242-245

46. Odole AC, Akinpelu AO. Translation and alternate forms reliability of the Visual Analogue Scale in the three major Nigerian Languages. *IJAHSP*2009;**7**(3):1-5.

47. Akinpelu AO, Odole AC, Adegoke BOA, Adeniyi AF. Development and initial validation of Ibadan Knee/ Hip Osteoarthritis Outcome Measure (IKHOAM). *S Afri JPhysiother*2007;**63**:3-8.

48. Odole AC, Akinpelu AO,Bamgboye EA. Validity and internal consistency of a Yoruba version of the Ibadan Knee/ Hip Osteoarthritis Outcome Measure (Yoruba IKHOAM). *Afr J Med MedSci* 2006;**35**:349-357.

49. Odole AC, Akinpelu AO.Validity and internal consistency of a Hausa version of the Ibadan Knee/ Hip Osteoarthritis Outcome Measure. *Health QualLife Outcomes*.2008;**6**: 86.

50. Odole AC, Akinpelu AO. Translation of the Ibadan Knee/Hip Osteoarthritis Outcome Measure into Igbo language. *Afr J Biomed Res*. 2010;**13**:169-175

51. Akinpelu AO, Akinwola MO, Odole AC, Gbiri CA. The reliability of the English version of Ibadan Knee/Hip Osteoarthritis Outcome Measure (IKHOAM). *PhysOccupTherGeriatr*: 2011: 1-8 DOI: 10.3109/02/0270 3181.2011.589566

52. Adegoke BOA. Comparative efficacy of open and closed kinetic chain exercises in the treatment of osteoarthritic knee. 2003: PhD Thesis. Department of Physiotherapy. University of Ibadan.

53. Awotidebe TO, Babalola JF, Oladipo OI, Abass AO, Mbada CE, Onigbinde AT,Sanusi S. Comparative efficacy of open kinetic-chain exercise and short-wave diathermy in the management of patients with knee osteoarthritis. *MedicinaSportiva*. 2011;**7**(3):1635-1642.

54. Stitik TP, Gazzillo G, Faye PM. State of the art review: osteoarthritis and therapeutic exercise. *Am J Lifestyle Med* 2007; **1**(5):360- 366.

55. Boling MC, Bolgla LA, Mattacola CG, Uhl TL,Hosey RG.Outcomes of a weight-bearing rehabilitation program for patients diagnosed with patellofemoral pain syndrome. *Arch Phys Med Rehabil* 2006; **87**:1428-35.

56. Durmus D, Alayli G,Canturk F. Effects of quadriceps electrical stimulation program on clinical parameters in the patients with knee osteoarthritis. *ClinRheumatol.*2007; **26**:674–678.

57. Shakoor A, Rahman S, Azad AK,Islam S. Effects of isometric quadriceps muscle strengthening exercise on chronic osteoarthritis of the knee.*Bangladesh Med Res Counc* 2010; **36:** 20-22 DOI: 10.3329/bmrcb.v36i1.5502

58.Lozada CJ, Altman RD. *Management of osteoarthritis. In Arthritis and Allied Conditions: A textbook of Rheumatology*1996: (13th Ed.) Koopman WJ, (Ed) Baltimore, Williams and Wilkins 2015-2025.

59. Anwer S, Alghadir A. Effect of isometric quadriceps exercise on muscle strength, pain, and function in patients with knee osteoarthritis: a randomized controlled study *J PhysTherSci* 2014; **26:** 745–748.

60. Pothier B, Allen ME. Kinesiology and the degenerative joint. *Rheum Dis Clin North Am*1991: 16: 989-1002

61. Marks R. Peripheral articular mechanisms of pain production in osteoarthritis. *Aust J Physiother* 1992; **38**:289-298.

62. Simkin PA, Hang A, Benedict RS. Effects of exercise on blood flow to canine articular tissues. *J Orthop Res*.1990;8:297-303.

63. Jan M, Lin J, LiauJ, LinY, Lin D.Investigation of clinical effects of high and lowresistance training for patients with knee osteoarthritis: A randomized controlled trial. *PhysTher* 2008; **88**: 427-436 doi10.2522/ptj.20060300.

64. Alnahdi AH,Zeni JA, Snyder-MacklerL. Muscle impairments in patients with knee osteoarthritis. *Sports Health* 2012; **4 (**4): 284-282

65. Daskapan A, Anaforoglu B, Pekyavas NO, Tuzun EH, Cosar SN,Karata M.Comparison of Mini-squats and Straight Leg Raises in Patients with Knee Osteoarthritis: A Randomized Controlled Clinical Trial. *Turk J Rheumatol* 2013;**28**(1):16-26

66. Odole AC,Ojo OD. A Telephone-based Physiotherapy Intervention for Patients with Osteoarthritis of the Knee. *Int J Telerehabi l*2013;**5**(2):11-20.

67.Adegoke BOA, Alao R,Odole A. Comparison of health-related quality of life of Nigerian patients with knee osteoarthritis and age-matched controls. *J PhysTher* 2012;(6):13-20.

68. Alghamdi, MAA, Olney S, Costigan P. Exercise treatment for osteoarthritis disability. *Annals of Saudi Medicine* 2004: **24**(5): 326-331.

69. Fu F, Woo S,Irrgang J. Current concepts for rehabilitation following anterior cruciate ligament reconstruction. *JOSPT* 1992; **15**(6):270-278

70. Irrgang JJ.Modern trends in ACL rehabilitation. In: Prentice WE, ed. *Rehabilitation technique in sports medicine.*1993: St Louis: Mosby: 181-194.

71. Durward BR, Bear GD, Rowe PJ. Measurement issues in functional human movement. In: Durward BR, ed. *Functional human movement*. 1999: Oxford: 1-13.

72. Mikkelsen C, Werner S, Erikson E. Closed kinetic chain alone compared to combined open and closed kinetic chain exercises for quadriceps strengthening after anterior cruciate ligament reconstruction with respect to return to sports: A prospective matched follow-up study. *Knee Surg Sports TraumatolArthrosc*2000; **8**(6): 337-342

73. Minoonejad H, Rajabi R, Ebrahimi-Takamjani E, Alizadeh MH, Jamshidi AA, Azhari A, Fatehi E. *World J Sport Sci*2012; **6**(3): 278-285

74. Freidhoff G, Malone T. Chain links rehabilitation should balance open and closed chain activities. *Biomechanics*1998: (March Edition).