Volume 38 • Number 1 • June 2018
www.worldscientific.com/worldscinet/hkpj

HONG KONG PHYSIOTHERAPY JOURNAL

World Scientific

HONG KONG PHYSIOTHERAPY JOURNAL

Volume 38 • Number 1 • June 2018
www.worldscientific.com/worldscinet/hkpj

Editor-in-Chief
Professor Marco Y.C. Pang, PhD
Department of Rehabilitation Sciences,
The Hong Kong Polytechnic University, Hong Kong

World Scientific
NEW JERSEY • LONDON • SINGAPORE • BEIJING • SHANGHAI • HONG KONG • TAIPEI • CHENNAI • TOKYO

Hong Kong Physiotherapy Journal

Aims & Scope

The Hong Kong Physiotherapy Journal (HKPJ) is the official peer-reviewed, Open Access (OA) publication of the Hong Kong Physiotherapy Association.

HKPJ publishes papers related to all areas of physiotherapy (education, research, practice, policies) and is committed to facilitating communication among educators, researchers and practitioners in the field with the aim of promoting evidence-based practice.

We are particularly interested in publishing randomized controlled trials, systematic reviews and meta-analyses. Animal studies are also welcome if the study question and findings have important relevance to physiotherapy practice.

HKPJ welcomes submissions from all over the world in the form of original research papers, reviews, editorials, treatment reports, technical notes, and correspondence.

Hong Kong Physiotherapy Journal [ISSN (print): 1013-7025 | ISSN (online): 1876-441X] is published by World Scientific Publishing Co Pte Ltd.

HONG KONG PHYSIOTHERAPY JOURNAL

Vol. 38, No. 1, June 2018

Hong Kong Physiotherapy Journal
Vol. 38, No. 1 (2018) i–ii
DOI: 10.1142/S1013702518010011

Hong Kong Physiotherapy Journal
http://www.worldscientific.com/worldscinet/hkpj

Non-pharmacologic supplementation as an adjunct treatment for osteoarthritis

Shirley P. C. Ngai

Department of Rehabilitation Sciences, Hong Kong Polytechnic University, Hong Kong

Associate Editor – Hong Kong Physiotherapy Journal

Shirley.ngai@polyu.edu.hk

Accepted 25 May 2018; Published 18 June 2018

Osteoarthritis (OA) is a degenerative joint disorder characterized by inflammation and structural changes at joints[1] with higher prevalence among females,[2–4] advanced age,[3,4] and individuals who are overweight/obese[2] or have a history of previous knee injury.[2] Knees and Hips are two of the commonly reported involved joints.[1,3] Joint pain, stiffness, limitation in range of motion and inactivity associated muscle weakness further limit the functions and activities of daily living, thereby contributing to increased years-lived with disability (YLDs).[1] Not only being a known cause of disability, recent studies reported that OA increases the risks of developing other conditions such as depressive symptoms[5] and myocardial infarction.[6] Due to its potential impact on influencing overall health,[7] OA may substantially increase both direct and indirect medical and rehabilitation costs. Recently, increasing number of studies examined the effect of potential adjunct supplementation used in musculoskeletal conditions such as improving muscle strength in frail elderly,[8] and reducing joint pain in people with osteoarthritis.[9] In this issue of Hong Kong Physiotherapy Journal, two studies investigated the effectiveness of non-pharmacologic supplementation for managing symptoms of osteoarthritic knee[10] and hip.[11] Oninbinde *et al.*[10] compared the effect of topical administration of glucosamine sulphate via 3 methods, i.e. (1) iontophoresis (IoT), (2) cross-friction massage (CFM) and (3) combined therapy of IoT and CFM (CoT) on pain intensity, joint space width, range of motion and physical function in people with osteoarthritic knee. Favourable post-treatment findings were reported. In the other study, Ikeda *et al.*[11] examined the effects of branched-chain amino acid (BCAA) supplementation in combination of exercise program on muscle strengthening in female patients with osteoarthritic hips who were awaiting for total hip arthroplasty. Individuals in experimental group who had oral intake of BCAA on top of exercise program (i.e. hip abductors strengthening program) showed a significant effect on 10-meter timed gait time and improvement rate of

muscle strength of the contralateral hip abductor when compared with control group.[11] While these studies have several limitations, the current findings provide support for conducting larger randomized controlled trials to investigate the potential effect of adjunct supplementation for managing osteoarthritis.

References

1. Cross M, Smith E, Hoy D, et al. The global burden of hip and knee osteoarthritis: Estimates from the global burden of disease 2010 study. Ann Rheum Dis 2014;73(7):1323–30.
2. Silverwood V, Blagojevic-Bucknall M, Jinks C, Jordan JL, Protheroe J, Jordan KP. Current evidence on risk factors for knee osteoarthritis in older adults: A systematic review and meta-analysis. Osteoarthritis Cartilage 2015;23(4):507–15.
3. Plotnikoff R, Karunamuni N, Lytvyak E, et al. Osteoarthritis prevalence and modifiable factors: A population study. BMC Public Health 2015; 15:1195.
4. Prieto-Alhambra D, Judge A, Javaid MK, Cooper C, Diez-Perez A, Arden NK. Incidence and risk factors for clinically diagnosed knee, hip and hand osteoarthritis: Influences of age, gender and osteoarthritis affecting other joints. Ann Rheum Dis 2014;73(9):1659–64.
5. Veronese N, Trevisan C, De Rui M, et al. Association of osteoarthritis with increased risk of cardiovascular diseases in the elderly: Findings from the progetto veneto anziano study cohort. Arthritis Rheumatol 2016;68(5):1136–44.
6. Schieir O, Tosevski C, Glazier RH, Hogg-Johnson S, Badley EM. Incident myocardial infarction associated with major types of arthritis in the general population: A systematic review and meta-analysis. Ann Rheum Dis 2017;76(8):1396–1404.
7. Vina ER, Kwoh CK. Epidemiology of osteoarthritis: Literature update. Curr Opin Rheumatol 2018;30(2):160–67.
8. Ikeda T, Aizawa J, Nagasawa H, et al. Effects and feasibility of exercise therapy combined with branched-chain amino acid supplementation on muscle strengthening in frail and pre-frail elderly people requiring long-term care: A crossover trial. Appl Physiol Nutr Metab 2016; 41(4):438–45.
9. Cohen M, Theroux P, Borzak S, et al. Randomized double-blind safety study of enoxaparin versus unfractionated heparin in patients with non-ST-segment elevation acute coronary syndromes treated with tirofiban and aspirin: The ACUTE II study. The antithrombotic combination using tirofiban and enoxaparin. Am Heart J 2002; 144(3):470–77.
10. Onigbinde AY, Owolabi AR, Lasisi K, Isaac SO, Ibikunle AF. Symptoms-modifying effects of electromotive administration of glucosamine sulphate among patients with knee osteoarthritis. Hong Kong Physiotherapy Journal 2018; 38(1): 63–75.
11. Ikeda T, Jinno T, Masuda T, et al. Effect of exercise therapy combined with branched-chain amino acid supplementation on muscle strengthening in persons with osteoarthritis. Hong Kong Physiotherapy Journal 2018;38(1):23–31.

Research Paper

Hong Kong Physiotherapy Journal
Vol. 38, No. 1 (2018) 1–11
DOI: 10.1142/S1013702518500014

Hong Kong Physiotherapy Journal
http://www.worldscientific.com/worldscinet/hkpj

Effectiveness of falls prevention intervention programme in community-dwelling older people in Thailand: Randomized controlled trial

Plaiwan Suttanon[1,*], Pagamas Piriyaprasarth[2], Kitsana Krootnark[1] and Thanyaporn Aranyavalai[3]

[1]*Department of Physical Therapy, Faculty of Allied Health Sciences Thammasat University, Pathumthani 12121, Thailand*

[2]*The Faculty of Physical Therapy, Mahidol University Nakhon Pathom 73170, Thailand*

[3]*The Faculty of Medicine Vajira Hospital, Bangkok 10300, Thailand*

[*]*plaiwan.s@allied.tu.ac.th*

Received 29 September 2016; Accepted 19 April 2017; Published 19 March 2018

Background: Although there is extensive research on falls prevention, most of this knowledge is from western countries, and this may limit its usefulness when implementing in countries with different culture and healthcare systems.
Objective: This study evaluated the feasibility and effectiveness of a falls prevention intervention programme for older people in Thailand.
Methods: Two hundred and seventy-seven community-dwelling older people were randomized to either an intervention programme which included an education about falls risk management plus a home-based balance exercise delivered by a physiotherapist for four-month duration or control group. Falls, balance, physical activity, and other falls risk factors were measured at baseline and after programme completion.
Results: About 90% of the participants in the intervention group completed the programme, with very high adherence to the exercise programme, though poor compliance with the suggestions of other falls risks management. There were no falls or injuries related to the exercise programme reported. There was no significant difference in falls rate between the two groups.
Conclusion: This falls prevention program was not effective in reducing falls in community-dwelling older

[*]Corresponding author.

people in Thailand. However, the study provided encouraging evidence that home-based balance exercise could be practically implemented in older people living in communities in Thailand.

Keywords: Exercise; falls prevention; older people; Thailand.

Introduction

Falling is a well-recognized health issue in older people, with one in three people aged over 65, living in the community, falling each year.[1,2] There have been extensive research in falls in older people including several systematic reviews conducted with the aim to find out which fall prevention interventions are effective for older people living in the community including older people with a high falls risk. Evidence-based interventions are available to prevent falls. The evidence for the effectiveness of falls prevention interventions for community-dwelling older people has been previously summarized in a systematic review[3] and updated up to the year 2012.[4] The recent review reported that an exercise programme as a single intervention, as well as multifactorial programmes (a combination of single interventions targeted an individual person's identified falls risk factors), were the most common interventions studied.[4] The meta-analysis revealed that two types of single intervention: (1) multi-component exercise programme and (2) home safety modification found to be effective in reducing falls risk and falls rate in older people. The effectiveness of the combination exercise programmes in reducing risk of falling has also been affirmed by two systematic reviews and meta-analyses by Sherrington and team.[5,6] Regarding the effectiveness of multifactorial intervention programmes, the recent systematic review by Gillespie *et al.* in 2012 also supported that multifactorial intervention programmes could also minimize falls rate; however, this would not have an effect on the falls risk level.[4] Even though these systematic reviews[3–6] demonstrated the evidence of several intervention programmes effectively preventing falls for community-dwelling older people, in different countries, falls by older people could be recognized and then managed in different ways depending upon the various factors in particular culture, living standards, as well as the healthcare and social welfare systems of each country. These could be factors influencing feasibility and also effectiveness of falls prevention intervention programmes to be implemented in each country.

In Thailand, there have been only a limited number of studies of falls prevention interventions. A review of Thai research of falls prevention programmes in 2007[7] identified only three published research studies in which two quasi-experimental studies were mainly educational interventions and the other one was a randomized controlled trial providing a falls prevention booklet combined with clinical assessment. Since then, there has been another study which was a qualitative study of older people's opinion and preferences on fall prevention programmes for Thai community-dwelling older people.[8] As such, there is little research evidence to guide falls prevention practice for Thai older people living in the community.[7]

As older population in Thailand is rising and is expected to reach 14%, 19.8% and 30% in 2015, 2025, and 2050, respectively,[9] and since we could anticipate consequences of falls as one of the health problems in the population, there is a clear need for studies to investigate the effect of falls prevention intervention focusing on exercise programmes specifically in community-dwelling older people in Thailand.

The aim of this study is to provide evidence of the effectiveness of a home-based falls prevention programme, focusing on balance exercise programmes on falls and falls risk factors including physical performance in community-dwelling older people in Thailand.

Methods

Study design

The study was a single-blinded randomized controlled trial. The study protocol was approved by the Human Research Ethics Committees, Thammasat University (Project No. 044/2556). The written informed consent was obtained from each participant.

Participants

People aged 60 and over who had been living in the community were eligible for inclusion in this study if they satisfied all the following criteria: (i) ability to walk outdoors with no more support than a single point stick; (ii) having no other serious orthopedic condition (e.g., recent lower limb surgery, severe arthritis of a lower limb) or major neurological disorder (e.g., stroke with unilateral or bilateral paresis or Parkinson disease) that could restrict functional mobility. Those who had a severe level of cognitive impairment that could limit participation would be excluded.

Sample size was calculated for the study, based on the data from the pilot study, with an estimated effect size of 0.5, indicating 138 participants per group (276 participants in total) would be required for power of 80% and alpha of 0.05, assuming a loss to follow up of 15%.

Participants were recruited from a previous study on balance and falls risk in older people in Thailand. After baseline assessment, each participant was randomized into either (1) the control or (2) the intervention programmes, using a concealed randomization procedure. A random number table with group allocation was computer-generated and packed in an opaque-sealed envelope by a staff member independent of the current research team. After baseline assessment, the next numbered envelope was opened by a research assistant who was not involved in assessments or interventions. The research assistant then contacted a physiotherapist who was delivering the intervention programme, but was not involved in assessment (single blind randomized controlled trial). The CONSORT diagram is presented Fig. 1.

Procedure

A baseline assessment was carried out, which included measures of falls rate, a comprehensive series of clinical measures of balance and mobility performance as well as level of physical activity, and measures of common falls risk factors, and then repeated after the intervention programme was completed (four months). All measurements on both assessment occasions were undertaken by trained assessors blind to group allocation.

Outcome measures

Measures of falls: The number of falls in the preceding 12 months (self-report, based on information from the participant and their falls calendars) was recorded.

Measures of balance and mobility performance, physical activity level and frequency of exercises:

(i) Functional Reach (FR) test,[10] a test of the maximum distance[11] that participants can reach forward with their dominant arm raised to 90°.

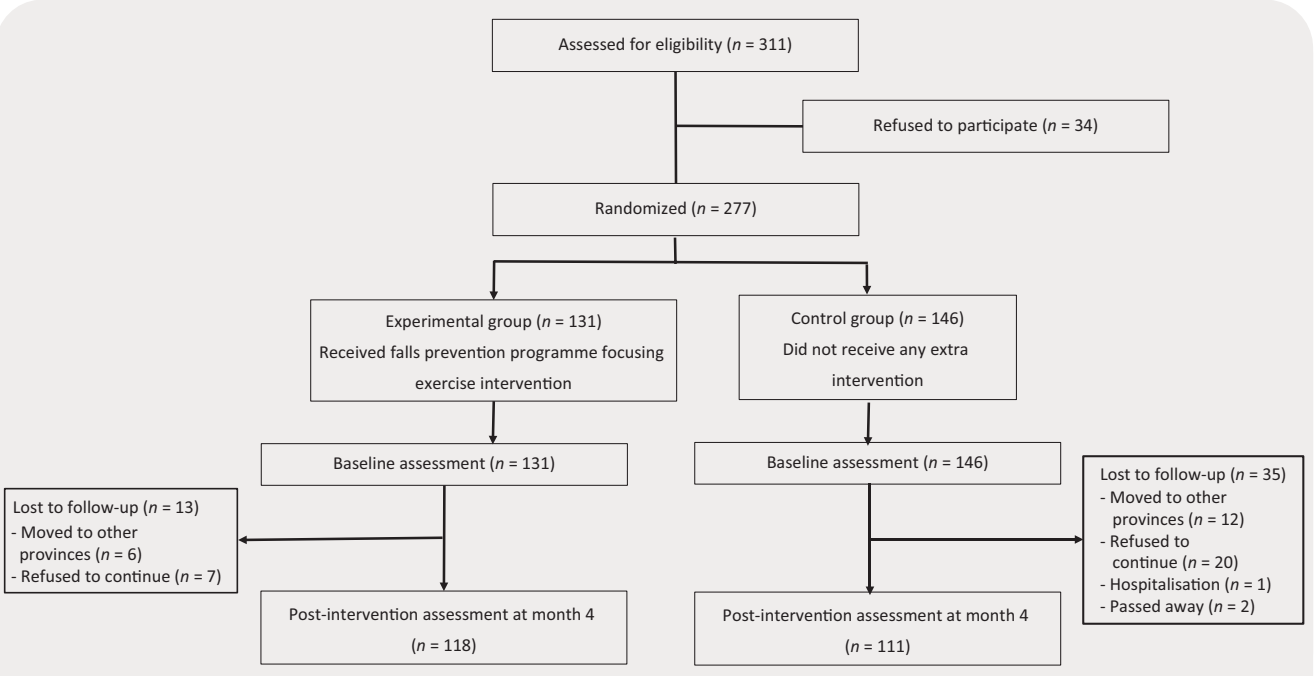


Fig. 1. CONSORT diagram of the study.

(ii) Step Test (ST),[12] a test that measures the number of times the participant steps with one foot fully on and then off a 7.5 cm-block as quickly as possible in 15 s was recorded. Each leg was tested separately, and performance on the side with a poorer score was recorded.
(iii) Timed Chair Stand (TCS),[13] a test measuring the speed of standing up/sitting down as fast as possible five times from a 45 cm-high chair.
(iv) Timed Up and Go (TUG) test,[14] an assessment that measures speed in standing up from a standard chair, walking 3 m at usual speed, turning, then returning to sit again in the chair (s). This task was reassessed under dual task conditions, with a secondary cognitive task (counting backwards by 3 s while performing the TUG), and with a secondary motor task (carrying a full cup of water while performing the TUG).[15]
(v) A Thai-translated version of the physical activity level assessment, modified from the Physical Activity Scale for the Elderly (PASE).[16]

Measures of other falls risk factors consisted of the following:

(i) Fear of falling: a Thai-translated version of the Modified Falls Efficacy Scale, which is a self-reported questionnaire to determine how confidently participants feel that they are able to perform each of 14 common activities in daily life.
(ii) Visual problems and treatment were reported by each participant.
(iii) Home environmental hazards were assessed by observation in/at walkways, bedrooms, kitchens, bathrooms, and stairs.
(iv) Appropriate footwear was assessed by observation using the checklist described as follows:
  - Poorly-fitting footwear/slippers.
  - Unstable footwear.
  - Slippery footwear.
  - Footwear with heels higher than one inch.
  - Worn-out footwear.

Participants were randomized to either the intervention group (received fall prevention programme focusing on balance exercise) or control group. Participants in both groups continued with their usual care and other activities while participating in this study.

Intervention

Falls prevention programme focusing on balance exercise.

Participants randomized to the intervention programme were provided with a four-month multifactorial falls prevention programme which focused on a balance training exercise. The intervention programme consisted of the following:

(1) An individualized home-based balance exercise programme was developed and monitored by a physiotherapist. The programme focused on lower extremity strengthening exercises and balance training. The programme was based on an existing home exercise programme (the Otago programme, http://www.acc.co.nz/PRD_EXT_CSMP/groups/external_providers/documents/publications_promotion/prd_ctrb118334.pdf) that has been shown to be effective in reducing falls in older people. The length of the programme and number of visits were modified from the originally described randomized trial (from 4 to 5 visits during 6 to 12 months to be a couple of visits during the 4-month period of the programme) to increase feasibility of the programme (due to the limited support both in terms of expenses and staff). However, frequency of exercises per week was modified to be increased from three days/week in original programme to be at least four days/week. Each participant was also provided with an exercise booklet with illustrations and instructions so that the participant could continue the exercises at home.
Two follow-up phone calls in between visits were also provided in order to ensure that there were no negative effects from the exercises and to gauge that the participant had done the exercises correctly. The participants were provided with the physiotherapist's contact phone details and were able to contact the physiotherapist if necessary.
Data on adherence to the exercise programme were collected by participants completing monthly exercise recording sheets, which were retrieved and reviewed by the physiotherapist during the subsequent home visits and phone calls.
(2) A booklet of falls risk management strategies based on common falls risk factors reported in community-dwelling older people was provided, together with advice for each participant about how to deal with their falls risk factors identified from the pre-intervention assessment (e.g., suggestion for taking medications review, eye check, and home environmental hazard modifications).

(3) A handrail (to be installed in the bathroom or toilet) or a walking-assistive device was provided for the participants who needed it (need was based on the pre-intervention assessment results).

Control

Participants randomized to the control group received usual care and continued their usual activities without any of the limitation from being participated in the study.

Statistical analysis

All analyses were conducted using the intention-to-treat principle that included all randomized participants. To manage missing data associated with participants dropping out from the study during the four months of intervention, Last Observation Carried Forward Method was used.[17]

To evaluate the effectiveness of the intervention programme, we used the generalized linear models (SPSS advance statistics 17.0), with group allocation as the factor (predictor) variable. Variables which are commonly recognized as falls risk factors as well as the variables which were found to be different between the intervention and control groups at the baseline assessment were considered as covariates for the first run of model of each outcome measure analyzed. Only variables with a significant level at the tests of model effects were included as covariates in the final model of each variable analysis. The final model of each outcome

Table 1. Type of model selected for each outcome measure.

		Generalized linear models	
Outcome	Measure	Distribution	Link function
Number of falls in the previous year	Count	Poisson	Log
Fallers: non-Fallers	Binary	Binomial	Logistic
Number of medical conditions ≥ 4	Binary	Binomial	Logistic
Number of medications ≥ 4	Binary	Binomial	Logistic
Normal eyesight: Abnormal eyesight, n (%)	Binary	Binomial	Logistic
Using bifocal or multifocal eyeglasses, n (%)	Binary	Binomial	Logistic
Other eye conditions[a] (treatment: non-treatment), (%non-treatment)	Nominal	Multinomial	Cumulative Logit
Appropriate footwear: Inappropriate footwear,[b] n (%inappropriate footwear)	Binary	Binomial	Logistic
Having ≥ 4 home hazard environments, n (%)	Binary	Binomial	Logistic
Regularly go to toilet at night ≥ 2 times, n (%)	Binary	Binomial	Logistic
Regularly go to toilet at night ≥ 4 times, n (%)	Binary	Binomial	Logistic
Number of medical conditions	Quantitative	Gamma	Identity
Number of medications	Quantitative	Gamma	Identity
Functional Reach test	Quantitative	Normal	Identity
Step Test (worst side)	Quantitative	Normal	Identity
Timed Up and Go test (TUG)	Quantitative	Gamma	Identity
TUG (secondary manual task)	Quantitative	Gamma	Identity
TUG (secondary cognitive task)	Quantitative	Gamma	Identity
Timed Chair Stand	Quantitative	Gamma	Identity
Hand reaction time	Quantitative	Gamma	Identity
Modified PASE[c] score	Quantitative	Gamma	Identity
Exercise frequency (times/week)	Quantitative	Gamma	Identity
Total exercise time (hours/week)	Quantitative	Gamma	Identity
Modified Falls Efficacy Scale	Quantitative	Gamma	Identity
MMSE[d]	Quantitative	Gamma	Identity
Number of home environmental hazards	Quantitative	Gamma	Identity

[a]Other eye conditions including cataract, glaucoma, Pterygium, Pinguecula; [b]Inappropriate footwear including poorly fitted shoes/slippers, unstable shoes, slippery shoes, shoes with > 1 inch high-heel, worn-out footwear; [c]Modified PASE (hours/week); [d]Mini-Mental State Examination (Thai version).

measure also contained baseline performance on the outcome as another covariate. Each outcome measure was analyzed by a separate model in which the type of model was selected based on the nature of the outcome measure and its distribution (Table 1).

Results

Participant characteristics

Two hundred and seventy-seven participants were randomized to the intervention (131) or the control (146) groups.

Baseline characteristics and possible falls risk factors for the total 277 participants are shown in Table 2. The mean age ± standard deviation of the participants in the control and intervention programmes were 72.92 ± 5.63 and 72.18 ± 5.41, respectively. Participants were predominantly female in both groups. At baseline, performance on the balance and mobility tests, and other falls risk factors between the two groups were similar on most outcome measures. However, there were several outcome measures significantly different between the two groups at baseline including the number of medical conditions, amount of prescribed medications taken, time to perform TCS test, score of physical activity level measured by PASE, and number of home environmental hazards. In general, the intervention group had better health conditions and mobility performance compared to the control at the baseline; however, the intervention group also had a greater number of home environmental hazards than the control group.

Intention to treat outcome analysis

One hundred and eighteen of the 131 participants in the intervention group completed the programme. In the control group, 111 of the 146 participants in the control group completed the study.

Table 2. Characteristics and falls risk factors of the participants at baseline ($n = 277$).

Characteristics and Falls risk factors	Intervention group ($n = 131$)	Control group ($n = 146$)
Age, mean ± SD	72.2 ± 5.4	72.9 ± 5.6
Gender (M:F), *n*	34:97	40:106
MMSE[a] score, mean ± SD	25.2 ± 4.3	24.6 ± 4.5
Number of medical conditions, mean ± SD	2.0 ± 1.1	2.4 ± 1.2*
Number of medical condition greater than 4, *n* (%)	11 (8.4%)	25 (17.1%)
Number of medications, mean ± SD	1.8 ± 1.7	2.2 ± 1.7*
Taken greater than 4 medications, *n* (%)	17 (13%)	31 (21.2%)
Falls in previous year, mean ± SD	0.3 ± 0.8	0.3 ± 0.9
Fallers: non-fallers, *n* (% fallers)	26:104 (19.9%)	28:118 (19.2%)
Functional Reach test (distance_cm), mean ± SD	22.1 ± 6.6	20.9 ± 6.1
Step Test (number of steps_worse side), mean ± SD	10.5 ± 3.4	10.2 ± 2.7
Timed Up and Go test (TUG) score (s), mean ± SD	13.3 ± 5.6	13.3 ± 3.9
TUG (secondary manual task) (s), mean ± SD	13.1 ± 5.2	13.9 ± 4.4
TUG (secondary cognitive task) (s), mean ± SD	16.5 ± 7.1	16.8 ± 5.5
Timed Chair Stand (s), mean ± SD	10.7 ± 4.5	11.4 ± 3.6*
Hand reaction time (ms)	1.4 ± 0.5	1.3 ± 0.7
Modified PASE[b] score (hours/week)	34.0 ± 7.9	32.2 ± 8.9*
Modified Falls Efficacy Scale	119.9 ± 23.5	122.0 ± 18.6
Normal eyesight: Abnormal eyesight, *n* (%non-normal eyesight)	35:96 (73.3%)	39:107 (73.3%)
Using bifocal or multifocal eyeglasses, *n* (%)	11 (8.4%)	18 (12.3%)
Other eye conditions[c] treatment: non-treatment, (%non-treatment)	48:18 (27.3%)	59:22 (27.2%)
Appropriate footwear: Inappropriate footwear,[d] *n* (% inappropriate footwear)	101:30 (22.9%)	99:47 (32.2%)
Number of home environmental hazards, mean ± SD	4.0 ± 2.1	3.7 ± 2.6*
Having home hazard environment ≥ 4, *n* (%)	63 (48.1%)	58 (39.7%)

*$p < 0.05$; [a]Mini-Mental State Examination (Thai version); [b]Modified PASE (hours/week); [c]Other eye conditions including cataract, glaucoma, Pterygium, Pinguecula; [d]Inappropriate footwear including poorly fitted shoes/slippers, unstable shoes, slippery shoes, shoes with > 1 inch high-heel, worn-out footwear.

Table 3. Outcome analysis.[a]

Outcome measures	Intervention group		Control group		IRR/OR (95% CI)	p value
	Baseline performance	Post-intervention performance	Baseline performance	Post-intervention performance		
Falls in the previous year, mean ± SD	0.3 ± 0.8	0.3 ± 0.7	0.3 ± 0.9	0.3 ± 0.7	IRR = 0.008 (−0.40–0.42)	0.971
Fallers: non-fallers, n (% fallers)	26:104 (19.9%)	31:100 (23.7%)	28:118 (19.2%)	35:111 (24.0%)	OR = −0.046 (−0.81–0.72)	0.907
Number of medical conditions ≥ 4	11 (8.4%)	11 (8.40%)	25 (17.1%)	18 (12.3%)	OR = 0.371 (−0.62–1.36)	0.462
Number of medications ≥ 4	17 (13.0%)	16 (12.2%)	31 (21.2%)	26 (17.8%)	OR = −0.060 (−1.01–0.89)	0.900
Normal eyesight: Abnormal eyesight, n (%)	35:96 (73.3%)	38:93 (71.0%)	39:107 (73.3%)	45:101 (69.2%)	OR = 0.121 (−0.57–0.81)	0.729
Using bifocal/multifocal eyeglasses, n (%)	11 (8.4%)	22 (16.8%)	18 (12.3%)	25 (17.1%)	OR = 0.117 (−0.67–0.91)	0.771
Other eye conditions[b] (treatment: non-treatment), (%non-treatment)	48:18 (27.3%)	52:17 (24.6%)	59:22 (27.2%)	58:24 (29.3%)	OR = 0.105 (−0.61–0.82)	0.774
Appropriate footwear: Inappropriate footwear,[c] n (%inappropriate footwear)	101:30 (22.9%)	85:46 (35.1%)	99.47 (32.2%)	87:59 (40.1%)	OR = −0.046 (−0.59–0.50)	0.870
Having ≥ 4 home hazard environments, n (%)	63 (48.1%)	60 (45.8%)	58 (39.7%)	55 (37.7%)	OR = −0.046 (−0.81–0.72)	0.858
Number of medical conditions	2.0 ± 1.1	1.9 ± 1.3	2.4 ± 1.2	2.1 ± 1.2	−0.023 (−0.22–0.17)	0.817
Number of medications	1.8 ± 1.7	1.9 ± 1.7	2.2 ± 1.7	2.3 ± 1.7	−0.109 (−0.33–0.11)	0.328
Functional Reach test[11]	22.1 ± 6.6	23.4 ± 6.9	20.9 ± 6.1	22.8 ± 6.8	0.416 (−0.79–1.630)	0.500
Step Test (worse side) (steps)	10.5 ± 3.4	10.5 ± 3.3	10.2 ± 2.7	10.1 ± 3.0	−0.033 (−0.50–0.43)	0.889
Timed Up and Go test (s)	13.3 ± 5.6	13.9 ± 5.2	13.3 ± 3.9	13.6 ± 3.8	−0.481 (−0.93–[−0.04])	0.034*
TUG (2nd task_manual task) (s)	13.1 ± 5.2	14.5 ± 5.4	13.9 ± 4.4	14.5 ± 4.3	−0.342 (−0.84–0.16)	0.181
TUG (2nd task_cognitive task) (s)	16.5 ± 7.1	19.4 ± 9.4	16.8 ± 5.5	18.4 ± 6.5	−0.972 (−2.04–0.10)	0.075
Timed Chair Stand (s)	10.7 ± 4.5	11.1 ± 4.9	11.4 ± 3.6	11.4 ± 3.4	−0.992 (−1.42–[−0.56])	0.000**
Hand reaction time	1.4 ± 0.5	1.3 ± 0.5	1.3 ± 0.7	1.2 ± 0.6	−0.053 (−0.13–0.03)	0.205
Modified PASE[d] score (hours/week)	34.0 ± 7.9	34.4 ± 9.7	32.2 ± 8.9	34.4 ± 11.7	0.995 (−1.38–3.37)	0.412
Exercise frequency (times/week)	3.7 ± 3.4	6.0 ± 2.3	3.3 ± 3.4	3.7 ± 3.3	−0.466 (−0.89–[−0.04])	0.032*
Total exercise time (hours/week)	13.2 ± 15.1	20.5 ± 13.1	12.5 ± 15.0	14.0 ± 16.2	−1.382 (−4.23–1.47)	0.342
Modified Falls Efficacy Scale	119.9 ± 23.5	119.4 ± 26.5	122.0 ± 18.6	121.1 ± 21.4	0.362 (−5.29–6.02)	0.900
MMSE[e]	25.2 ± 4.3	25.8 ± 4.1	24.6 ± 4.5	24.8 ± 4.8	−0.731 (−1.32–[−0.15])	0.014*
Number of home environmental hazards	4.0 ± 2.1	4.3 ± 2.7	3.7 ± 2.6	3.8 ± 2.8	−0.202 (−0.43–0.03)	0.084

Notes: Test scores reported are mean and standard deviation. *$p < 0.05$; **$p < 0.01$; [a]The adjusted IRR, OR, B coefficient (95% confidence interval (CI)), and p values are based on generalized linear models in which the intervention group is compared with the control group; [b]Other eye conditions including cataract, glaucoma, Pterygium, Pinguecula; [c]Inappropriate footwear including poorly fitted shoes/slippers, unstable shoes, slippery shoes, shoes with > 1 inch high-heel, worn-out footwear; [d]Modified PASE (hours/week); [e]Mini-Mental State Examination (Thai version).

The combined discontinuing rate of this study was 17.33%.

Table 3 demonstrates the comparison of outcome measures assessed at pre- and post-intervention time points between the intervention and control groups. Also, B (coefficient) values are presented which represent the average values of the outcome measures of the exercise group compared with the control group, after adjusting for the effects of all other factors and/or covariate (s) in the models selected for analysis (the relevant p values are reported). A negative B value means that the average value of the outcome of the intervention group is higher than the control group when analyses contained baseline performance and other falls risk factors as covariates.

At the post-intervention reassessment, the number of falls in the previous year of both the intervention and control groups did not change in comparison to the baseline, and were not significantly different between the two groups. As for the percentage of participants reporting one or more falls in the preceding year at the reassessment, the intervention group increased by approximately 4% which was similar with the control group.

No changes and no differences between the groups were found in the majority of the outcome measures. A significantly slower mobility during TUG and TCS tests was found in the intervention group compared with the control group. However, this was only a small change (mean value increased by less than 1 s). It was also found that the number of home environmental hazard had increased in the intervention group.

Safety and compliance to the intervention programme

Home-based balance exercise programme

There were no falls or injuries associated with performing the exercise programme. Only a few participants reported (mild) pain or bodily discomfort when a new exercise was introduced. However, those symptoms eased with continuing the exercises.

Full compliance (100%) was defined as a participant doing the exercises four days a week. The average of percentage of adherence of all participants who completed the exercise programme (4th month period) (118 of 131 participants) was 90%. Around 90 out of 118 participants had greater than 80% adherence, with 51 of them completing the exercise programme with 100% adherence. The common reasons for limited exercise-adherence of the participants were health conditions which could lead to hospitalization in some cases, being away from home.

Education and falls prevention booklet

Most suggestions about minimizing falls risk by managing falls risk factors in particular, such as number of medications used, visual problems, and in particular home hazard modification, could not be implemented in practice. For example, the provided handrail could not be installed in some participants' bathrooms or toilets due to the limitations of house structure (e.g., wall built with corrugated sheets).

Discussion

This study is adding evidence that a falls-prevention advisory programme together with a booklet regarding falls risk factors, falls risk management and falls prevention guidelines, and in particular a home-based balance exercise programme delivered by a physiotherapist, can be implemented safely in older people living in communities in Thailand. However, the programme was not effective in terms of reducing occurrences of falling in the population. Referring to the understanding that falls often involve a mix of contributory intrinsic and extrinsic falls risk factors,[18] the study hypothesized that a multifactorial intervention programme would effectively reduce falls in older people. However, the findings did not support our initial hypothesis that a multifactorial intervention programme which targeted identified falls risk factors would reduce falls rate and improve physical performance as several previous studies suggested.[3,4] Main explanation for the lack of effectiveness of the programme could be a combination of several factors including the design of the programme especially the exercise programme, the way to implement the education intervention offering knowledge and suggestions of falls risk management strategies as well as some possible variations among participants included in the study.

Regarding the implementation of the education programme, one possible reason is that the falls risk management strategies suggested could not practically implemented by most of our participants, particularly the advice to modify home environmental hazards and inappropriate footwear. In addition, several falls risk factors identified could not

be practically modified by the older people themselves, but required assistance from varied health care professionals as well as support from the healthcare system and government, for example, medications reviews, eye check-ups and treatment. These could be affirmed by the lack of differences in numbers of medications taken, untreated visual problem and home environmental hazards at the post-intervention assessment compared with the baseline in both the intervention and control groups. This finding emphasizes that a falls prevention intervention for older people in Thailand should be a multifactorial programme delivered by multidisciplinary team of health care professionals.

Focusing on the effect of the home-based balance exercise intervention programme, there was no improvement in balance or mobility performance or any falls outcome measures found in the intervention group after the completion of the programme. The findings were not consistent with the findings previously reported from a number of randomized controlled trials as well as several systematic reviews regarding the effectiveness of exercise intervention in reducing falls risk and falls rate in older people.[3–6] The non-significant results might be explained by the design of the exercise programme in particular intensity, and challenges of the programme. In terms of intensity, the exercise programme in the present study was a four-month duration programme, which was less than the intensity recommended for exercise aiming to reduce falls by Sherrington *et al.*[5,6] Additionally, the exercises prescribed in this study could be less challenging to postural and balance control systems in particular participants who were healthy and still living actively in the community.[5,6] The mean age of participants of the study was approximately 70 s which was younger than participants (mean age 81.6 $\pm$ 3.9 years) of several randomized controlled trails found effectiveness of the Otago exercise programme reported in a recent systematic review and meta-analysis.[19] This could be affirmed by the findings that there was no significant improvement in physical performance outcomes such as strength and balance, and consequently the non-reduction in falls rate at post-intervention assessment. Future exercise programmes could be modified from the current one by increasing the duration of the programme to at least six months and increasing the intensity of each exercise session. In addition, exercises prescribed should effectively challenge healthy older people's postural and balance control. Even though the exercise programme has not been found to be effective in this study, the programme achieved a very high level of adherence. This is an encouraging finding that a home-based exercise intervention programme aiming to increase balance and mobility performance and consequently reduce risk of falling could be practically implemented in community-dwelling older people in Thailand.

Issues related to variation among participants of the study and the potential for other physical activity programmes involved in both control and intervention groups may have partly contributed to the lack of significant effects of the exercise programme. Participants of the study were recruited from several communities in urban and suburban areas. This may result in variation in physical health (i.e., the number of medical conditions of the included participants varied from 0 to 7 conditions), as well as variation in some socioeconomic factors including access to medical care, family support and education. Variation among participants could influence how the prescribed exercise and falls management strategies could be implemented by the participants in real practice. Therefore, future study aiming to develop practical falls prevention intervention programme in particular multifactorial type programme should take into consideration the participant's right to medical care and services.

There are limitations of the study. The lack of quantitative data is recorded on compliance of other falls risk management strategies apart from the exercise programme (e.g., home hazard modification, medications review, eye check). However, the results (number of home hazard environment, number of medications, number of participants using bifocal or multifocal eyeglasses, number of eye conditions and number of participants wearing inappropriate footwear) at the post-intervention which remained similar with those reported at the baseline assessment might assist in confirming the low compliance of the falls risk management strategies suggested for the study's participants. Future study should consider collecting participant compliance in every item of intervention and this would be beneficial in improving future falls risk management programme. A further limitation of the study is the high number of outcome measures of the study which may result in significance of the findings by statistical chance. To account for multiple variables, significant level at $p < 0.01$ might be considered. However, applying significant

level at $p < 0.01$ to the study did not change the current conclusion of study's findings.

Conclusion

Falls prevention programme focusing exercise programme could be implemented safely in community-dwelling older people in Thailand. However, the lack of effectiveness of the programme might be addressed by increasing the intensity and challenge of the exercise programme as well as tailoring the falls prevention programme with participant's right to medical care and services and delivering the programme by multidisciplinary team of health care professionals.

Conflict of Interest

The authors declare that there is no conflict of interest relevant to the study.

Funding/Support

The study was funded by the Health Systems Research Institute under the National Research Council of Thailand. We are grateful to all the participants of this study. We also acknowledge the assistance and support from the physiotherapists and staff from the Faculty of Allied Health Sciences, Thammasat University and the Faculty of Medicine Vajira Hospital, Bangkok.

Author Contributions

All authors contributed to the study concept and design. All project management aspects were mainly carried out by P. Suttanon. Data was collected by all authors. Data analysis and interpretation were mainly carried out by P. Suttanon with suggestions from all other authors. Drafting of the manuscript was conducted by P. Suttanon, with revision of the manuscript by all authors.

References

1. Gill T, Taylor AW, Pengelly A. A population-based survey of factors relating to the prevalence of falls in older people. Gerontology 2005;51:340–5.
2. Morris M, Osborne D, Hill K, et al. Predisposing factors for occasional and multiple falls in older Australians who live at home. Aust J Physiother 2004;50:153–9.
3. Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev 2009; doi:10.1002/14651858.CD007146.pub2.
4. Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev 2012;2012.
5. Sherrington C, Whitney JC, Lord SR, Herbert RD, Cumming RG, Close JC. Effective exercise for the prevention of falls: A systematic review and meta-analysis. J Am Geriatr Soc 2008;56:2234–43.
6. Sherrington C, Tiedemann A, Fairhall N, Close J, Lord SR. Exercise to prevent falls in older adults: An updated meta-analysis and best practice recommendations. N S W Public Health Bull 2011;22:78–83.
7. Piphatvanitcha N, Kespichayawattana J, Aungsuroch Y, Magilvy JK. State of sciences: Falls prevention program in community-dwelling elders. Thai J Surg 2007;28:9097.
8. Jitramontree N, Chatchaisucha S, Thaweeboon T, Kutintara B, Intanasak S. Action research development of a fall prevention program for Thai community-dwelling older persons. Pac Rim Int J Nurs Res 2015;19:69–79.
9. Thailand U. Population Ageing in Thailand: Prognosis and Policy Response. Bangkok: United Nations Population Fund, 2006:2–3.
10. Duncan PW, Weiner DK, Chandler J, Studenski S. Functional Reach: A new clinical measure of balance. J Gerontol 1990;45:M192–M7.
11. Kaufer DI, Cummings JL, Ketchel P, et al. Validation of the NPI-Q, a brief clinical form of the Neuropsychiatric Inventory. J Neuropsychiatry Clin Neurosci 2000;12:233–9.
12. Hill KD, Bernhardt J, McGann AM, Maltese D, Berkovits D. A new test of dynamic standing balance for stroke patients: Reliability, validity, and comparison with healthy elderly. Physiother Can 1996;48:257–62.
13. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical measurement of sit-to-stand performance in people with balance disorders: Validity of data for the Five-Times-Sit-to-Stand test. Phys Ther 2005;85:1034–45.
14. Podsiadlo D, Richardson S. The timed Up & Go: A test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39:142–8.
15. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go test. Phys Ther 2000;80:896–903.

16. Washburn RA, Ficker JL. Physical activity scale for the elderly (PASE): The relationship with activity measured by a portable accelerometer. J Sports Med Phys Fitness 1999;39:336–40.
17. Teri L, Gibbons LE, McCurry SM, et al. Exercise plus behavioral management in patients with Alzheimer disease: A randomized controlled trial. J Am Med Assoc 2003;250:2015–22.
18. Lord SR, Sherrington C, Menz HB, Close JC. Falls in Older People: Risk Factors and Strategies for Prevention. 2nd ed. New York: Cambridge University Press, 2007.
19. Thomas S, Mackintosh S, Halbert J. Does the 'Otago exercise programme' reduce mortality and falls in older adults? A systematic review and meta-analysis. Age and Ageing 2010;39:681–7.

Research Paper

Hong Kong Physiotherapy Journal
Vol. 38, No. 1 (2018) 13–22
DOI: 10.1142/S1013702518500026

Hong Kong Physiotherapy Journal
http://www.worldscientific.com/worldscinet/hkpj

Reliability and validity of a new clinical test for assessment of the sacroiliac joint dysfunction

Apurv Shimpi[1,*], Renuka Hatekar[2], Ashok Shyam[2] and Parag Sancheti[2]

[1]*Department of Community Physiotherapy*
Sancheti Institute College of Physiotherapy, Pune, India

[2]*Sancheti Hospital, Pune, India*

[*]*apurvshimpi@sha.edu.in*

Received 26 April 2016; Accepted 8 April 2017; Published 27 March 2018

Background: Dysfunctional sacroiliac joint (SIJ) has been cited as a source of low backache (LBA). Numerous non-invasive clinical tests are available for its assessment having poor validity and reliability which challenges their clinical utility. Thus, introduction of a new clinical test may be necessary.
Objective: To assess reliability and validity of a new clinical test for the assessment of patients with SIJ movement dysfunction.
Methods: Forty-five subjects (23 having LBA of SIJ origin and 22 healthy asymptomatic volunteers) with mean age 28.62 +/− 5.26 years were assessed by 2 blinded examiners for 3 different clinical tests of SIJ, including the new test. The obtained values were assessed for reliability by intraclass correlation, kappa coefficient and percentage agreement. Validity was assessed by averaging sensitivity and specificity. Positive and negative predictive values and accuracy were assessed.
Results: The new test demonstrates good intra- ($r = 0.81$) and inter-rater ($r = 0.82$) reliability with substantial agreement between raters ($k > 0.60$). It has 79.9% validity, 82% sensitivity, 77% specificity, 79% positive-predictive, 80% negative-predictive value and accuracy.
Conclusion: The new "Shimpi Prone SIJ test" has a good intra- and inter-rater reliability with a substantial rater agreement and a good validity and accuracy for the assessment of patients with SIJ movement dysfunction.

Keywords: Sacroiliac dysfunction; new clinical test; Shimpi test; validity; reliability.

[*]Corresponding author.

Introduction

Humans are bipedal locomotor animals who have the gift and the ability to ambulate on the hind limbs whilst functioning with the forelimbs. This adaptation allows humans to perform multiple tasks required for recreation or function or survival. The hind limb allows the person to attain stability as well as movement from one place to other.[1] Technology has enabled humans to invent multiple means and ways of obtaining this ambulation by virtue of the functional adaptation to the bipedal stance.[2]

This adaptation had come at its own costs wherein stability is challenged and compromised by loading the hind limbs with the complete body weight. As against in animals who demonstrate a cross loading of the forelimb and hind limb in slow ambulation and a reciprocal loading of front and hind limbs in fast ambulation, humans have to comprise by alternatively loading the hind limb in slow ambulation by having a double stance phase to an excessive loading in fast ambulation by having a double swing phase.[1] But, these motions alternatively load the lower limbs with 3 to 10 times the body loads and thus have proved to be detrimental in a long run.[2]

The load of the head, arms and trunk (HAT) is transmitted to the lower limbs via the pelvis, which consists of the Ilium, Ischium and the Pubis. This further transmits the body loads to the femur via the hip joint which is a synovial joint having three degrees of freedom of movement. But, the connection of the spine to the pelvis is via the sacroiliac joint (SIJ), which is a fibro-cartilaginous type of a joint with a limited mobility.[3,4] Although there has been a wide assumption that the SI is a joint with minimum mobility, it has been proved that this joint not only aids in load transmission from the axial skeleton to the appendicular skeleton, but also helps in providing motions to the pelvis which assists in effective load distribution and in providing an effective channel for the reduction of the pelvic mobility by absorption of shearing forces during normal ambulation.[2,3]

Low backache (LBA) is one of the most common complaints encountered in routine musculoskeletal practice. Although low back pain has been understood to be associated with a multitude of clinical findings like a prolapsed disc, facetal arthropathy or mechanical in nature, seldom there is a connection established between dysfunction of the SIJ and LBA.[5–7] Reduction in the mobility of the SIJ may result in inability of the spine to efficiently transmit loads to the lower limbs and thus may be a source of symptom.[7] SIJ maintains its stability by virtue of its shape (form closure) and its ability to exert and distribute forces from the trunk to the limbs (force closure). Dysfunction of the SIJ may be either due to the failure of the support system (force closure failure) or due to its inability to move during load transmissions (form closure failure) and thus lead to loss of function in the spine.[4,8,9]

Studies have reported motions in the SIJ from around 1–6 mm (1–9°) which efficiently help in the pelvic motions.[4,8] These motions may vary based on the movement initiation from trunk or the lower limbs.[4] Laslett has introduced multiple test batteries of using three or more tests for identifying SIJ pain. This is due to the fact that these tests are more reliable and valid in identifying SIJ pathology when used together rather than the tests employed for identifying the SIJ motions (dysfunction).[9] Thus, he proposed a variety of clinical tests that help to understand and evaluate the pain associated with dysfunction of the SIJ. Tests like sacral distraction/compression, thigh thrust, Gaenslen, sacral thrust, Patricks FABER, finger point, SIJ pain mapping, etc., have been used to understand SIJ pain with an extremely good efficiency as compared to the Gillet and other palpation-based tests.[9] There is a good validity and reliability for using these pain provocation tests in routine clinical practice.[10–16] But, the dysfunction tests are supposed to have a poor validity, high sensitivity and less specificity.[9] These tests require the performer to either perform active motions which are evaluated by the clinician by assessing the surface motions of the surrounding structures, or are based on elicitation of a clinical response from the patients, which is usually in the form of pain and movement dysfunction in the articular region.[4,6,17] Thus, the presence of pain and assessment of loss of motion have been considered as the source of diagnosis. But, the most common factor shared by almost all of these tests is the performance of specific motions or movements, either passively or actively, requiring a detailed understanding of the motions of the sacrum over the innominate and also understanding and identifying the surface landmarks which may, at times, be challenging. Also, few of these tests may require an appropriate exposure of the surface regions, which may be a challenge in few of the cultures.[4,17,18] Thus, there is

a need to develop and understand a clinical test for assessment of SIJ dysfunction which may require the patient to perform controlled motions without exposure of the body parts and to avoid challenges to the examiner in knowing the motions of the surface areas in relation to each other.[19,20]

Methods

Post approval from the institutional ethical committee, a diagnostic study for evaluation of reliability and validity of a new clinical test for assessment of SIJ dysfunction was conducted in a secondary healthcare center in Pune city, India consisting of mixed population. About 128 patients of LBA were referred for Physical Therapy treatment by three Orthopedic Surgeons from July to December 2015 and were screened by an independent post graduate Physical Therapist with eight years of experience and who was not part of the study authors. Thirty-nine subjects from these were considered as patients with SIJ involvement based on non-centralized pain, asymmetry of presentation below L5 spinous process and localizing to the SIJ.[9] Patients who had presented with clinical symptoms of LBA since minimum one month with pain from visual analog scale (VAS) 2–8 of 10, which was non-radiating and localized asymmetrically to the SIJ, were selected. These subjects had been ruled out for any spinal pathology like prolapsed inter-vertebral disc, spinal malignancies, Potts spine, etc. by the concerned referring orthopedic surgeons based on clinical and radiological findings. The independent assessor also assessed the subjects for the basic demographic details and for pain duration (in months) and intensity on a 0–10 VAS.

Healthy subjects who were accompanying their relatives for Physical Therapy and were asymptomatic for any back pain or dysfunction and without any history of LBA in the last three years and willing for voluntary participation in the study without any coercion were also recruited. Post a written informed consent; all the participants were assessed for SIJ mobility by the Gillet test[20–22] (also known as March/Stalk/sacral fixation test), SIJ pain provocation by the Gaenslen test[11,12] and the new test for SIJ dysfunction, termed as the "Shimpi Prone SIJ test" by two independent assessors. Since the objective of the study was to assess the efficacy of the new test (measured by its validity, reliability, sensitivity and specificity) in assessment of SIJ dysfunction as against the current SIJ pain and dysfunction tests, the most common tests used widely for diagnosis of SIJ pathology in the given clinical setup and having a good reliability and validity were chosen.[10,11,22–24] The Gillet test (validity 55.5%[10,23]) and Gaenslen test (validity 48.5%[10]; 56.5%[23]; 65%[25]) were considered as reference tests for the given study as they are being widely used in the current clinical setup rather than the Laslett battery. The gold standard fluoroscopically guided pain block injections test for SIJ dysfunction, which is an invasive procedure by administration of an injection to the SIJ, could not be considered in the present study.[10,18–21]

Assessor 1, who was a Physical Therapist with three years of clinical experience and trained in spinal biomechanical assessment, assessed the subjects twice on day 1 after an interval of 30 min. Assessor 2, who was a Physical Therapist with 11 years of clinical experience and trained in spinal biomechanical assessment, assessed the subjects once on day 2.[10–12] Both the assessors were blinded towards the findings of the other assessor. For subjects presenting with LBA, the SIJ of the painful side was considered for assessment while for the asymptomatic volunteers; any SIJ was taken on a random basis. The patients were asked to give a positive response to pain only if they experienced the familiar pain that they were experiencing due to the SIJ involvement (for the Gaenslen and Shimpi tests).

The Gillets test (March/Stalk/sacral fixation test)[11,22] (Fig. 1) and Gaenslens test[11,12] (Fig. 2) were performed on all the subjects in standing and supine lying position, respectively. The Shimpi Prone SIJ test (new test) was performed with the subject in a prone lying position on a plinth. The assessor palpated for the anterior superior iliac spine (ASIS) and placed the palm of their hand underneath the ASIS. The subject was instructed to extend their hip to around 15° so as to lift the foot just off the examination table (Fig. 3). A normal response to the SIJ movement, i.e., a negative test, was considered when the ASIS was pressed more on the palm of the assessor without the presence of any pain or discomfort. An abnormal response of the SIJ movement, i.e., a positive test, was considered when the ASIS was lifted off the palm of the assessor and concurrently patient experiencing familiar pain or discomfort localized to the SIJ.

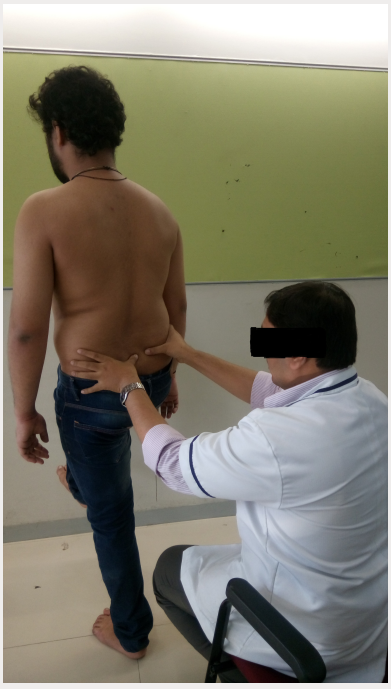


Fig. 1. Gillet test for SIJ dysfunction.

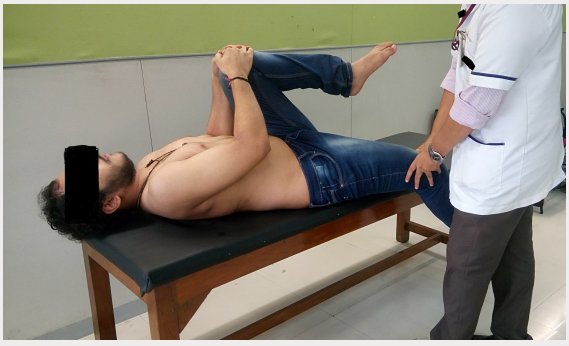


Fig. 2. Gaenslen test for SIJ dysfunction.

Statistical analysis

A sample size of 30 was calculated for the study considering the proportion of positive rating for a dichotomous variable by two raters at 0.5 and kappa coefficient set at ≥ 0.6 for a two-tailed test with power at 90%.[26] An independent sample t-test was used to compare the baseline parameters between both the groups with an alpha level set at ≤ 0.05. The obtained results of all participants were assessed for intra-tester and inter-tester reliability by interclass correlation coefficient (ICC)

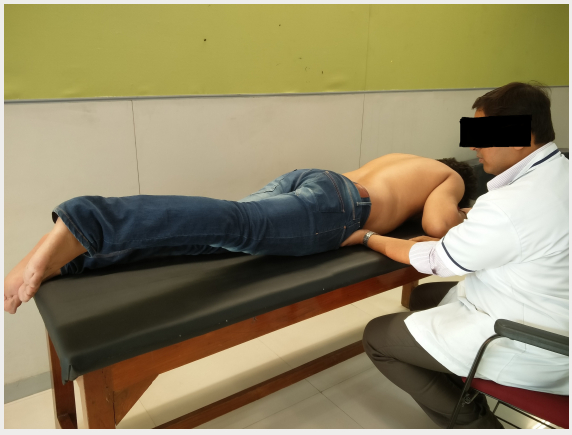


Fig. 3. Shimpi prone SIJ test.

Cronbach's alpha set at 80%[27] and by kappa coefficient set at $k \geq 0.6$[26] by SPSS version 17 (IBM Corporation). The sensitivity, specificity, positive and negative predicted values and accuracy of the tests were set at 80%[25] and were calculated by "Microsoft Office Excel 2010". The Validity was calculated as the average of the sensitivity and specificity and measured in percentages.[23]

Results

Of the 39 patients with SIJ dysfunction, 9 subjects had severe pain with VAS > 8 of 10, acute tenderness on movement with inability to tolerate the tests, and hence were excluded, while 7 patients did not consent for study participation and 23 subjects with LBA having pain from around 1–8 months with intensity from 2–7 on VAS along with 22 healthy volunteers participated in the study (Fig. 4). Both the groups were age matched and comparable post performing an independent sample t-test ($p = 0.26$). The analysis for the intra-rater and intra-rater reliability showed a good correlation by the ICC ($r > 0.8$) and a substantial agreement by the kappa coefficient ($k > 0.6$), both at 95% CI for the Shimpi Prone SIJ test. The test also showed good validity (79.9%) as compared to the other two tests, which was measured in terms of averaging the sensitivity (82%) and specificity (77%), 79% positive predictive, 80% negative predictive values and 80% accuracy (Tables 1–3).

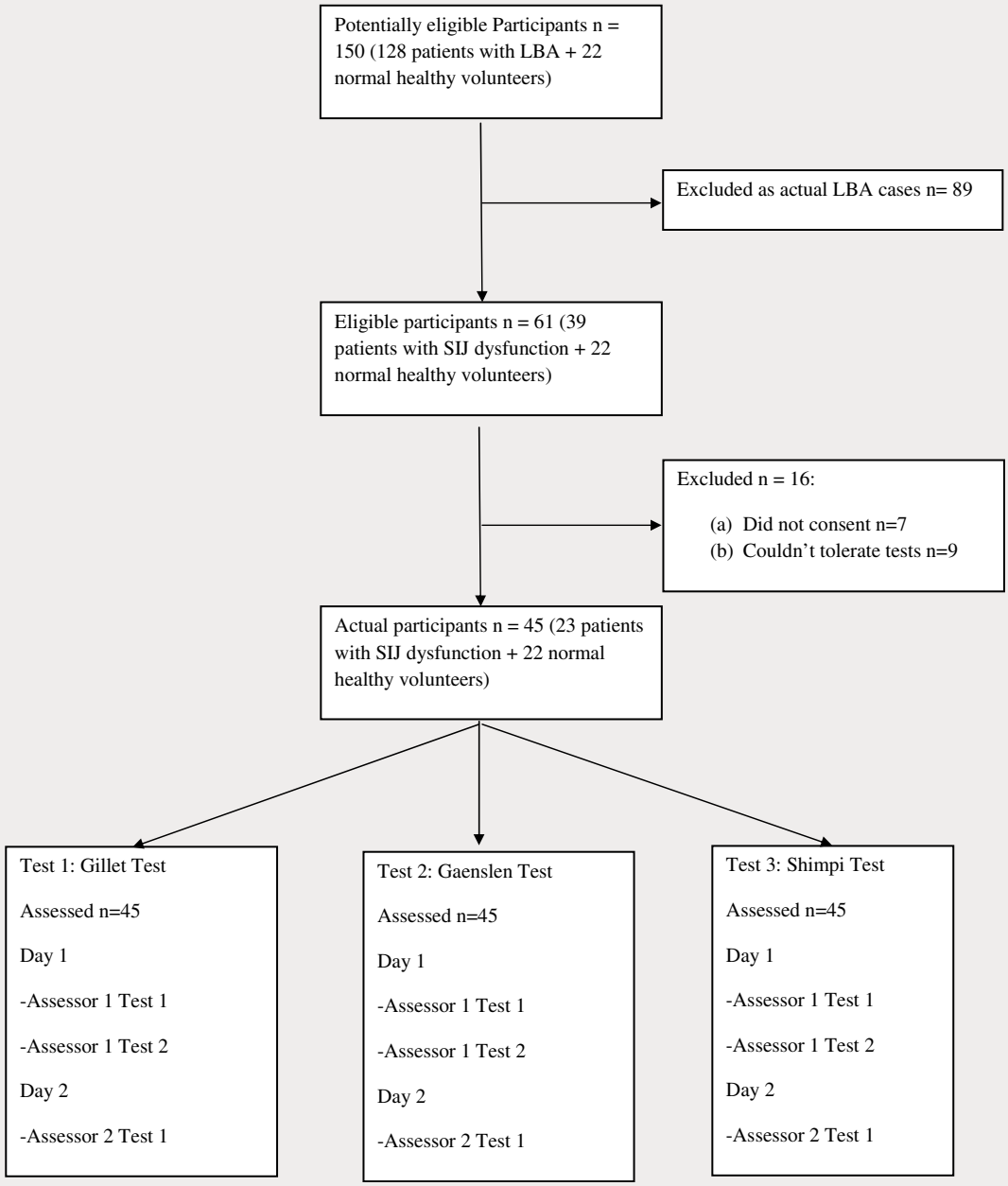


Fig. 4. STARD flowchart of participant's recruitment.

Table 1. Demographic details of the study participants.

Demographics	Subjects with low back pain	Subjects without back pain	Total	*P* value
Mean age (SD) (in years)	29.4 (4.5)	27.8 (6.1)	28.6 (5.3)	0.265
Females: Males (number)	13:10	13:9	26:19	
Total (number)	23	22	45	
Duration of pain (SD) (months)	4.0 (2.3)	—	—	
Pain intensity (SD) (VAS/10)	4.4 (1.7)	—	—	
Females with history of childbirth (number)	5	3	8	

Note: SD = Standard deviation expressed as +/− mean scores; VAS = Visual analog scale; p = probability value (alpha) significant at ≤ 0.05.

Table 2. Reliability of the Shimpi Prone SIJ test (new test) using ICC and Kappa coefficients.

Test	Intra-rater		Inter-rater	
	95% CI		95% CI	
ICC (r)	0.81	0.66–0.89 ($p = 0.000$)	0.82	0.67–0.90 ($p = 0.000$)
Kappa coefficient (k)	0.68	0.47–0.90	0.69	0.48–0.89
Prevalence index	0.08		0	
Bias index	0.02		0.06	
Percent agreement (%)	84		84	
Unachieved agreement ($1 - k$) (%)	31		30	
Maximum attainable kappa (k max)	0.95	0.85–1.0	0.86	0.72–1.0
Greatest possible agreement (%)	97		93	

Note: ICC = Intraclass correlation coefficient; 95% CI = 95% confidence interval; p = probability value (alpha) significant at ≤ 0.05.

Table 3. Validity of the three tests (averaged with the sensitivity and specificity expressed as percentages) as obtained in present study.

Test	Gillet test	Gaenslen test	Shimpi Prone SIJ test
Validity (%) (SD)	62.54 (20.82)	71.14 (2.23)	79.94 (3.77)

Note: SD = Standard Deviation expressed as +/− mean.

Discussion

The SIJ is poorly understood in its functional role.[28] The dysfunctional SIJ has been cited as a source of low back pain by many authors.[6–19,24,25,28] Symptoms can include pain in the low back, buttock region, pain radiating to thigh region or one side of the body.[29] The primary function of the SIJ is load transfer which is largely dependent on its available mobility and joint stability. It also functions in torque conversion, allowing the transverse rotations that take place in the lower extremity to be transmitted up the spine. The SIJ, like all lower extremity joints, provides a "self-locking" mechanism, where the joint occupies or attains its most congruent position, i.e., the close pack position by the form closure. This helps with stability during the push-off phase of walking. The joint locks (or rather becomes close packed) on one side as weight is transferred from one leg to the other, and through the pelvis, the body weight is transmitted from the sacrum to the hip bone.[30] Compared to the quadruped gait, the bipedal gait needs to have a very strong support to overcome the resistance from gravity. In the upright posture, increased lumbo pelvic compression forces are necessary for stability, which occur at the expense of the joint mobility.[31] This compromise is done by the SIJ.

The SIJ is a true diarthrodial synovial joint, and is unlike any other joint in the body wherein only the ventral third of the joint is a true synovial joint.[29] The pelvis comprises of an arch system which helps in transmitting force across this joint. The posterior arch transmits body weight while the anterior arch provides stability to the posterior arch, and acts as a compression strut for the ground reaction forces which transmits through the femur and across the pubic rami.[32] Normal motions of the SIJ are Nutation and Counter Nutation.[4,29] Nutation of the sacrum is the anterior tilting and rotatory motion of the sacrum wherein the articular surfaces of the innominate move posterior–inferior on the sacrum (Fig. 5). The counter-nutation exhibits the opposite motion. These movements are opposed by the shape of the sacrum, ligamentus system and the friction coefficient of the joint surface. Disturbances in these motions are exhibited as increased linear and angular motions over the lumbosacral junction as well as increased motions of the hip.[33] These movements can never be isolated in a closed chain as the lumbopelvic motions function as an entire biomechanical unit which can be

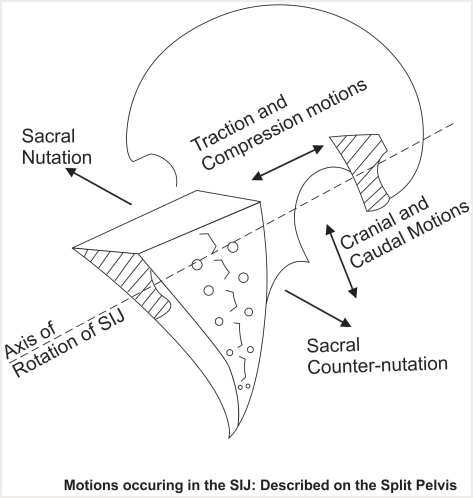


Fig. 5. Normal motions of the SIJ.

understood in many routine activities of daily living, including the normal human bipedal gait.[4] But, these motions are too complicated to be assessed in routine clinical assessments and thus, to examine the SIJ, a series of tests have been proposed in an open-chain fashion. Goode *et al.* have documented extremely minimal movement of the SIJ and have questioned the validity and clinical utility of such movement dysfunction studies, like the Gillet test, which rely on motion production, in diagnosing the SIJ pathology.[4]

Tests for the SIJ basically look at two components: (a) mobility of the SIJ in terms of a translatoric glide (movement based tests) and (b) mobility of the SIJ in terms of traction or compression of the joint surfaces (pain provocation-based tests). Such tests can also be performed by loading the joint surfaces for their ability to transfer loads through the posterior arch system.[34] Most of the movement dysfunction tests of SIJ make it difficult to stabilize the proximal sacral component whilst assessing the movement of the innominate over it. As a closed kinematic system, it may be difficult to restrict motions only to the side being tested and authors feel that there is always a probability of the motions being transferred/translated to the contra lateral SIJ as well. But, the lumbosacral motions, in the absence of clinical motions in SIJ during hypomobile pathology, can be used clinically to establish the diagnosis. Dysfunction of the SIJ may occur due to the reduction in the nutation or counter-nutation motions which may be presented clinically as SIJ pain (radiating or non-radiating to the posterior of the thigh) or rarely as low back pain (due to the transfer of the shearing forces on the lumbosacral junction).[34,35] Thus, there arises a need to identify such SIJ dysfunctions faster and with good accuracy in routine clinical practice.

The "Shimpi Prone SIJ test" is based on a normal versus an abnormal clinical response to SIJ mobility along with pain provocation. The assessor checks the movement of the SIJ in a prone position by asking the patient to actively lift the leg off the examination table (Hip extension to 15°). Also, the patient has to report for the presence of familiar pain in the SIJ during this motion. When this movement is performed actively, the gluteus maximus, assisted by the hamstrings, lifts the leg off to perform hip extension. This can be done only when the back muscles, the multifidi and erector spinae, stabilize the vertebrae thereby allowing the hip extensors to act on the pelvis and the thigh. The gluteus connects to the thoracolumbar fascia and performing the extension motion by the glutei also adds to the SIJ stability by virtue of force closure of the pelvis and obtaining a dynamic stability to it. Also, the deep group of back muscles, the multifidi, helps in dynamically stabilizing the spine thereby preventing any excessive motion in the vertebral column. Such compressive and translatoric forces acting across the SIJ may provoke the pain within the joint region by stimulating the intra-articular nociceptive structures within the joint[35–37] and may be the reason for the pain response in the Shimpi test.

Mobility in the Shimpi test includes movement at the lumbosacral junction and allows extension of the hip (acetabulofemoral) joint by causing a counter-nutation motion of the SIJ. A normal response in performing hip extension is the initiation of extension at the lower lumbar and lumbosacral regions along with an anterior rotation of the pelvis (pelvic nutation) and the extension of the hip. These motions cause the ASIS to move ventrally and press on the palm of the examiner under the ASIS (Fig. 6).[15,18,35] A dysfunctional SIJ would have a reduced motion and thus, when active extension is initiated, the possible movements would be the extension at the lower lumbar, lumbosacral regions along with the hip extension.[18] The absence of pelvic nutation would cause the entire ipsilateral pelvis to get lifted off the examination table (Fig. 6). This mechanism, in addition to the elicitation of pain, is used in the Shimpi test to assess

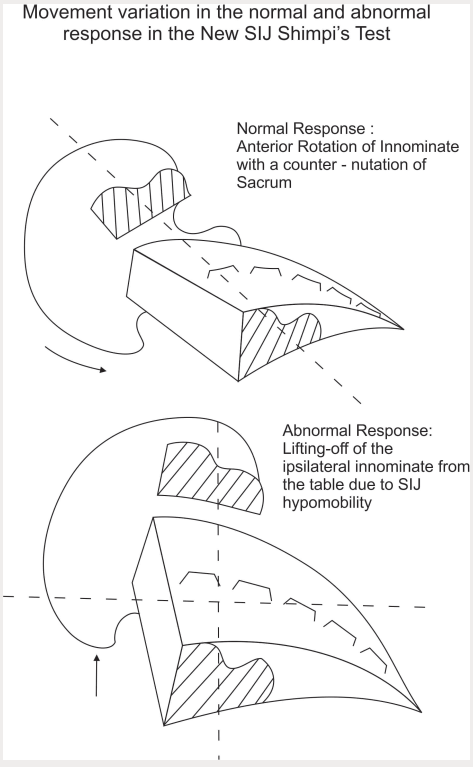


Fig. 6. Normal (above) and abnormal (below) response to the Shimpi test.

SIJ dysfunction. The motion-based tests available currently attempt to assess the minimal motions in the SIJ in isolation which is their limitation.[4] But, using the motions of the lumbar and lumbosacral unit, motion dysfunction at the SIJ can be assessed by the Shimpi test with repeatability and accuracy making it a clinically highly reliable (intra- and inter-rater) and valid (79.9%) motion-based assessment test.

The Shimpi test is fairly identical to the anterior SLR (ASLR) test which assesses the pelvic girdle pain by loading the SIJ during an active leg lift to around 20 cm.[38] The ASLR test would be based on various factors, including the lower limb strength and the abdominal bracing ability.[39] But, as the range of hip flexion is greater than extension, there is no incorporation of pelvic motion till later 2/3rd of its movement. Also, it becomes difficult to identify movement dysfunction with this test. Shimpi test, unlike the ASLR, not only loads the SIJ for elicitation of familiar pain, but also assesses the motion of the pelvic region by ASIS lift and thus provides a double check system for diagnosing SIJ pathology. The Shimpi's test can easily be performed even in obese patients and does not even require exposure of the low back and gluteal region which is ethically acceptable in many cultures. The only pre-requisite is the skill of identification and palpation of the ASIS, which is a bony landmark and an easily recognizable one in most of the population.[33] Also, the patient lies in a comfortable prone position and does not possess difficulties for stability or balance concerns. The motion required is just an active 15° hip extension which can initiate and differentiate between a normal and abnormal response of the SIJ.

The limitations in performance of this test would be the requirement to lie in a prone position. This may be a challenge in severely obese patients or in pregnant females in their 2nd and 3rd trimester who are frequently predisposed to SIJ dysfunction.[14,15,35] Also, patients with weaknesses of the erector spinae, multifidi or gluteus maximus and hamstrings may be unable to perform this movement actively.[36] Also, this test largely relies in the motion of the hip joint and would not be useful in diagnosing SIJ pathologies in the presence of hip joint pathologies like Avascular Necrosis or Hip Osteoarthritis which may limit motions and thus may not be a good tool for assessment in them. The assessor may also need to get conditioned to gauging the pressures exerted by the SIJ during normal and abnormal motions, especially, in conditions with lower cross syndromes, etc. But such skills can be easily gained with training and experience.

Conclusion

The authors would like to conclude by introducing the "Shimpi Prone SIJ test" as an extremely useful non-invasive clinical tool having a good intra- and inter-rater reliability with a substantial rater agreement and having a good validity and accuracy for the assessment of the SIJ in patients with SIJ movement dysfunction.

Conflict of Interest

All contributing authors declare that they have no conflicts of interest.

Funding/Support

No financial or material support of any kind was received for the work described in this paper. The authors would like to acknowledge the patients as well as the healthy volunteers who participated in

the study. The authors would also like to acknowledge the help of Mrs. Aruna Deshpande, Biostatistician, for her help with the statistical analysis of the study, Mr. Sanjay Bhope for the computer images and Dr. Rachana Dabadghav (PT) for all her valuable contribution.

Author Contributions

The study concept and design, data acquisition, data analysis and interpretation and manuscript drafting were carried out by Apurv Shimpi. Renuka Hatekar contributed to data acquisition and manuscript drafting. Ashok Shyam contributed to manuscript revision and critical analysis and the project management and manuscript approval were carried out by Parag Sancheti.

References

1. Harcourt-Smith WE, Aiello LC. Fossils, feet and the evolution of human bipedal locomotion. J Anat 2004;204(5):403–16.
2. Niemitz C. The evolution of the upright posture and gait — A review and a new synthesis. Naturwissenschaften 2010;97(3):241–63, doi: 10.1007/s00114-009-0637-3.
3. Shi D, Wang F, Wang D, Li X, Wang Q. 3-D finite element analysis of the influence of synovial condition in sacroiliac joint on the load transmission in human pelvic system. Med Eng Phys 2014;36(6):745–53, doi: 10.1016/j.medengphy.2014.01.002.
4. Goode A, Hegedus EJ, Sizer P, Brismee JM, Linberg A, Cook CE. Three-dimensional movements of the sacroiliac joint: A systematic review of the literature and assessment of clinical utility. J Man Manip Ther 2008;16(1):25–38.
5. Simpson R, Gemmell H. Accuracy of spinal orthopaedic tests: A systematic review. Chiropr Osteopat 2006;14:26.
6. Vleeming A, Albert HB, Ostgaard HC, Sturesson B, Stuge B. European guidelines for the diagnosis and treatment of pelvic girdle pain. Eur Spine J 2008;17(6):794–819, doi: 10.1007/s00586-008-0602-4.
7. Polly DW, Cher D. Ignoring the sacroiliac joint in chronic low back pain is costly. Clinicoecon Outcomes Res 2016;8:23–31, doi: 10.2147/CEOR.S97345.
8. Vleeming A, Schuenke MD, Masi AT, Carreiro JE, Danneels L, Willard FH. The sacroiliac joint: An overview of its anatomy, function and potential clinical implications. J Anat 2012;221(6):537–67, doi: 10.1111/j.1469-7580.2012.01564.x.
9. Laslett M. Evidence-based diagnosis and treatment of the painful sacroiliac joint. J Man Manip Ther 2008;16(3):142–52.
10. Stuber KJ. Specificity, sensitivity, and predictive values of clinical tests of the sacroiliac joint: A systematic review of the literature. J Can Chiropr Assoc 2007;51(1):30–41.
11. Cattley P, Winyard J, Trevaskis J, Eaton S. Validity and reliability of clinical tests for the sacroiliac joint. A review of literature. Australas Chiropr Osteopa 2002;10(2):73–80.
12. Laslett M, Williams M. The reliability of selected pain provocation tests for sacroiliac joint pathology. Spine 1994;19(11):1243–9.
13. Hansen HC, McKenzie-Brown AM, Cohen SP, Swicegood JR, Colson JD, Manchikanti L. Sacroiliac joint interventions: A systematic review. Pain Physician 2007;10(1):165–84.
14. McKenzie-Brown AM, Shah RV, Sehgal N, Everett CR. A systematic review of sacroiliac joint interventions. Pain Physician 2005;8(1):115–25.
15. Szadek KM, van der Wurff P, van Tulder MW, Zuurmond WW, Perez RS. Diagnostic validity of criteria for sacroiliac joint pain: A systematic review. J Pain 2009;10(4):354–68, doi: 10.1016/j.jpain.2008.09.014.
16. Kokmeyer DJ, van der Wurff P, Aufdemkampe G, Fickenscher TCM. The reliability of multitest regimens with sacroiliac pain provocation tests. J Manip Physiol Ther 2002;25:42–48.
17. Bates CK, Carroll N, Potter J. The challenging pelvic examination. J Gen Intern Med 2011;26(6):651–7, doi: 10.1007/s11606-010-1610-8.
18. Simopoulos TT, Manchikanti L, Singh V, Gupta S, Hameed H, Diwan S, Cohen SP. A systematic evaluation of prevalence and diagnostic accuracy of sacroiliac joint interventions. Pain Physician 2012;15(3):E305–44.
19. Mitchell B, Verrils P, Vivian D. Sacroiliac joint pain: Diagnosis and treatment. Australas Musculoskelet Med 2012;17(1):15–24. Availabe at http://search.informit.com.au/documentSummary;dn=482415868079808;res=IELHEA.
20. Cohen SP, Chen Y, Neufeld NJ. Sacroiliac joint pain: A comprehensive review of epidemiology, diagnosis and treatment. Expert Rev Neurother 2013;13(1):99–116, doi: 10.1586/ern.12.148.
21. Savran Sahin B, Aktas E, Haberal B, et al. Sacroiliac pain and CT-guided steroid injection treatment: High-grade arthritis has an adverse effect on outcomes in long-term follow-up. Eur Rev Med Pharmacol Sci 2015;19(15):2804–11.
22. Meijne W, Van Neerbos K, Aufdemkampe G. Intraexaminer and interexaminer reliability of the Gillet test. J Manip Physiol Ther 1999;22:4–9.

23. Mangen J, Folia V. Validity of clinical tests for sacroiliac and lumbar joint dysfunction: A systematic review of literature. 2009. Available at http://kennisbank.hva.nl/document/219268.
24. Arab AM, Abdollahi I, Joghataei MT, Golafshani Z, Kazemnejad A. Inter- and intra-examiner reliability of single and composites of selected motion palpation and pain provocation tests for sacroiliac joint. Man Ther 2009;14(2):213–21, doi: 10.1016/j.math.2008.02.004.
25. Nicholls B, Thompson J. Reliability and validity of selected pain provocation tests at the sacroiliac joint. Available at http://vuir.vu.edu.au/932/1/Thompson_et.al_2003.pdf.
26. Sim J, Wright CC. The kappa statistic in reliability studies: Use, interpretation, and sample size requirements. Phys Ther 2005;85(3):257–68.
27. Domholdt E. Physical therapy research. In: Priniciples and Application. 2nd ed. Philadelphia, PA: WB Saunders Co. 2000.
28. Beal MC. The sacroiliac problem: Review of anatomy, mechanics, and diagnosis. J Am Osteopath Assoc 1982;81:667–79.
29. Kapandji IA. The Physiology of the Joints. Vol 3. New York: Churchill Livingstone, 1974:54–71.
30. Ward C. Interpreting the posture and locomotion of Australopithecus afarensis: Where do we stand? Am J Phys Anthropol 2002;119(S35):185–215.
31. Yin W, Willard F, Carreiro J, et al. Sensory stimulation-guided sacroiliac joint radiofrequency neurotomy: Technique based on neuroanatomy of the dorsal sacral plexus. Spine 2003;28:2419–25.
32. Poley RE, Borchers JR. Sacroiliac joint dysfunction: Evaluation and treatment. Phys Sportsmed 2008;36(1):42–9, doi: 10.3810/psm.2008.12.10.
33. Stovall BA, Bae S, Kumar S. Anterior superior iliac spine asymmetry assessment on a novel pelvic model: An investigation of accuracy and reliability. J Manip Physiol Ther 2010;33(5):378–85, doi: 10.1016/j.jmpt.2010.05.005.
34. Harrison DE, Harrison DD, Troyanovich SJ. The sacroiliac joint: A review of anatomy and biomechanics with clinical implications. J Manip Physiol Ther 1997;20(9):607–17.
35. Ilaslan H, Arslan A, Koç ON, Dalkiliç T, Naderi S. Sacroiliac joint dysfunction. Turk Neurosurg 2010;20(3):398–401, doi: 10.5137/1019-5149.JTN.2612-09.2.
36. Haufe SM, Mork AR. Sacroiliac joint debridement: A novel technique for the treatment of sacroiliac joint pain. Photomed Laser Surg 2005;23(6):596–8.
37. Szadek KM, Hoogland PV, Zuurmond WW, De Lange JJ, Perez RS. Possible nociceptive structures in the sacroiliac joint cartilage: An immunohistochemical study. Clin Anat 2010;23(2):192–8, doi: 10.1002/ca.20908.
38. Liebenson C, Karpowicz AM, Brown SH, Howarth SJ, McGill SM. The active straight leg raise test and lumbar spine stability. PM R 2009;1(6):530–5, doi: 0.1016/j.pmrj.2009.03.007.
39. Hu H, Meijer OG, Hodges PW, et al. Understanding the Active Straight Leg Raise (ASLR): An electromyographic study in healthy subjects. Man Ther 2012;17(6):531–7, doi: 10.1016/j.math.2012.05.010.

Research Paper

Hong Kong Physiotherapy Journal
Vol. 38, No. 1 (2018) 23–31
DOI: 10.1142/S1013702518500038

Hong Kong Physiotherapy Journal
http://www.worldscientific.com/worldscinet/hkpj

Effect of exercise therapy combined with branched-chain amino acid supplementation on muscle strengthening in persons with osteoarthritis

Takashi Ikeda[1,2,*], Tetsuya Jinno[2], Tadashi Masuda[3], Junya Aizawa[4], Kazunari Ninomiya[5], Koji Suzuki[5] and Kazuo Hirakawa[5]

[1]*School of Nursing and Rehabilitation Sciences, Showa University, Yokohama, Japan*

[2]*Department of Rehabilitation Medicine*
Tokyo Medical and Dental University Graduate School, Tokyo, Japan

[3]*Faculty of Symbiotic Systems Science, Fukushima University, Japan*

[4]*Clinical Center for Sports Medicine & Sports Dentistry*
Tokyo Medical and Dental University, Tokyo, Japan

[5]*Shonan Kamakura Joint Reconstruction Center, Kamakura, Japan*

[*]*tk.ikeda@nr.showa-u.ac.jp*

Received 19 October 2016; Accepted 19 July 2017; Published 27 March 2018

Background: Improving lower limb muscle strength is important in preventing progression of osteoarthritis (OA) and its symptoms. Exercise with branched-chain amino acid (BCAA) supplementation has been reported to affect protein anabolism in young and elderly persons. However, few studies provided daily BCAAs for patients with OA.
Objective: This study examined the effects of combined BCAAs and exercise therapy on physical function improvement in women with hip OA scheduled for total hip arthroplasty.
Methods: The subjects were 43 women with OA (age: 64.2 ± 9.4). The participants were randomly divided into two groups: BCAA ($n = 21$) and control ($n = 22$). The combined therapy was carried out for one month. Exercise intervention involved hip abductor muscle exercise in both groups. For the nutritional intervention, 6 g of BCAAs or 1.2 g of starch were consumed within 10 min before starting the exercise.

[*]Corresponding author.

Results: There was a marginally significant difference in the main effect between the groups in 10-m timed gait time. The improvement rate in hip abductor muscle strength of the contralateral side was significantly greater in the BCAA group.
Conclusion: By combining BCAA intake and exercise therapy, a significant improvement in hip abductor muscle strength of the contralateral side was achieved in women with OA.

Keywords: Amino acid supplementation; combined therapy; exercise therapy; muscle strength; osteoarthritis.

Introduction

Hip osteoarthritis (OA) can cause worsening of mechanical dynamic efficiency due to shortening of the lever arm associated with joint deformity. Moreover, activity restriction due to joint pain and limited range of motion (ROM) and muscle weakness due to disuse may occur. Liu *et al.*[1] reported a significant decrease in cross-sectional area and length of the gluteus medius muscle in patients with hip dysplasia compared to the healthy side. Rosemann *et al.*[2] found that physical activity in OA patients was affected by limited lower limb function, pain and disease duration. Because decreased lower limb muscle strength further reduces physical activity and function associated with disuse, improving lower limb muscle strength is important in preventing OA progression and symptoms. Effective exercise therapy for OA includes pool exercises and muscle strengthening exercises,[3] but exercise intensity and specific regimens have not been established.[4]

In recent years, the effects of amino acid ingestion have actively been investigated in nutritional science, and an effect on muscle protein anabolism has been demonstrated physiologically. Muscle protein metabolism requires more branched-chain amino acids (BCAAs), particularly more in older than in younger persons.[5] In addition, the BCAA uptake response is reduced[6] and delayed[7] with aging.

In regard to muscle protein synthesis, Burd *et al.*[8] reported that amino acid uptake into the vastus lateralis muscle stops after a certain amount, even though serum amino acid levels remain elevated. However, exercise combined with amino acid ingestion increases this uptake, and this increase may continue for up to 24 h in recreationally active men. In terms of muscle strengthening, low-load high-volume exercise stimulates muscle protein synthesis at the vastus lateralis muscle more than high-load low-volume exercise in young men.[9] Combined treatment using BCAAs with low-load high-volume exercise, even twice weekly in frail elderly persons, can effectively strengthen muscles (quadriceps and gluteus maximus).[10] These studies[8–10] suggest that low-load exercise can strengthen muscles, and when combined with BCAAs, it may be more effective in muscle strengthening.

Therefore, this study investigated the effects of combined treatment with muscle strengthening exercises and BCAA supplementation on improving muscle strength in OA patients.

Methods

Subjects

The eligible patients were 55 women with secondary hip OA scheduled for primary unilateral total hip arthroplasty (THA) with a delay of 1.5 months. Exclusion criteria were as follows: patients with Charnley classes B and C; rheumatoid arthritis; osteonecrosis; untreated OA on the contralateral side hip; previous surgery on the affected hip; disorders of the nervous system and muscles; dementia; or a schizophrenic disorder. Recruitment was conducted at Shonan Kamakura Joint Reconstruction Center from February 1, 2015 to June 1, 2015. The follow-up was conducted 1 month after the pre-intervention period.

This trial was registered at UMIN-CTR clinical trial as UMIN000016333. The trial protocol of this paper can be found at https://upload.umin.ac.jp/cgi-open-bin/ctr/ctr.cgi?function=brows&action=brows&recptno=R000016333&type=summary&language =E

The Tokushukai Group Ethics Committee approved the study protocol (ID: TGE00454-115). The intervention procedures were fully explained to all participants, and their written, informed consent was obtained. Twelve patients were excluded; 6 met the exclusion criteria, and 6 declined to participate. The demographic data of the 43 participants (age: 64.2 ± 9.4 years) are presented in Table 1.

Table 1. Demographic data of the patients.

		BCAA group ($n = 21$)	Control group ($n = 22$)
Age		63.6 ± 8.9	64.8 ± 9.9
BMI		24.4 ± 4.4	23.9 ± 4.5
Comorbidity index		1.3 ± 1.9	1.1 ± 1.8
FAI		28.3 ± 6.6	29.2 ± 5.7
JHEQ (score)	Pain score	8.6 ± 4.7	11.6 ± 6.7
	Mental score	9.6 ± 5.2	12.2 ± 6.2
Analgesic medicines (times of doses)	Tramadol	5.5 ± 17.7	2.7 ± 12.2
	Acetaminophen	10.9 ± 22.9	5.5 ± 17.5
	NSAIDs	8.0 ± 22.1	6.2 ± 21.3

Experimental design

A single-blinded, randomized experimental study was designed. A one-month period of supplementation was combined with exercise.

The Clinical Trial Center of Shonan Kamakura Joint Reconstruction Center created the assignment list using computer-generated random numbers in advance. Participants were allocated a code number in order of recruitment. Randomization was performed using the assignment list and the code number after recruitment to the study. The subjects were randomly divided into two groups: the BCAA group ($n = 21$) and the control group ($n = 22$). The chief-researcher (IK) was informed of the allocation using the number container method from the Clinical Trial Center.

Interventions

BCAA supplementation

BCAA supplementation was conducted on the basis of Kim *et al.*[11] and Ikeda *et al.*[10] A BCAA supplement was provided every day for participants in the BCAA group. Within 10 min before the exercise, participants ingested a 6-g tablet amino acid supplement (6 tablets, amino-vital tablet, Ajinomoto Co., Inc., Tokyo, Japan). The supplement contained 500 mg of amino acids per 1 g: 260 mg of BCAA and 240 mg of conditionally essential amino acids (105 mg leucine, 85 mg isoleucine, 70 mg valine, 123 mg glutamate and 117 mg arginine; the percentage content of leucine was 21%). Starch was provided for participants in the control group every day. Within 10 min before starting exercise, participants ingested 1.2-g starch (6 tablets). BCAA supplements and starch were taken with 200-mL water. Amino acid supplementation contained 3 g of amino acids per 6 g. Starch, a polysaccharide, did not contain amino acids.

A comparison study[12] of supplementation before and after exercise indicated that post-exercise supplementation had better effectiveness than pre-exercise supplementation. In the present study, however, supplementation was performed before exercise to gain a greater effect on muscle protein kinetics[13] and to prevent muscle soreness during and after exercise,[14,15] considering the low exercise tolerance of patients with OA.

Exercise

The exercise intervention was performed as self-exercise in both groups without any supervision at home every day for 1 month. Muscle strength exercises included hip abduction (HA) exercise and clamshell (CS) exercise and was performed using an exercise band (TheraBand Latex Free Resistance Bands: yellow color, Hygenic Co., Akron, OH, USA). An exercise band was placed around the femur 5 cm proximal to the lateral joint space of the knee. Exercise was conducted while the subjects lay in the supine position with their hips in the neutral position (HA: Fig. 2(a)) or the knee at 90° of flexion (CS: Fig. 2(b)). The exercise protocol was matched to that of the report of Watanabe *et al.*[16]: low-intensity resistance training with slow movement and the tonic force generation method (seated on the muscle training machine, 3 s eccentric, 3 s concentric, and 1 s isometric actions, with no rest between each repetition). Each exercise session consisted of 2 sets of 20 repetitions.

Outcome measures

Demographic data were collected from clinical records and included age, body mass index (BMI),

diagnosis, co-morbidity index, duration of intervention and prescribed analgesic medicine. Evaluations were conducted in the pre-intervention period and the post-intervention period. Investigators assessed muscle strength and the 10-m timed gait test before and after the intervention. The Frenchay Activities Index (FAI) and the Japanese Orthopedic Association Hip-Disease Evaluation Questionnaire (JHEQ) were evaluated before the intervention. The compliance rate with home exercise was measured after the intervention.

Muscle strength

(i) Hip abductor muscle strength
Isometric hip abductor strength on the affected side and the contralateral side was measured in all patients using a handheld dynamometer (Micro-FET2, Hoggan Health Industries, Salt Lake City, UT, USA) in the supine position. The handheld dynamometer was placed lateral to the fibula, 2.5 cm proximal to the malleolus. The torque and body weight ratio (Nm/kg) were measured using the spina malleolar distance and body weight.

(ii) Grip strength
The grip strength of all patients was measured using a Smedley-type grip dynamometer (Grip-D, Takei Scientific Instruments Co., Ltd., Niigata, Japan). The grip strengths of the dominant side and the non-dominant side at maximum effort were measured, and the higher value was used for analysis.

10-m timed gait test

The 10-m timed gait test was performed using a 16-m straight gait lane that contained a 3-m approach lane and a 3-m supplement lane. Each test was done twice, and the lower value was used for analysis.

Physical activities during activities of daily living (ADLs)

Physical activities were measured by the FAI.[17,18] The FAI evaluates the frequency and intensity of physical activities in the ADL setting. The FAI score (0–45 points) ranges from 0 points for a sedentary lifestyle to 45 points for a very active lifestyle. Patients completed a questionnaire form regarding regular activities in the ADL setting three months before the start of the present study.

Japanese Orthopedic Association Hip-Disease Evaluation Questionnaire

Hip joint function status measurements of all patients were performed using the JHEQ score of two subscales: the pain score and the mental score.[19] The JHEQ score is a self-administered questionnaire that can be useful in patients who frequently engage in deep flexion of the hip joint due to lifestyle and culture.

Compliance rate with self-exercise and supplementation

Patients were told to do self-exercises and supplementation and to complete the self-report sheet every day for one month. They were also asked to collect the self-report sheets at the preoperative evaluation before THA (one month after the first evaluation). The compliance rates with exercises and supplementation were calculated based on the number of exercise sessions and supplementation.

Statistical analyses

Statistical analyses were conducted by a co-investigator (JA) who was independent of the recruitment, intervention and data collection.

On the basis of Pennings *et al.*,[20,21] the minimum sample size for two-way repeated-measures analysis of variance (ANOVA) to examine differences between the groups ($\alpha = 0.05$, power $= 0.8$, effect size $= 0.35$) was calculated, and 44 participants were required. The two groups were created by random assignment of supplementation: BCAA group ($n = 21$) and control group ($n = 22$) (Fig. 1).

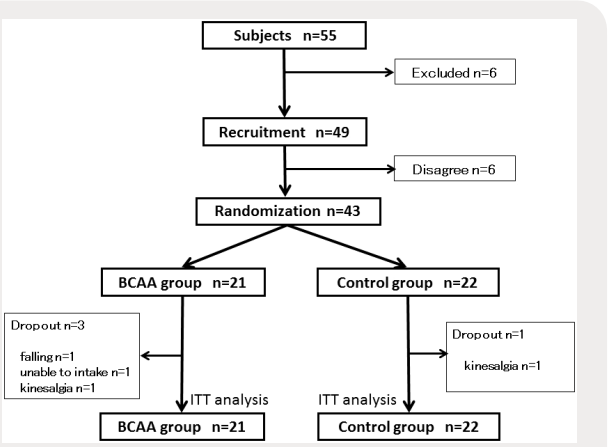
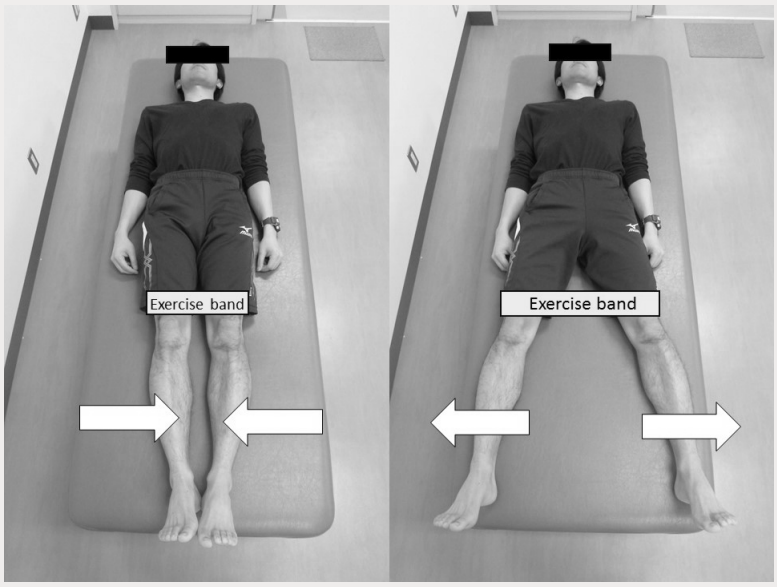
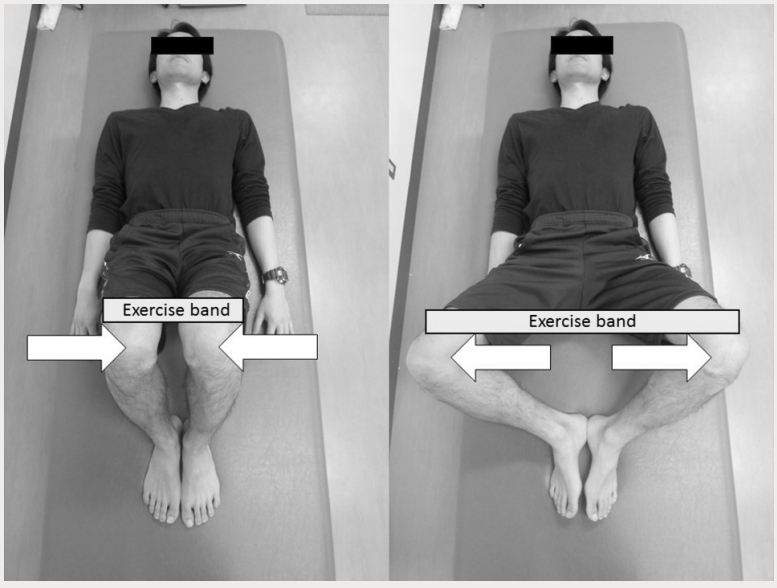


Fig. 1. Flowchart of patients in the randomied, controlled trial of exercise therapy combined with BCAA supplementation.



(a)



(b)

Fig. 2. (a) Hip abduction (HA) exercise and (b) Clamshell (CS) exercise.

Notes: An exercise band was placed to the femur, 5 cm proximal to the lateral joint space of the knee. Each exercise session consisted of 2 sets of 20 repetitions in the supine position.

An intention-to-treat analysis was conducted for the groups. The data of participants who dropped out of the intervention were replaced by the last observation carried forward method.

The unpaired t-test was used to determine the significance of differences between the groups. The unpaired t-test was used for age, BMI, the duration of interventions, FAI and JHEQ score. Muscle strength, the 10-m gait test and grip strength were analyzed with two-way repeated-measures ANOVA (group $\times$ time). The interaction was evaluated by the combined BCAA intake and exercise therapy. The comparison of the BCAA group with the control group was conducted using the improvement rate of the muscle strength and prescribed analgesic medicines; the U test was used

Table 2. Group × time analysis of physical function and compliance rate with interventions.

		BCAA group ($n = 21$)	Control group ($n = 22$)
Hip abductor strength (affected side)	pre-intervention	0.68 ± 0.18	0.69 ± 0.2
	post-intervention	0.7 ± 0.15	0.68 ± 0.2
Hip abductor strength (contralateral side)	pre-intervention	0.78 ± 0.15	0.81 ± 0.19
	post-intervention	0.87 ± 0.14	0.8 ± 0.22
10-m timed gait test	pre-intervention	8.6 ± 2.2	8.3 ± 2.3
	post-intervention	7.7 ± 1.5	7.6 ± 1.9*
Grip strength	pre-intervention	23.0 ± 4.9	23.3 ± 5.6
	post-intervention	24.7 ± 3.2	24.1 ± 4.9
Intervention duration (days)		27.8 ± 3.5	27.3 ± 4.0
Compliance rate (%)			
	Exercise	85.0 ± 22.0	88.2 ± 13.1
	Supplementation	83.4 ± 27.7	92.0 ± 11.8

Note: *$p < 0.1$.

to evaluate the significance of differences. All data were analyzed using SPSS software (version 21, IBM, Chicago, IL, USA).

Results

Demographic data and intervention duration were similar between the two groups (Tables 1 and 2). The compliance rates for exercise and supplementation in each period were at least 80%, and they did not differ significantly between the two groups (Table 2). The percentage of patients prescribed non-steroidal anti-inflammatory drugs (NSAIDs) as analgesics was approximately 20% (BCAA group: 19.0%; control group: 18.2%). The times of doses of analgesic medicines were similar between the two groups (Table 1).

Four participants were unable to complete the study after randomization because of kinesalgia ($n = 2$), stopped ingesting BCAAs due to the flavor ($n = 1$), or falling ($n = 1$; Fig. 1). No participants had adverse events associated with BCAA supplementation.

There was a marginally significant difference in the main effect between the groups in 10-m timed gait time (pre- and post-combined therapy: $p = 0.057$) (Table 2). There were no significant effects and interactions between the groups in hip abductor muscle strength and grip strength.

A comparison of improvement rates for hip abductor muscle strength showed that the contralateral side rate (BCAA group: 14.2% ± 19.4%; control group: −2.6% ± 16.5%) was significantly higher in the BCAA group (Table 3). The affected side rate (BCAA group: 8.9% ± 21.6%; control group: −0.3% ± 14.2%) did not differ significantly between the two groups (Table 3). The 10-m timed gait time and grip strength did not show significant differences between the two groups (Table 3).

Table 3. Comparisons of the improvement rates of physical function between the groups.

	BCAA group ($n = 21$)	Control group ($n = 22$)
Hip abductor muscle strength (%) (affected side)	8.9 ± 21.6	−0.3 ± 14.2
Hip abductor muscle strength (%) (contralateral side)	14.2 ± 19.4	−2.6 ± 16.5*
10-m timed gait test (%)	−10.0 ± 13.6	−6.6 ± 10.1
Grip strength (%)	8.0 ± 14.5	6.1 ± 9.4

Note: *$p < 0.01$.
The percentage of each parameter means the difference from baseline. Hip abductor muscle strength of the contralateral side differed significantly between the groups.

Discussion

The present study showed that BCAA supplementation combined with muscle strengthening exercises showed a marginally significant effect with 10-m timed gait time. In addition, the improvement rate of hip abductor muscle strength on the contralateral side was significantly higher in the BCAA group than in the control group.

Considering the fact that lower limb function affects physical activity of both of the affected side and the unaffected (healthy) side in OA patients,[22] lower limb function and physical activity are mutually affected. Arai *et al.*[23] reported that muscle strength of the unaffected lower limb is important for gait independence after a femoral neck fracture. In OA, which is also a hip-joint disease, improved function of the unaffected lower limb contributes to increased physical activity and prevents a further decrease in lower limb function due to disuse.

On the other hand, there was no significant interaction for hip abductor muscle strength, and the muscle strength improvement rate on the affected side did not differ significantly between the groups. Considering the fact that the combined therapy showed a marginally significant effect in the 10-m timed gait time, even though there was no significant interaction between the groups in muscle strength, the improvement rate for hip abductor muscle strength on the contralateral side may also have affected 10-m timed gait time. What can be assumed is that joint deformity or pain with movement was involved. In regard to joint deformity, most participants with secondary OA scheduled for THA had shortening of the lever arm associated with joint deformity.

The JHEQ pain score did not differ between the groups when the intervention was started, and one patient in each group discontinued the intervention because of pain with movement (kinesalgia). The exercise intervention was performed without supervision, but this was complemented by self-report sheets to confirm that exercise was performed. The compliance rate for independent training was $\geq 80\%$ in both groups, so this served as a type of check function. However, one cannot exclude the effect of joint pain that may also have affected muscle strengthening in the present study.

Moreover, in the 10-m timed gait test, another related factor besides muscle strength is stride length. Stride length reflects the magnitude of the arc of hip flexion and extension ROM on the affected and unaffected sides during walking. Exercise intervention in the present study included muscle strengthening exercises, but without specific intervention for joint ROM. Although hip abductor muscle strength did improve, this did not lead to improvement in the 10-m gait time.

Grip strength results did not show a significant main effect and, improvement rates from before to after intervention were not significantly different. Ikeda *et al.*[10] reported that combined exercise therapy twice weekly with BCAA supplementation in frail elderly patients improved lower limb muscle strength, but had no effect on grip strength. A common feature in the study by Ikeda *et al.* and the present study was the absence of any direct exercise intervention for grip strength. Kim *et al.*[11] reported that BCAA supplementation alone did not enhance muscle strength, and even with combined therapy, specific exercise intervention for target muscles was necessary.

THA is widely performed in OA patients to relieve pain and improve function. However, even after hip geometry is restored, decreased hip abductor muscle strength is often prolonged.[22,24,25] Disuse muscle atrophy may persist after surgery, especially in OA patients.[26] Rooks *et al.*[27] reported that preoperative rehabilitation was important. They found that six weeks of preoperative exercise therapy in OA patients undergoing THA improved lower limb function before surgery and greatly reduced postoperative rehabilitation admission rates. For smooth gait independence after THA, muscle strengthening exercises combined with BCAA supplementation may be useful from the standpoint of effectively improving hip abductor muscle strength on the unaffected side even before surgery.

This study has several limitations, including: (1) muscle strengthening exercises and BCAA supplementation were not supervised; (2) nutritional parameters based on hematological data were not evaluated; (3) dietary intake was not controlled during the study period; (4) some participants used NSAIDs regularly or on an as-needed basis and (5) the duration of combined treatment was limited to one month, so whether a longer period would have been more effective is unknown.

Because the nutritional and exercise interventions were not supervised, one cannot exclude the

fact, even though the compliance rates were high, that the intake and use of BCAA supplementation and the implementation and methods of muscle strengthening exercises may not have been followed as prescribed. In regard to dietary intake, if caloric intake does not meet required energy demands, malnutrition can lead to a high risk of malnutrition-related sarcopenia. However, the patients in this study had no underlying diseases associated with a nutritional disorder or dysphagia. Therefore, the risk of malnutrition was relatively low.

In regard to NSAIDs, the anti-inflammatory activity of NSAIDs is reported to impair satellite cell activity, which is required for muscle protein synthesis.[28,29] Mikkelsen *et al.*[30] reported that local NSAID infusion significantly inhibited satellite cell activity up to eight days after eccentric muscle strengthening exercise, and that, in the non-infusion group, satellite cell activity increased up to about two times higher than the previous exercise. Therefore, one cannot exclude the fact that NSAID use, even though the utilization rate of NSAIDs was approximately 20%, may also have affected muscle strengthening in the present study. NSAID use, dietary intake control and intervention duration need to be considered in future studies.

Exercise therapy for OA, exercise intensity and specific regimens have not been established. Based on the current findings, the optimal amount of BCAA intake and exercise intensity for combined therapy for OA in the pre-operative period should be investigated. Future work should be devoted to a study of the best combination for improving muscle weakness.

Conclusion

BCAA supplementation combined with muscle strengthening exercises showed a marginally significant effect in 10-m timed gait time. There was no significant effect on hip muscle strength. In addition, the improvement rate of hip abductor muscle strength on the contralateral side was significantly higher in the BCAA group than in the control group.

Conflict of Interest

There were no financial relationships to disclose in the present study.

Funding/Support

The present study received no funding or support.

Author Contributions

Study design (TI, TJ and TM), data collection (KN and KS), subject recruitment (TI and KH), data analysis (JA), data interpretation (TI and TM), writing the manuscript (TI, TJ and TM), revising the manuscript (TI, TJ and TM) and project management (TI and KH) were contributed.

References

1. Liu RY, Wen XD, Tong ZQ, Wang K, Wang C. Changes of gluteus medius muscle in the adult patients with unilateral developmental dysplasia of the hip. BMC Musculoskelet Disord 2012; 13(1):101, doi: 10.1186/1471-2474-13-101.
2. Rosemann T, Kuehlein T, Laux G, Szecsenyi J. Factors associated with physical activity of patients with osteoarthritis of the lower limb. J Eval Clin Pract 2008;14:288–93.
3. Fransen M, McConnell S, Hernadez-Molina G, Reichenbach S. Exercise for osteoarthritis of hip. Cochrane Database Syst Rev 2014, doi: 10.1002/14651858.CD007912.pub2.
4. Regnaux JP, Lefevre-Colau MM, Trinquart L et al. High-intensity versus low-intensity physical activityor exercise in people with hip or knee osteoarthritis. Arthritis Rheumatol 2015;67:2916–7, doi: 10.1002/14651858.CD010203.pub2.
5. Katsanos CS, Kobayashi H, Moore MS, Aarsland A, Wolfe RR. A high proportion of leucine is required for optimal stimulation of the rate of muscle protein synthesis by essential amino acids in the elderly. Am J Physiol Endocrinol Metab 2006;291: E381–7.
6. Katsanos CS, Kobayashi H, Moore MS, Aarsland A, Wolfe RR. Aging is associated with diminished accretion of muscle proteins after the ingestion of a small bolus of essential amino acids. Am J Clin Nutr 2005;82:1065–73.
7. Drummond MJ, Dreyer HC, Pennings B, et al. Skeletal muscle protein anabolic response to resistance exercise and essential amino acids is delayed with aging. J Appl Physiol 2008;104(5):1452–61, doi: 10.1152/japplphysiol.00021.
8. Burd NA, West DW, Moore DR et al. Enhanced amino acid sensitivity of myofibrillar protein synthesis persists for up to 24 h after resistance

exercise in young men. J Nutr 2011;141(4):568–73, doi: 10.3945/jn.110.135038.
9. Burd NA, West DW, Staple AW, et al. Low-load high volume resistance exercise stimulates muscle protein synthesis more than high-load low volume resistance exercise in young men. PLoS One 2010;5 (8):e12033, doi: 10.1371/journal.pone.0012033.
10. Ikeda T, Aizawa J, Nagasawa H, et al. Effects and feasibility of exercise therapy combined with branched chain amino acid supplementation on muscle strengthening in frail and pre-frail elderly people requiring long-term care: A crossover trial. Appl Physiol Nutr Metab 2016;41(4):438–45, doi: 10.1139/apnm-2015-0436.
11. Kim HK, Suzuki T, Saito K, et al. Effects of exercise and amino acid supplementation on body composition and physical function in community-dwelling elderly Japanese sarcopenic women: A ramdomized controlled trial. J Am Geriatr Soc 2012;60(1):16–23, doi: 10.1111/j.1532-5415.2011. 03776.x.
12. Burke JM, Hawley JA, Ross ML, et al. Preexercise aminoacidemia and muscle protein synthesis after resistance exercise. Med Sci Sports Exerc 2012;44(10): 1968–77, doi: 10.1249/MSS.0b013e31825d28fa.
13. Tipton KD, Rasmussen BB, Miller SL, et al. Timing of amino acid-carbohydrate ingestion alters anabolic response of muscle to resistance exercise. Am J Physiol Endocrinol Metab 2001;281: E197–206.
14. Matsumoto K, Koba T, Hamada K, Sakurai M, Higuchi T, Miyata H. Branched-chain amino acid supplementation attenuates muscle soreness, muscle damage and inflammation during an intensive training program. J Sports Med Phys Fitness 2009;49:424–31.
15. Shimomura Y, Inaguma A, Watanabe S et al. Branched-chain amino acid supplementation before squat exercise and delayed-onset muscle soreness. Int J Sport Nutr Exerc Metab 2010;20:236–44.
16. Watanabe Y, Madarame H, Ogasawara R, Nakazato K, Ishii N. Effect of very low-intensity resistance training with slow movement on muscle size and strength in healthy older adults. Clin Physiol Funct Imaging 2014;34(6):463–70, doi: 10.1111/cpf.12117.
17. Wade DT, Leigh-Smith J, Langton HR. Social activities after stroke: Measurement and natural history using the Frenchay Activities Index. Int Rehabil Med 1985;7:176–81.
18. Schuling J, de-Haan R, Limburg M, Groenier KH. The Frenchay Activities Index: Assessment of functional status in stroke patients. Stroke 1993;24:1173–77.
19. Matsumoto T, Kaneuji A, Hiejima Y, et al. Japanese orthopedic association hip disease evaluation questionnaire (JHEQ): A patient-based evaluation tool for hip-joint disease. The subcommittee on hip disease evaluation of the clinical outcome committee of the Japanese orthopedic association. J Orthop Sci 2012;17(1):25–38, doi: 10.1007/s00776-011-0166-8.
20. Pennings B, Koopman R, Beelen M, Senden JM, Saris WH, van Loon LJC. Exercising before protein intake allows for greater use of dietary protein-derived amino acids for de novo muscle protein synthesis in both young and elderly men. Am J Clin Nutr 2011;93:322–31, doi: 10.3945/ajcn.2010. 29649.
21. Pennings B, Groen B, de Lange A, et al. Amino acid absorption and subsequent muscle protein accretion following graded intakes of whey protein in elderly men. Am J Physiol Endocrinol Metab 2012;302:E992–9, doi: 10.1152/ajpendo.00517. 2011.
22. Rosenbaum LS, Light KE, Behrman AL. Gait, lower extremity strength and self-assessed mobility after hip arthroplasty. J Gerontol 2002;57A:M47–51.
23. Arai T, Kaneko S, Fujita H. Decision trees on gait independence in patients with femoral neck fracture. Nihon Ronen Igakkai Zasshi 2011;48:539–44.
24. Arokoski MA, Arokoski JPA, Haara M, et al. Hip muscle strength and muscle cross-sectional area in men with and without hip osteoarthritis. Rheumatology 2002;29:2185–95.
25. Reardon K, Galea M, Dennett X, Choong P, Byrne E. Quadriceps muscle wasting persists 5 months after total hip arthroplasty for osteoarthritis of the hip: A pilot study. Intern Med J 2001;31:7–14.
26. Bertocci GE, Munin MC, Froste KL, Burdett R, Wassinger CA, Fitzgerald SG. Isokinetic performance after total hip replacement. Am J Phys Med Rehabil 2004;83:1–9.
27. Rooks DS, Huang J, Bierbaum BE, et al. Effect of preoperative exercise on measures of functional status in men and women undergoing total hip and knee arthroplasty. Arthritis Care Res 2006;55:700–8.
28. Schoenfeld BJ. The use of nonsteroidal anti-inflammatory drugs for exercise-induced muscle damage: Implications for skeletal muscle development. Sports Med 2012;42(12):1017–28, doi: 10.2165/11635190-000000000-00000.
29. Mackey AL. Does an NSAID a day keep satellite cells at bay? J Appl Physiol 2013;115(6):900–8, doi: 10.1152/japplphysiol.00044.2013.
30. Mikkelsen UR, Langberg H, Helmark IC, et al. Local NSAID infusion inhibits satellite cell proliferation in human skeletal muscle after eccentric exercise. J Appl Physiol 2009;107(5):1600–11, doi: 10.1152/japplphysiol.00707.2009.

Research Paper

Hong Kong Physiotherapy Journal
Vol. 38, No. 1 (2018) 33–40
DOI: 10.1142/S101370251850004X

Hong Kong Physiotherapy Journal
http://www.worldscientific.com/worldscinet/hkpj

Determining the reliability of craniocervical flexion test in asymptomatic individuals

Seema Kotwani[1], D. N. Bid[1], Dinesh Ghatamaneni[2], Khalid A Alahmari[2], Thangamani Ramalingam[1] and S. Paul Silvian[2,*]

[1]*The sarvajanik college of physiotherapy*
Opp. Lockhat & Mulla Hospital
Chhada-ole, Badatwadi, Rampura
Surat 395003, Gujarat, India

[2]*Department of Medical Rehabilitation Sciences*
College of Applied Medical Sciences
King Khalid University, Abha, Saudi Arabia

[*]*paulsilvian@gmail.com*

Received 9 October 2016; Accepted 19 July 2017; Published 6 April 2018

Background: The inter-rater reliability of the craniocervical flexion test (CCFT) has not been established.
Objective: To investigate the intra-rater and inter-rater reliabilities of the CCFT in asymptomatic subjects.
Methods: Sixty asymptomatic subjects were randomly selected for the study. The CCFT was measured on each subject by two testers for inter-rater reliability and by one of the testers after a gap of seven days for the intra-rater reliability. Before testing, the participants were trained for the movement and compensations were corrected.
Results: The CCFT has high inter-rater reliability (intra-class correlation coefficient = 0.907, standard error of mean = 0.735) and high intra-rater reliability (intra-class correlation coefficient = 0.986, standard error of mean = 0.287). A Bland & Altman limits of agreement analysis has confirmed the high inter- and intra-rater reliabilities of the test.
Conclusion: The CCFT has high inter-rater and intra-rater reliabilities in asymptomatic subjects.

Keywords: Craniocervical flexion test; deep cervical flexors; reliability.

[*]Corresponding author.

Introduction

The human neck is a complex structure that is highly susceptible to irritation. In fact, 10% of people will have neck pain in any given month. Almost any injury or disease process within the neck or adjacent structures will result in reflexive protective muscle spasm and loss of motion. Reported incidence rate increases with age up to 40 to 60 years, and then decreases slightly. Neck pain is a common and significant problem in modern society, with one year prevalence values in world population varying from 16.7% to 75.1%, with a mean of 37.2%.[1]

An understanding of anatomy and physiology and of their association with the pathogenesis of neck pain provides a better understanding about neck pain. The primary function of the cervical spine is to orient the head against the opposing forces of gravity while permitting multi-directional movement. To complete this task, the cervical spine must be mechanically stable, both in static as well as dynamic postures. In neutral upright posture, resistance to cervical spine motion by passive structures is minimal.[2] About 80% of the mechanical stability of cervical spine is contributed by the neck muscles and the remaining 20% by the osseoligamentous structures.[3] All the muscles of cervical spine play a role in movement and postural control, however, the different location, attachment, lever arm and fiber composition of individual muscles determine their primary function.[4] Deep and superficial axial muscles have different roles in stabilizing and moving the spine. As the deep axial muscles have small moment arms and attachment to adjacent vertebrae, they are believed to stabilize the spine. The more the superficial muscles have larger movement of arm and attachment to skull and trunk, thus they are believed to be predominantly prime movers.

According to Janda, each muscle group has a predisposition to become either tight or weak. In particular, postural muscles are prone to tightness, whereas phasic muscles are prone to weakness. Janda has described the upper crossed syndrome and has observed regular impairment of deep neck flexor muscles in patients with neck pain disorders.[5] Likewise, forward head posture is also considered as one of the postural risk factors among neck pain patients.[6] The reduced range of upper cervical extension may reflect a habituated sitting posture with more extended upper cervical spine.[7] Dysfunction of deep cervical flexors (DCF) is seen in different conditions like non-specific neck pain,[8] whiplash-associated disorder (WAD)[9] and cervicogenic headache.[10] Specific therapeutic retraining of DCF has demonstrated efficacy in management of patients with neck pain and cervicogenic headache.[11]

Endurance measurement is done by using three methods: electromyographic method (changes occurring in the EMG signal and in the action potential velocities during a contraction) (usually questionnaires) to measure perceived effort during sustained contractions (subjective estimation not fatigue) and clinical tests that measure time-dependent changes (mechanical fatigue).[12] Commonly, the craniocervical flexion test (CCFT) is used. Different methods used to assess DCF function found in the literature are the CCFT, conventional cervical flexion (a test that instruct the subjects to "tuck in their chins" (craniocervical flexion) and then to raise their heads from supine position), craniocervical flexion dynamometry, electromyography analysis, digital imaging, magnetic resonance imaging and ultrasonography. Clinically, only the first three methods can be used. The conventional cervical flexion and the craniocervical dynamometry (which measures the maximal voluntary contraction) both assess the superficial and deep flexor muscles. These methods do not allow clinical differentiation between the superficial and deep muscles.

It is important to be aware that the activity of superficial muscles may mask the impaired performance of the DCF muscles. From the available literature, it is seen that CCFT can give specific information about the DCF. The CCFT developed by Jull is an easy, non-invasive, low load clinical test used to assess as well as retrain the DCF.[13]

This test consists of precise and controlled performance and maintenance of positions of craniocervical flexion. There is no head lift component which engages the more superficial muscles like sternocleidomastoid and anterior scalene muscles.[13] In this method, an air filled pressure sensor is placed between the testing surface and upper neck to monitor the flattening of cervical lordosis along with the contraction of deep cervical flexors.[13] The instrument used is "Stabilizer" Pressure Biofeedback Unit (PBU), Chattanooga, USA. The outcome measure used in this study is Cumulative Performance Index (CPI) which is obtained by adding preceding score to performance index (PI). PI is defined as activation score (pressure level the

subject is able to achieve) * number of successful repetitions.

This outcome measure is not yet used in Indian population and it has also not been used till date for evaluating the inter-rater reliability in any of the populations. This point is unique to this study. This study therefore tries to find the reliability of the CCFT, moreover, the scoring system used in this study for measuring the endurance of the deep cervical flexors is not yet explored among Indian population.

The purpose of this study is to test the intra-rater and inter rater reliabilities of the CCFT in asymptomatic individuals. If reliability of the CCFT is good, it can be used as an effective assessment tool for assessing the DCF endurance.

Methods

In this study, 60 asymptomatic subjects were studied. Sample size was calculated using the software *Power Analysis and Sample Size 11*. Sample size was estimated based on the 95% confidence interval (CI). For an expected ICC of 0.9 with 95% CI, the minimum sample size required was less than 15. Sample size calculated using the formula also provided a minimum sample size requirement of 15 with 95% CI:

$$\mathrm{SS} = \frac{Z^2 \times (p) \times (1-p)}{C^2},$$

where $Z = 1.96$ for 95% confidence level, $P = 0.99$, $1 - P = 0.01$, $C = 0.05$ (error term).

At the same time, a large sample size would result in a more precise reliability estimate with a narrow CI. Hence, 60 subjects were recruited.[14] According to the calculation, only five subjects should be studied and two observations per subject should be taken. In practice, there were conventional choices for high statistical power; when the p value is set at 0.05, and power will generally be somewhere between 80% and 95%, depending on the resulting sample size.[15] Total three municipal wards (community blocks are known as wards in India) were selected out of 38 wards. About 20 subjects were studied in each municipal ward randomly selected. Subjects were selected randomly from different areas of Surat, India, by using systematic random sampling. The design of the study used is cross-sectional study. Inclusion criteria included respondents from ages 20 to 60 years, from either gender as well as subjects without any kind of cervical pathology.

Likewise, history of severe neck pain in the last 12 months, current neck pain, undergone neck surgery, frequent headaches (> once per month), previous cervical spine trauma, long-term steroid usage and those who had undergone dental work in the previous 12 months and those with any neuromuscular conditions (including cervical spondylosis) are excluded from the study.

These are easy and non-invasive standardized tool available for measuring endurance of DCF. It is also utilized in the previous studies. Hence, this tool was selected. The Pressure Biofeedback Unit (PBU) (stabilizer, Chattanooga, USA), along with a screening form, recording sheet, towel and a stop watch was used for data collection.

The PBU consists of a non-elastic three-chambered pneumatic bag, a catheter and a manometer gauge ranging from 0 mm Hg to 200 mm Hg, with an accuracy of ± 3 mm Hg (Fig. 1(a)).[16] The outcome measure was CPI. A PI (AS * number of successful repetitions) could be calculated.[10] However, an AS of 2 mm Hg * 10 repetitions and an AS of 4 mm Hg * 5 repetitions yielded the same PI.[10] Hence, the PI as a quantity could not be exclusively identified or ranked, and would not comply with any criteria for classification as one of the four main levels of measurement.[17] Data obtained were CPI, which was obtained by adding preceding score to the PI. Table 1 shows the calculation of CPI.

To avoid any misinterpretation, the preceding score was added to the PI, thus resulting in a CPI which reflects the entire test, not just the position at which it terminates.[18]

Both raters were qualified manipulative physiotherapist with more than five years of academic

Table 1. Calculation of CPI.

Pressure (mm Hg)	PI (activation score * repetitions)	Range of possible scores at this level	Added score*
20			
22	2 × [1–10] repetitions	0–20	0
24	4 × [1–10] repetitions	24–60	20
26	6 × [1–10] repetitions	66–120	60
28	8 × [1–10] repetitions	128–200	120
30	10 × [1–10] repetitions	210–300	200

*Added score is equivalent to 10 repetitions of the levels below that of the current activation score. The total score therefore includes all attempts at all activation scores achieved.

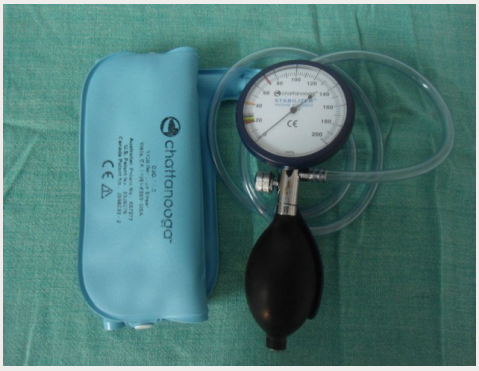
and clinical experience in orthopedic and manipulative physical therapy and were well versed in the CCFT procedures based on the recommended guidelines.[19]

Random selection of the subjects for the study was divided into two steps. In the first step, three municipal wards were randomly selected from a total of 38 municipal wards (community blocks are known as wards in India) in Surat, Gujarat, India. In the second step, five subjects per age group were selected from each ward by systematic random sampling method.

One tester performed the test on each subject twice for the intra-rater reliability and two testers performed the test on each subject for the inter-rater reliability. All the subjects completed the screening form and signed the written informed consent form.

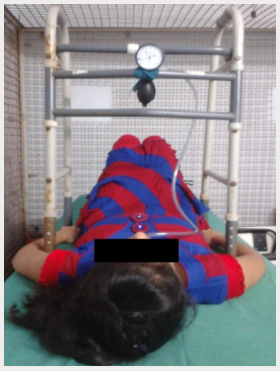
The following steps for the CCFT were followed:

Subjects were positioned in crook lying position so that forehead and chin are in a horizontal plane (Fig. 1(b)). Additionally, layers of towel were used under the head if the subject needed. Deflated pressure sensor was placed behind the neck and then inflated to a baseline pressure of 20 mm Hg, which was a standard pressure sufficient to fill in the space between the testing surface and the neck, without pushing the neck into lordosis. The device provided the feedback and direction to the patient to perform the required five stages of the test. The patients were instructed that the test is not one of the strengths, but rather one of the precisions. Subjects were asked to perform gentle and slow head nodding action, as if saying "yes". All the participants were advised to place their tongue on roof of mouth, with lips together and teeth slightly apart, in order to reduce activity of jaw musculature.[19] Once the set up was done, the dial of PBU is turned to the subject. Practice session was done to ensure that the subject properly understood the required movement. Once the subject learnt how to perform the craniocervical flexion action, a brief rest period was given. Subjects were asked to elevate target pressure from 20 mm Hg to 22 mm Hg and hold it for 2 s to 3 s before relaxing and returning to the starting position (20 mm Hg) (Fig. 1(c)). This was repeated through each 2 mm Hg increment up to 30 mm Hg, with verbal and visual cueing on correct technique given by the investigator. The investigator monitored the movement of head and activity of superficial cervical flexors by observation only. Compensation strategies like increased superficial cervical flexors activity, overshooting target pressure, dial needle flickering and neck retraction were also identified. If incorrect strategies were identified, verbal guidance was given to avoid such faulty strategies and further practice was given. Pressure was elevated in 2 mm Hg increments from a baseline value of 20 mm Hg to a maximum of 30 mm Hg.



(a) "Stabilizer" Pressure Biofeedback Unit (PBU)

(b) Subject positioning



(c) Position of the PBU dial

Fig. 1. (a) Deflated pressure sensor cuff is placed behind the neck and then inflated to a baseline pressure of 20 mm Hg, which is a standard pressure sufficient to fill in the space between the testing surface and the neck, without pushing the neck into lordosis and the dial used for visual cueing. (b) Subject is positioned in supine lying with knee flexed to 90° and a walking frame is placed on top to mount the dial of the pressure feedback unit for visual feedback. The investigators in this position will observe the movement of head and activity of superficial cervical flexors. (c) Pressure sensor unit is mounted on the walking frame and the inflated cuff is placed behind the neck along with verbal and visual cueing the subject is asked to elevate target pressure from 20 mm Hg to 22 mm Hg and hold it for 2 s to 3 s before relaxing and returning to the starting position (20 mm Hg). This is repeated through each 2 mm Hg increment up to 30 mm Hg.

Ten repetitions were carried out at each 2 mm Hg increment and each contraction is held for 10 s.[20] Both the therapists simultaneously did the procedure for the inter-rater reliability.

All the subjects were again tested after one week by one of the testers keeping the time and environment same. Data thus obtained were used to calculate intra-rater reliability of the CCFT. The same testing procedure and equipment was used for all the subjects. The above procedure utilized was the one given by Jull *et al.*[21]

Data analysis was done using the SPSS software (version 20.0). Results are considered to be significant at $p < 0.05$ and CI of 95%. An intra-class correlation coefficient for intra- and inter-rater reliabilities was used for the study. Bland–Altman limits of agreement analysis for assessing the agreement between two testers' scores were taken by tester one, twice. Standard error of measurement (SEM) was used to calculate the variability in measurements of same tester and measurements taken by two testers.

Results

The mean score for tester one was found to be 10.80 ± 9.45 and 10.83 ± 10.07 for tester two. In the retest, tester one obtained the mean score of 10.83 ± 9.51. Intra-class correlation coefficient (ICC) for both intra- and inter-rater reliabilities along with the CIs with a p-value of < 0.05 is used. The ICC value of the study indicated high reliability. The ICC intra-rater reliability was 0.986 at CI lower 0.977 and CI higher 0.992. For inter-rater reliability, it is 0.907 at CI lower 0.899 and CI higher 0.907. Figure 2 shows the Bland–Altman limits of agreement analysis between two testers. The Bland–Altman chart is a scatter-plot with the difference of the two measurements for each sample on the vertical axis and the average of the two measurements on the horizontal axis. Three horizontal reference lines were superimposed on the scatter-plot — one line at the average difference between the measurements, along with lines to mark the upper and lower control limits of plus and minus 1.96 * sigma, respectively, where sigma was the standard deviation of the measurement differences. When the two methods were comparable, then differences should be small, with the mean of the differences close to 0.[22] It showed reasonable agreement between the testers as most of the values fell in the range of $M \pm 2SD$ ($p < 0.05$). It indicated excellent reliability. Figure 2 shows the Bland–Altman limits of agreement analysis between two testers. The SEM is a measure of

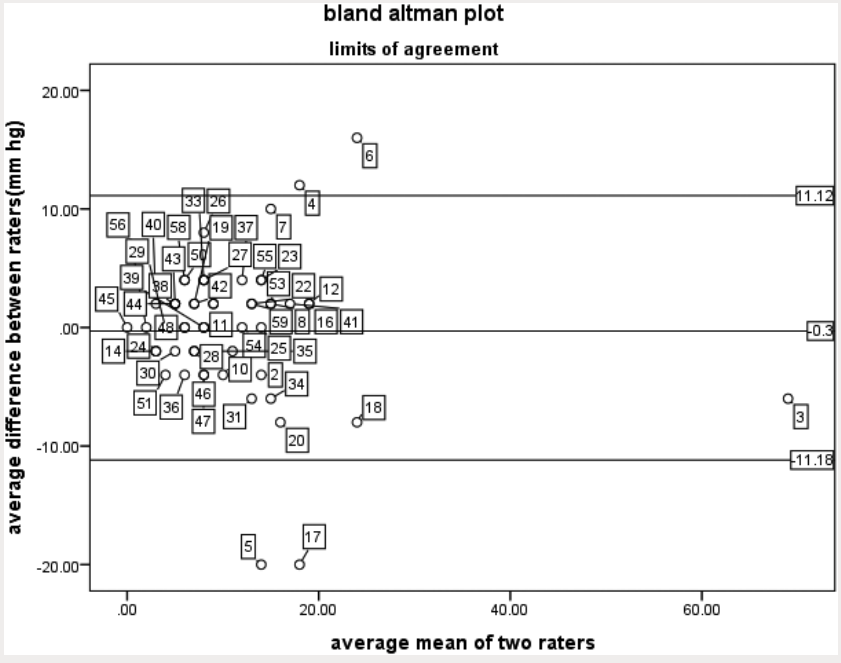


Fig. 2. Bland–Altman limit of agreement analysis between scores taken by the same tester twice. Three horizontal reference lines are superimposed on the scatter-plot — one line at the average difference between the measurements, along with lines to mark the upper and lower control limits of +/−1.96 sigma, which is the standard deviation of the measurement differences.

absolute reliability — the smaller the SEM, the more reliable the measurements.[18] SEM value calculated for variability in measurements between two testers was 0.735, which was very small; whereas the value for variability in measurements of the same tester was 0.287, which was also very small. Thus, these measurements were reliable.

The true SEM value for variability in measurements between two testers ($0.735 * 1.96 = 1.441$) suggested that any individual value was within the range of ± 1.441 CPI from their measured value. The true SEM value for variability in measurements of the same tester ($0.287 * 1.96 = 0.562$) suggested that any individual value was within the range of $\pm$ 0.562 CPI from their measured value.

The smallest real difference (SRD) value for variability of measurements between two testers ($1.96 * \sqrt{2} * \text{SEM} = 2.039$) and between the measurement taken by same tester ($1.96 * \sqrt{2} * \text{SEM} = 0.795$) was claimed to be capable of representing "real" clinical change, but these values could not simply be generalized to a symptomatic population.

Discussion

This cross-sectional study aimed at investigating the inter-rater and intra-rater reliabilities of the CCFT in asymptomatic individuals. The PBU which was placed behind the neck, monitored the flattening of cervical spine as the deep neck flexors were activated. This test was developed because of interest in functional role of the muscles particularly in relation to active spinal segmental stabilization and the clinical need of more specific exercise for patients with neck pain. For developing the CCFT, the DCFs primary anatomical action, flexion of the head on stable cervical spine, is utilized. The result of this study shows high intra-rater and inter-rater reliabilities. Reliability refers to consistency or dependability of a measurement technique.[23] More specifically, it is concerned with consistency or stability of the score obtained from a measure or assessment technique over time and across settings or conditions.[24] Reliability of a test is important as it is a precursor to test validity. If a test is unreliable, it will not be valid. Another reason to be concerned about reliability is that it gives idea about random measurement error in subject's scores. If a test is unreliable, subject's scores will consist largely of the measurement errors. Four studies evaluating intra-rater reliability[10,24–26] and one study evaluating inter rater reliability[20] of the CCFT are available in the literature. But, one systematic review[27] has questioned the reliability of CCFT because of the methodological flaws in the previous studies. There was a lack of information on the examiners, patients, the number of subjects included and blinding. In a study that investigated the validity of PBU instrument has concluded that the PBU provides valid measures, but their findings are not conclusive due to the small sample size ($n = 15$).[28] In a recent low risk of bias study, it was found that the reproducibility of PBU was observed as ICCs of 0.74 and 0.76 for intra- and inter-examiner reproducibility.[16] This study using 60 subjects therefore establishes the reproducibility of PBU in measuring CCFT. Arumugam *et al.* evaluated the inter-rater reliability of the test.[29] But, the scoring system used and measured only the holding capacity and not the endurance of the DCF. The ICC for inter-rater reliability is 0.907 ($p < 0.05$) whereas for intra-rater reliability, it is 0.986 ($p < 0.05$). The ICC is interpreted by using the work of Portney and Watkins.[22]

Although the reliability is good, the subjects have poor contractile capacity of DCF because the mean of the scores recorded by one rater is 10.80 mm Hg and by another rater is 10.833 mm Hg. Individuals could not achieve higher pressure levels and none of them were able to achieve 30 mm Hg. The Bland–Altman agreement analysis also supports these results. The Bland–Altman plot shows mean measurements against the differences. The result of this plot shows that most of the readings fall in $\text{M} \pm 2$ SD ($p < 0.05$). The results of this study are similar to those found by James and Doe, who have also used CPI as an outcome measure.[25] They have also showed high intra-rater reliability. But the difference between the two studies lies in the scores. The mean scores of CCFT seen in this study are very less compared to that seen in study of James and Doe. Racial differences and a wide variability of age range selected in this study could be a reason for this difference. The results for inter-rater reliability cannot be compared to any other study as no study has yet evaluated it using this CPI outcome measure, either in symptomatic or asymptomatic individuals. Accuracy of the scores could be influenced by testers' scoring abilities. For these reasons, the testers' were adequately experienced and trained in administering the test procedure. As both the testers scored the test simultaneously, factors like duration of contraction or fatigue will have a homogenous effect on the

performance of test. This study shows that the CCFT is a good method to assess the DCF endurance. Common compensations seen in subjects during the test were chin retraction or taking the chin down with fast movement. Both these compensations were corrected by properly training the subjects.

Conclusion

This study shows that the CCFT is a good method to assess the DCF endurance. The PBU has an accuracy of ± 3 mm Hg. This can cause random error between tests. But, this random error must be reduced by maintaining the same area of contact between neck and pneumatic bag for all trials. Common compensations seen in subjects during the test were chin retraction or taking the chin down with fast movement. Both these compensations were corrected by properly training the subjects. Results of this study support the use of CCFT as an objective outcome measure in evaluating DCF endurance. The results of this study cannot be generalized as it is done on asymptomatic subjects. As this is the first study evaluating the inter-rater reliability using the CPI as an outcome measure, further research needs to be done by using the same CPI, to make future comparison possible.

Conflict of Interest

There are no conflicts of interest.

Funding/Support

There are no funding and supporting agencies for the study.

Author Contributions

Seema Kotwani and D.N Bid conceived and designed the study, conducted research, provided research materials. Thangamani Ramalingam collected and Dinesh Ghatamaneni organized the data. Paul Silvian and Khalid Alahmari analyzed and interpreted data. Seema Kotwani wrote initial draft and Paul Silvian and Dinesh Ghatamaneni wrote the final draft of the paper. D.N Bid provided logistic support. Paul Silvian has carried out the revision of the manuscript. Khalid Alahmari provided the native language proofing. All authors have judiciously reviewed and approved the final draft and are responsible for the content of the manuscript.

References

1. Fejer R, Kyvik KO, Hartvigsen J. The prevalence of neck pain in the world population: A systematic critical review of the literature. Eur Spine J 2006;15 (6):834–48.
2. Oatis CA. Kinesiology: The Mechanics and Pathomechanics of Human Movement. Philadelphia: Lippincott Williams & Wilkins, 2009.
3. Panjabi MM, Cholewicki J, Nibu K, Grauer J, Babat LB, Dvorak J. Critical load of the human cervical spine: An in vitro experimental study. Clin Biomech 1998;13(1):11–7.
4. Cholewicki J, Panjabi MM, Khachatryan A. Stabilizing function of trunk flexor–extensor muscles around a neutral spine posture. Spine 1997;22 (19):2207–12.
5. Janda V. Muscles and motor control in cervicogenic disorders: Assessment and management. In: Physical Therapy of the Cervical and Thoracic Spine. New York: Churchill Livingstone, 1994:195–216.
6. Haughie LJ, Fiebert IM, Roach KE. Relationship of forward head posture and cervical backward bending to neck pain. J Man Manip Ther 1995;3 (3):91–7.
7. Rudolfsson T, Björklund M, Djupsjöbacka M. Range of motion in the upper and lower cervical spine in people with chronic neck pain. Man Ther 2012;17(1):53–9.
8. O'Leary S, Jull G, Kim M, Vicenzino B. Craniocervical flexor muscle impairment at maximal, moderate, and low loads is a feature of neck pain. Man Ther 2007;12(1):34–9.
9. Jull GA, Deep cervical flexor muscle dysfunction in whiplash. J Musculoskelet Pain 2000;8(1–2):143–54.
10. Jull G, Barrett C, Magee R, Ho P. Further clinical clarification of the muscle dysfunction in cervical headache. Cephalalgia 1999;19(3):179–85.
11. Jull G, Trott P, Potter H, Zito G, et al. A randomized controlled trial of exercise and manipulative therapy for cervicogenic headache. Spine 2002;27(17):1835–43.
12. Strimpakos N. The assessment of the cervical spine. Part 2: Strength and endurance/fatigue. J Bodyw Mov Ther 2011;15(4):417–30.
13. Jull GA, O'leary SP, Falla DL. Clinical assessment of the deep cervical flexor muscles: The craniocervical flexion test. J Manip Physiol Ther 2008; 31(7):525–33.

14. Karanicolas PJ, Bhandari M, Kreder H, et al. Evaluating agreement: Conducting a reliability study. J Bone Joint Surg 2009;91(Supplement 3):99–106.
15. Whitley E, Ball J. Statistics review 4: Sample size calculations. Crit Care 2002;6(4):335.
16. Falla D, Lindstrøm R, Rechter L, Boudreau S, Petzke F. Effectiveness of an 8-week exercise programme on pain and specificity of neck muscle activity in patients with chronic neck pain: A randomized controlled study. Eur J Pain 2013;17(10):1517–28.
17. Bland JM, Altman D. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;327(8476): 307–10.
18. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Med 1998;26(4):217–38.
19. Jull GA, Falla DL, Treleaven JM, Sterling MM, O'Leary SP. A therapeutic exercise approach for cervical disorders. In: Boyling J, Jull G, eds. Grieve's Modern Manual Therapy. Edinburgh, UK: Churchill Livingstone, 2004:451–470.
20. Hudswell S, Von Mengersen M, Lucas N. The cranio-cervical flexion test using pressure biofeedback: A useful measure of cervical dysfunction in the clinical setting? Int J Osteopath Med 2005;8(3):98–105.
21. Jull G, Kristjansson E, Dall'Alba P. Impairment in the cervical flexors: A comparison of whiplash and insidious onset neck pain patients. Man Ther 2004;9(2):89–94.
22. Portney LG, Watkins MP. Foundations of Clinical Research: Applications to Practice. Vol. 2. Upper Saddle River, NJ: Prentice Hall, 2000.
23. Leary MR, Hoyle RH. Handbook of Individual Differences in Social Behavior. New York: Guilford Press, 2009.
24. MacKenzie SB, Podsakoff PM, Podsakoff NP. Construct measurement and validation procedures in MIS and behavioral research: Integrating new and existing techniques. MIS Q 2011;35(2):293–334.
25. James G, Doe T. The craniocervical flexion test: Intra-tester reliability in asymptomatic subjects. Physiother Res Int 2010;15(3):144–9.
26. Wing Chiu TT, Hung Law EY, Fai Chiu TH. Performance of the craniocervical flexion test in subjects with and without chronic neck pain. J Orthop Sports Phys Ther 2005;35(9):567–71.
27. de Koning CH, van den Heuvel SP, Staal JB, Smits-Engelsman BC, Hendriks EJ. Clinimetric evaluation of methods to measure muscle functioning in patients with non-specific neck pain: A systematic review. BMC Musculoskelet Disord 2008;9(1):142.
28. de Paula Lima PO, de Oliveira RR, de Moura Filho AG, Raposo MC, Costa LO, Laurentino GE. Reproducibility of the pressure biofeedback unit in measuring transversus abdominis muscle activity in patients with chronic nonspecific low back pain. J Bodyw Mov Ther 2012;16(2):251–7.
29. Arumugam A, Mani R, Raja K. Interrater reliability of the craniocervical flexion test in asymptomatic individuals — A cross-sectional study. J Manipulative and Physiol Ther 2011;34(4):247–53.

Research Paper

Hong Kong Physiotherapy Journal
Vol. 38, No. 1 (2018) 41–51
DOI: 10.1142/S1013702518500051

Hong Kong Physiotherapy Journal
http://www.worldscientific.com/worldscinet/hkpj

Effect of muscle energy technique with and without strain–counterstrain technique in acute low back pain — A randomized clinical trial

Vivek Dineshbhai Patel[1], Charu Eapen[1,*], Zulfeequer Ceepee[1] and Ramachandra Kamath[2]

[1]*Department of Physiotherapy, Kasturba Medical College Hospital Attavar, KMC Mangalore, MAHE (Manipal Academy of Higher Education), Mangalore 575001, Karnataka, India*

[2]*Department of Orthopaedics, Wenlock Government Hospital, Hampankatta, KMC Mangalore, MAHE (Manipal Academy of Higher Education), Mangalore 575001, Karnataka, India*

[*]*charu_mak@hotmail.com*

Received 27 August 2016; Accepted 14 May 2017; Published 4 April 2018

Background: Muscle energy technique (MET) and strain–counterstrain (SCS) technique are found to be effective as a sole treatment of acute low back pain (LBP), but the combined effect of these two techniques has not been evaluated.
Objective: The purpose of this randomized clinical trial was to evaluate the added effect of SCS to MET in acute LBP patients.
Methods: In this trial, 50 patients were randomly allocated to MET or MET-SCS group to receive the assigned two treatment sessions for two consecutive days. Oswestry disability index (ODI) and Roland Morris disability questionnaire (RMDQ), visual analogue scale (VAS), lumbar range of motion (ROM) were recorded at baseline, after first and second session.
Results: All the outcome measures showed statistically significant ($p < 0.05$) improvement in both the groups after second session. Between the groups, analysis showed no statistically significant difference ($p > 0.05$) after the first or second session.

[*]Corresponding author.

Conclusions: The improvement after second treatment sessions was noted in pain, ROM, and disability in both the groups, but immediate effect was seen only on pain intensity after first treatment session. When compared between the groups, no added effect of SCS to MET was found in reducing pain and disability and increasing lumbar ROM in acute LBP patients.

Keywords: Muscle energy technique; strain counterstrain technique; acute low back pain.

Introduction

Low Back Pain (LBP) is defined as tiredness, discomfort, or pain in the low back region, with or without radiating symptoms to one or both lower extremities.[1] LBP is an extremely common problem that most people experience at some point in their lives.[2] The point prevalence of activity-limiting LBP lasting more than one day is $11.9 \pm 2.0\%$.[3] LBP is the single largest contributor to musculoskeletal disability and causes substantial personal, community and financial burden globally.[4–8]

LBP is a multifactorial condition which can be associated with risk factors like gender, age, lifestyle, psychosocial profile, physical demands of the workplace, social support, pain perception, etc.[9] It may start with an injury and can be exacerbated by factors like deconditioning, psychological issues, other chronic illnesses, genetics and even cultural factors.[10] Only 15% of LBP has an identifiable cause while the rest of the 85% is non-specific LBP.[11]

Approaches use physiotherapy treatment to manage acute LBP by employing a variety of interventions such as exercise involving neuromuscular re-education, resistance training, therapeutic modalities and manual therapy[12] to reduce the chances of developing chronic LBP.[11] In the field of manual therapy, there are many techniques which include soft tissue mobilization, articulatory techniques, myofascial release techniques, muscle energy techniques (MET), functional techniques and strain–counterstrain technique (SCS) to address somatic dysfunctions associated with LBP.[13]

MET is a versatile technique traditionally used to address muscular strain, pain, localoedema and joint dysfunction and to improve range of motion (ROM), to relieve muscle tension and increase the strength of the muscle.[14,15] It is a direct technique in that the patient, instead of the care provider, supplies the corrective force.[16,17] SCS is a technique derived from positional release therapy (PRT) which uses a pain monitor (trigger points, TrP) to find the position of the pain when it is no longer felt at the monitoring point.[13,18]

MET is found to be effective in reducing lumbopelvic pain as a sole treatment[19] and reducing disability in acute LBP when combined with neuromuscular re-education and resistance training.[20] MET has also shown to lead to improvement in lumbar and cervical ROM in asymptomatic individuals.[21,22] A recent systematic review done on MET concluded that MET is effective in the treatment of LBP, but needs to be compared with other manual therapy interventions.[23] A case study on LBP showed that SCS is effective in reducing pain and disability.[24] A randomized control trial showed the equal effectiveness of MET and SCS on pain reduction in acute LBP individuals.[25] A study on SCS for the treatment of trapezius trigger points found that it can be effectively used to reduce pain and improve cervical ROM.[26] SCS alone has no immediate effect in improving cervical ROM, but it was found to be effective when it was combined with other osteopathic techniques including myofascial release, MET, craniosacral treatment and high-velocity low amplitude mobilization.[27] It was suggested that it could be combined with other osteopathic techniques like MET to determine its effectiveness in the treatment of conditions, including acute LBP.[27]

Acute LBP is documented as a substantial cause of disability. While clinicians have found an increased interest in MET for addressing acute LBP, SCS had no effectiveness as a single treatment intervention. We were interested in determining whether SCS along with MET had any added effect in reducing pain and disability and increasing ROM in acute LBP individuals.

The aim of this study is thus to determine the immediate effect of the MET, with and without the employment of the SCS technique, on pain, disability and ROM in patients with acute LBP.

Methodology

The study was approved by the Institutional Ethics Committee, Kasturba Medical College, Manipal Academy of Higher Education, Mangalore.

This study was a randomized clinical trial conducted at tertiary hospitals from June 2014 to March 2015. The sample size of 25 in each group was calculated using 95% confidence level and 80% power from the previous study.[19]

Inclusion criteria for patients were set based on a previous study of MET on acute LBP.[20] These criteria were a symptom duration of ≤ 6 weeks, age between 18 and 65 years, initial Oswestry disability index (ODI) score of 20–60% since a majority of patients with acute LBP have been found to have an initial ODI score within this range. Other inclusion criteria such as unilateral symptoms proximal to the knee and no bilateral symptoms were set based on treatment-based classification criteria[28] since it provides an evidenced-based framework in the appropriate conservative management of individuals with LBP. The final inclusion criterion was confirmed lumbar dysfunction based on MET structured diagnostic protocol.[17] Patients were excluded if they had a history of spinal surgery, spondylolisthesis, lumbar hypermobility, spinal structural deformity, piriformis and sacroiliac (SI) joint dysfunction.

Consultant-diagnosed cases of acute LBP referred for physiotherapy were approached and screened for inclusion and exclusion criteria. The purpose of the study was explained and informed consent was taken from willing patients, after which they were allocated to two groups based on the sequence generated by the computerized randomization method.

The outcome measure chosen for pain intensity was visual analogue scale (VAS) which was a 10 cm long horizontal line with no pain and the worst possible pain at the extremes of the line, ODI version 2.0 as advocated by the original author and the Roland Morris disability questionnaire (RMDQ) were used to measure disability, and lumbar ROM was measured with the Baseline™ Bubble Inclinometer as described by Norkin.[29] The pre-treatment baseline data of pain, disability and lumbar ROM were collected by a blinded assessor, who was a physiotherapist but was not involved in the examination or treatment of the patient.

After completion of self-reported outcome measures and lumbar ROM assessment, the patients were examined by another physiotherapist, using a structured MET diagnostic protocol for lumbar spine dysfunction as described by Greenman.[17] The diagnostic procedure followed the palpatory assessment of the paired transverse processes of the lumbar spine from caudal to cephalad. The examiner located the lumbar spinous processes and moved his thumbs laterally over the area of the transverse processes. An overall weighted kappa of 0.92 was found for the palpation of nominated lumbar spinal levels.[20] The assessment was performed in neutral prone, forward-bent and sphinx positions. The patient was first assessed in neutral prone position, then sphinx position and last in forward bending with patient seated on a stool resting his feet on a floor. If one transverse process was fully posterior in the forward bent position and became symmetrical in the sphinx position, then the patient was diagnosed with extension dysfunction. If one transverse process was more prominent in the sphinx position but became symmetrical in the forward bent position, then the patient was diagnosed with flexion dysfunction. Side-bending dysfunction was diagnosed based on the side of the prominent transverse process. The same physiotherapist gave two treatment sessions for two consecutive days to all the patients. He was not blinded to the treatment groups.

A re-assessment of pain and lumbar ROM was made immediately after the first treatment session and again on the second day of the post-treatment session. ODI and RMDQ were reassessed only at the end of the second treatment session. In post-treatment, all the outcome measurements were taken by an independent assessor blinded to the group allocation.

MET group

Subjects randomized to the MET group received treatment as described by Seffinger[13] and Greenman[17] either in the erect sitting posture or lateral recumbent position. Large patients were treated in the erect sitting position so that gravity could be used as an assisting activating force while other patients were treated in the lateral recumbent position on the table on the side opposite to their side-bending dysfunction.[17] During MET, patient's trunk was drawn in to certain available lumbar ROM, depending upon the dysfunction, until the barrier was engaged. Dysfunctional barriers such

as motion barrier is encountered before the physiologic barrier is reached and it shows distinctive qualities of restriction due to increased myotonus (neuromuscular barrier) which has a consistent elastic quality.

MET in sitting position

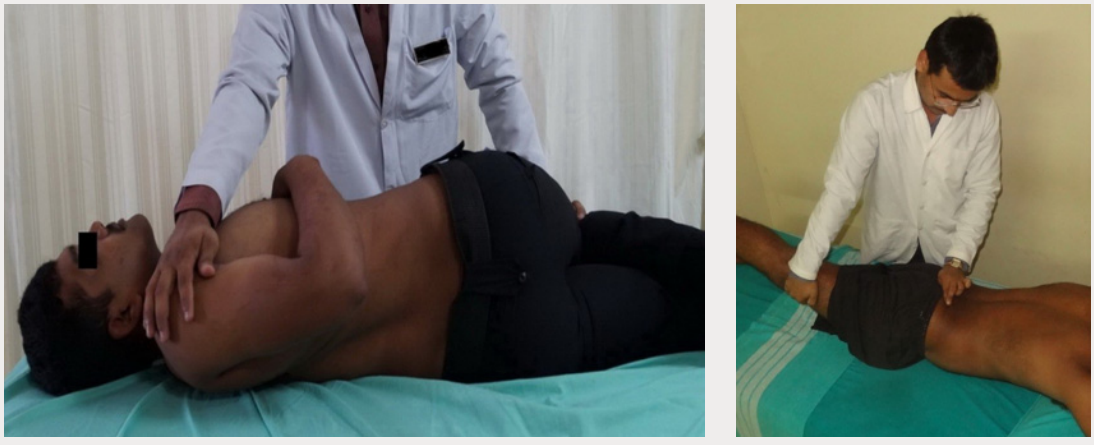
The patient was seated on the examination table with arms folded across the chest. The physiotherapist sat opposite the patient's side-bending dysfunction. One hand of the physiotherapist monitored the vertebral segment being treated. While he placed the axilla of his other arm over the patient's shoulder, brought his arm in front of the subject and placed the hand under the patient's axilla. Then the physiotherapist extended or flexed the subject depending on the flexion or extension dysfunction, respectively, by palpating on the vertebral segment being treated with his hand until a barrier was engaged. Then the physiotherapist rotated and side bent the subject towards him until barrier was engaged.

Then the patient was asked to push his/her shoulder toward the ceiling using approximately 30% of his/her effort against the physiotherapist's unyielding counterforce and to hold this position for 3 s to 5 s. The physiotherapist then re-engaged the barrier by further extending or flexing, rotating and side-bending the patient. The maneuver was repeated 3–5 times with a relaxation of 2 s to 3 s duration in between.

MET in lateral recumbent position

The patient was in the lateral recumbent position on the side opposite to his/her side-bending dysfunction while the physiotherapist stood facing the subject. The physiotherapist monitored the lumbar area with his one hand while with the other hand flexed the subject's knees and hips until the barrier was engaged at the vertebral segment being treated. For flexion dysfunction, the physiotherapist induced an extension of the spine by pushing hips and knees posteriorly. The patient was then asked to straighten his/her bottom leg, and the foot of the leg positioned above was placed in the bottom leg's popliteal space. The physiotherapist then palpated the dysfunctional vertebra and then the patient was pulled anteriorly and superiorly from the arm positioned below to introduce a rotation and side-bending of the lumbar spine until the barrier was engaged at the vertebral segment being treated. Then the physiotherapist's other hand was placed over the upper shoulder of the patient and the patient was asked to push anteriorly with his/her shoulder using approximately 30% of their effort against the physiotherapist's unyielding counterforce and to hold there for 3 s to 5 s. The physiotherapist then re-engaged the barrier by pulling the patient anteriorly and superiorly from the arm positioned below. The maneuver was repeated for 3–5 times with a relaxation of 2 s to 3 s duration in between (Fig. 1(a)).

To treat the side-bending component, the physiotherapist flexed both of the patient's hips



(a) (b)

Fig. 1. (a) Muscle energy technique (MET) in lateral recumbent and (b) Strain-counterstrain (SCS) technique.

and knees and lifted the ankles toward the ceiling until the barrier was reached. The patient then asked to push his/her ankles toward the floor using approximately 30% of their effort against the physiotherapist's unyielding counterforce. The barrier was re-engaged by lifting the patient's ankle further and the maneuver was repeated 3–5 times with a relaxation of 2 s to 3 s duration in between.

MET with SCS technique group

This group of patients was treated with MET as described above. In the SCS, specific distal tender points were localized over the posterior pelvis region of the lumbar spine, and then the position of ease was offered for the tender points till pain was reduced by approximately 70%. Clinically, this was determined by first asking patients to rate their initial tenderness to palpation at tender points at 100%. Then, in order to passively arrive at a position of ease, patients were asked to report if their tenderness was reduced at the same site by approximately 70%. Both perceived tissue tension and the patients' reported tissue tenderness upon intermittent probing were used to guide the physiotherapist to the appropriate relieving position at tender points. This position was maintained passively for 90 s. The same maneuver was repeated three times with a rest interval of 30 s duration in between (Fig. 1(b)).

Data Analysis

SPSS version 17.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. Sociodemographic and clinical characteristics of the participants were summarized with mean, standard deviation and percentages of descriptive statistics of frequency distributions. Data for the lost follow-up patients on the second day were analyzed using intention to treat analysis. P value less than 0.05 was considered statistically significant.

A repeated measure ANOVA was used to assess within the group differences from baseline to post-first treatment session and post-second treatment session for VAS and lumbar ROM. Differences between the mean for the time period i.e., baseline to post-first treatment session and baseline to post-second treatment session were calculated using Bonferroni "t" test. For within-group analysis of mean difference at baseline and post-second treatment session for ODI and RMDQ student, "t" test was used. Independent sample t-test was used to see the mean difference between the two groups for all the outcome measures at baseline, immediately post-first treatment session and then after the second treatment session.

Results

Figure 2 shows the progress of patients at each stage of the study. Gender distribution in both the group was statistically insignificant ($p = 1.00$) with male in MET 18 (72%) and MET-SCS 17 (68%), while female in MET 7 (28%) and MET-SCS 8 (32%). The mean age of participants in MET (38.32 ± 14.92 years) and MET-SCS (44.72 ± 12.82 years) was statistically insignificant ($p = 0.12$). The symptom duration of both the MET (16.32 ± 10.53 days) and the MET-SCS (11.40 ± 9.17 days) group was also statistically insignificant ($p = 0.05$).

Outcome measures at baseline (Table 1) between the groups were homogenous and not statistically significant.

In both the groups, when analysis was done within the group, a statistically significant difference ($p < 0.05$) was seen in VAS and lumbar ROM after the second day post-treatment (Table 2).

*Time * group*

VAS showed improvement in both the groups after the first day post-treatment. Lumbar extension ROM did not show improvement after the first day post-treatment in any group. But lumbar flexion ROM showed a statistically significant difference in the MET-SCS group, but not in the MET group after first day post-treatment. After second day post-treatment, both groups showed a statistically significant difference on ROM and VAS measures (Table 3).

Disability outcome measures also showed a statistically significant difference ($p < 0.001$) within the groups after the second day post-treatment in both the MET and the MET-SCS group.

When a between groups' analysis was carried out for all the outcome measures, no statistically significant difference ($p > 0.05$) was noted after the first day and the second day post-treatment (Table 4).

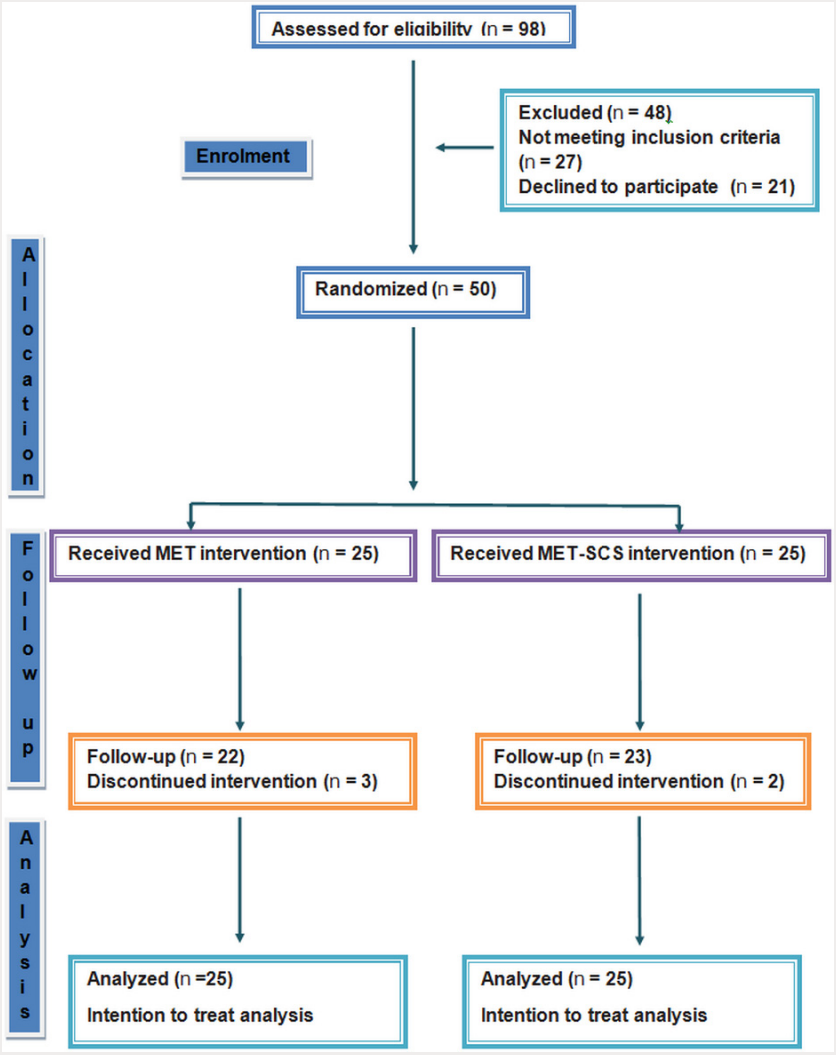


Fig. 2. Consort flow diagram.

Table 1. Outcome measures at baseline.

Variable	MET (Mean ± SD)	MET-SCS (Mean ± SD)	*P*-value
VAS (cm)	5.28 ± 1.42	5.16 ± 1.75	0.932
Lumbar flexion (Degrees)	36.08 ± 12.60	30.48 ± 12.30	0.148
Lumbar extension (Degrees)	14.16 ± 6.79	13.68 ± 7.70	0.536
ODI (%)	39.00 ± 12.99	36.38 ± 11.71	0.445
RMDQ	10.60 ± 5.44	6.88 ± 5.46	0.491

Discussion

The purpose of the study was to compare the added effect of SCS to MET in treating acute LBP patients. The results showed a significant improvement in both groups in VAS, lumbar ROM, ODI and RMDQ at the end of the treatment. However, no significant difference was seen between the groups.

The hypothesis of this study was generated favoring the MET-SCS group. The result of this

Table 2. Differences of VAS and ROM within the group.

Variable	Group	Pre-day 1 (Mean ± SD)	Post-day 1 (Mean ± SD)	Post-day 2 (Mean ± SD)	*F*	*P*-value
VAS (cm)	MET	5.28 ± 1.42	4.08 ± 1.65	3.08 ± 1.46	40.44	< 0.001*
	MET-SCS	5.16 ± 1.75	4.04 ± 1.67	3.20 ± 1.84	37.44	< 0.001*
Flexion (Degrees)	MET	36.08 ± 12.60	37.88 ± 13.31	40.44 ± 13.13	5.25	< 0.012*
	MET-SCS	30.48 ± 12.30	36.08 ± 14.30	35.08 ± 13.34	12.58	< 0.001*
Extension (Degrees)	MET	14.16 ± 6.79	13.92 ± 9.02	18.12 ± 7.56	9.37	< 0.001*
	MET-SCS	13.68 ± 7.70	14.48 ± 7.59	17.92 ± 7.64	10.36	< 0.001*

*$p < 0.05$ significant.

Table 3. Differences of VAS and ROM time × group.

Variable	Group	Factors	Mean difference	Std. error	*p*-value	95% confidence interval
Vas	MET	Pre-day 1 × Post-day 1	1.20*	0.25	<0.001*	0.55–1.84
		Pre-day 1 × Post-day 2	2.20*	0.28	<0.001*	1.48–2.92
	MET-SCS	Pre-day 1 × Post-day 1	1.12*	0.19	<0.001*	0.62–1.62
		Pre-day 1 × Post-day 2	1.96*	0.28	<0.001*	1.24–2.68
Lumbar flexion ROM	MET	Pre-day 1 × Post-day 1	−1.80	1.10	0.344	−4.63–1.03
		Pre-day 1 × Post-day 2	−4.36*	1.50	0.023*	−8.21–−0.51
	MET-SCS	Pre-day 1 × Post-day 1	−5.600*	1.14	<0.001*	−8.54–−2.65
		Pre-day 1 × Post-day 2	−4.600*	1.08	0.001*	−7.38–−1.81
Lumbar extension ROM	MET	Pre-day 1 × Post-day 1	0.24	1.14	1.000	−2.72–3.20
		Pre-day 1 × Post-day 2	−3.96*	1.01	0.002*	−6.55–−1.37
	MET-SCS	Pre-day 1 × Post-day 1	−0.80	0.86	1.000	−3.01–1.41
		Pre-day 1 × Post-day 2	−4.24*	1.06	0.002*	−6.96–−1.51

*$p < 0.05$ significant.

Table 4. Analyses between MET and MET-SCS groups.

Variable		MET	MET-SCS	*P*-value
VAS (cm)	Post-day 1	4.00, 3.00–5.00	4.00, 3.00–4.50	0.706
	Post-day 2	3.00, 2.00–4.00	3.00, 2.00–4.00	0.889
Flexion (Degrees)	Post-day 1	38.00, 31.00–47.50	33.00, 25.50–50.00	0.793
	Post-day 2	40.00, 30.50–50.00	40.00, 25.00–48.50	0.145
Extension (Degrees)	Post-day 1	13.00, 9.00–17.50	15.00, 10.00–18.50	0.681
	Post-day 2	16.00, 14.00–22.50	17.00, 12.50–24.50	0.992
ODI (%)	Post-day 2	26.00, 15.35–40.00	25.00, 19.00–34.44	0.907
RMDQ	Post-day 2	7.00, 4.00–12.00	5.00, 4.00–8.00	0.370

study refuted the hypothesis, as there was no statistically significant difference found between groups post-treatment, in respect to VAS, lumbar ROM, ODI and RMDQ.

Pain

At the end of the treatment, the pain scores improved significantly within both groups, but there was no significant difference noted between the groups.

In this study, the MET technique used was post-isometric relaxation stretch procedure for the patient's group of muscles to lengthen a shortened or contracted muscle, and to mobilize restricted articulation into its proper position.[13] The possible hypoalgesic effect can be explained by golgi tendon reflex inhibition, sympathoexcitation evoked by somatic efferents and localized activation of periaqueductal gray matter, which can be produced by muscle and joint proprioception activation.[30] The other possible mechanism for the therapeutic effects of MET may involve a variety of biomechanical mechanisms such as the change in tissue fluids, altered proprioceptions, motor programming and control and neurophysiologic responses.[31]

A number of studies have been carried out in which MET has been used in combination with other modalities or compared with other forms of treatment, but these have given mixed results. These studies have been done in both acute and chronic LBP patients and hence, the results cannot be generalized to acute LBP.

One study has shown greater effectiveness of MET combined with neuromuscular re-education and strength training rather than neuromuscular re-education and strength training alone, in acute LBP patients.[20] In another study, MET was compared with a sham technique in the management of lumbopelvic pain, and was found to be effective in reducing pain.[19] Another clinical trial concluded that for improvement and reduction in pain, core stability exercises are superior to MET. But in this trial, the groups of LBP patients were heterogeneous and treatment-based classification criteria for manual therapy intervention and stabilization exercise were not followed. Further methodology was not clearly defined.[32] MET with interferential therapy (IFT) was found to be better on VAS, ODI and spinal ROM than IFT alone in acute LBP.[33] MET has been shown to have a superior effect than transcutaneous electrical nerve stimulation (TENS) in non-specific acute LBP patients.[34] In chronic LBP patients, MET and SCS have produced similar effects after four weeks of intervention.[35]

In another study treating SI joint dysfunction, MET was found to be equally effective as SI joint manipulation,[36] but more effective than TENS.[37] When used in adjunct to conventional physiotherapy, MET has also been found to be effective in reducing pain in other joints like those of the shoulder,[38,39] the knee,[40] temporomandibular joint[41] and the cervical spine.[30,31,42]

To the best of our knowledge, this is the first study which compared the added effect of SCS to MET. The results showed that adding SCS to MET did not have any beneficial immediate effect on VAS. In this study, we have followed the therapeutic approach advocated by MET authors, something that was not followed by many previously mentioned studies using MET for the treatment of acute LBP.[37]

When the SCS technique was used in the treatment of LBP, it showed immediate pain relief, but there was no short-term (24–72 h) effect on pain.[24] Similar results were also shown in our study. Another study which combined SCS with exercise in acute LBP did not show any added effect.[43] When SCS and MET were used in the treatment of acute LBP, both were found to be equally effective in reducing pain after eight days of intervention.[25] SCS shows no better improvement than the sham protocol in the treatment of cervical tender points.[44] However, SCS is proved to be more effective in the upper trapezius latent trigger points than ultrasound.[45] Large effect size was noted in terms of active mouth opening and pressure pain threshold when SCS was used for masseter muscle trigger points.[46]

Range of motion

Lumbar flexion ROM showed significant difference immediately after the first treatment session in the MET-SCS group, but not for the lumbar extension ROM. After the second treatment session, both the MET and the MET-SCS group showed significant improvement for lumbar ROM. However, no difference between the groups was seen in the ROM at the end of the second treatment session.

The reason for the immediate improvement could be the combined action of MET and SCS. It could be that MET produced reflex muscle relaxation and lengthened the shortened muscle of the back and improved joint function.[30] Post-isometric relaxation could have activated the golgi tendon organ and inhibited the influence on the motor neuron pool.[31] Improved ROM can also be attributed to a change in the viscoelastic property and change in stretch tolerance.[47]

According to the proprioceptive theory, altered neurophysiologic regulation can lead to aberrant activity of agonist and antagonist muscle spindles.

In the SCS technique by passively shortening dysfunctional agonist muscle, its spindle activity can be reset and aberrant neuromuscular activity can be reduced. This may be caused by altered neurophysiologic regulation. It is also proposed to be effective because it improves local blood circulation influenced by the sympathetic nervous system. SCS may also affect muscle-ligament reflex by reducing the strain over the ligament which, in turn, reduces muscle excitability.[48]

MET was found to be effective in improving the overall trunk rotation ROM in asymptomatic volunteers.[49] MET and positional release therapy both showed lumbar extension ROM improvement when given along with a moist heat pack in acute LBP individuals.[43]

Disability questionnaire

The two groups showed a significant difference in ODI and RMDQ scores. Reduced pain and improved ROM might be the reason for a reduction in disability. Both outcome measures have been found to be used widely for clinical trials to document LBP-associated disability. In this study, ODI was administered as a tool for inclusion criteria and also as an outcome measure to determine the effectiveness of the treatment. RMDQ is found to be used to monitor short-term effects of intervention in mild to moderate LBP. Patients who have a disability score of 20–60% on ODI are found to be more suited for MET intervention.[19] A change in the ODI score in our study was found to be 5.84 points which falls in the range of minimum detectable change (MDC) of 4–10 points in the literature.[28] The minimal clinically important difference (MCID) values for RMDQ depend on the initial score of the patients. The MCID values are calculated in five subgroups i.e., 0 to 8 (MCID = 2), 5 to 12 (MCID = 4), 9 to 16 (MCID = 5), 13 to 20 (MCID = 8) and 17 to 24 (MCID = 8).[50] In our study the MCID value could not be achieved (it was 2.92 as against the value of 4 required for a 5–12 initial score of RMDQ).[50] This could probably be owing the number of treatment sessions being restricted to two. A greater number of treatment sessions may be required to achieve a clinically significant difference. Hence, future studies should be done over a longer period of time to get clinically significant results in the treatment of acute LBP.

Limitation

The SCS intervention procedures used in this study did not conform to the general treatment guidelines recommended by SCS technique proponents such as tender points located anteriorly in the abdominal and pelvic regions. The therapist had no control over the patients' pain medications.

Conclusion

Examination of the results revealed no added effect of SCS to MET in acute LBP patients. Immediately following one treatment session, the effect of MET was determined for pain and disability, but not for lumbar ROM. While MET-SCS showed a reduction in pain and disability and an increase in lumbar flexion ROM immediately upon one treatment session, it did not display the same for lumbar extension ROM. Both MET and MET-SCS showed improvement in all the outcome measures after the second day, post-treatment. When a comparison was drawn between the groups, both the MET and MET-SCS groups were found to be equally benefitted in terms of a reduction of pain and disability. An increase in lumbar ROM was observed in acute LBP patients following the two treatment sessions.

Conflict of Interest

The authors have no conflict of interest relevant to this paper.

Funding/Support

Partial financial support was provided by Manipal Academy of Higher Education for the work discussed in this paper.

Author Contributions

All authors contributed to the study design. Data were collected by Vivek D Patel. Data analysis and interpretation, and writing of the manuscript were carried out by Vivek D Patel, Dr. Charu Eapen and Mr. Zulfeequer CP, with the revision of the manuscript by all the authors.

References

1. Jacobs P, Golmohammadi K. The Cost of Low-Back Pain: A Review of the Literature. Alberta: Health Services Utilization and Outcomes Commission of Alberta, 2003.
2. Anderson GB. Epidemiological features of chronic low-back pain. Lancet 1999;354(9178):581–5.
3. Hoy D, Bain C, Williams G, et al. A systematic review of the global prevalence of LBP. Arthritis Rheumatol 2012;64(6):2028–37.
4. Anderson GB. Epidemiology of LBP. Acta Orthop Scand Suppl 1998;28:28–31.
5. Dionne CE, Dunn KM, Croft PR. Does back pain prevalence really decrease with increasing age? A systematic review. Age Ageing 2006;35:229–34.
6. Rapoport J, Jacobs P, Bell NR, Klarenbach S. Refining the measurement of the economic burden of chronic diseases in Canada. Chronic Dis Can 2004;25:13–21.
7. Deyo RA, Cherkin D, Conrad D, Volinn E. Cost, controversy, crisis: LBP and the health of the public. Annu Rev Public Health 1991;12: 141–56.
8. Coste J, Delecoeuillerie G, Cohen de Lara A, et al. Clinical course and prognostic factors in acute LBP: An inception cohort study in primary care practice. BMJ 1994;308:577–80.
9. Schneider S, Randoll D, Buchner M. Why do women have back pain more than men? A representative prevalence study in the federal republic of Germany. Clin J Pain 2006;22:738–47.
10. Goertz M, Thorson D, Bonsell J, et al. Institute for Clinical Systems Improvement. Bloomington: Adult Acute and Subacute Low Back Pain, 2012.
11. Patel AT, Ogle AA. Diagnosis and management of acute LBP. Am Fam Physician 2000;61(6): 1779–86.
12. Hoehler FK, Tobis JS, Buerger AA. Spinal manipulation for LBP. JAMA 1981;245:1835–8.
13. Seffinger MA, Hruby RJ, Evidence-Based Manual Medicine — A Problem-Based Approach. Philadelphia, PA: Saunders Publishing, 2007.
14. Chaitow L. Muscle Energy Techniques. 3rd ed. Philadelphia, PA: Churchill Livingstone, 2006.
15. Varghese S. A study on the effectiveness of muscle energy techniques compared to manipulation therapy in chronic low back pain. Int J Latest Res Sci Technol 2012;1(2):D214–7.
16. Derosa CP, Porterfield JA. A physical therapy model for the treatment of LBP. Phys Ther 1992;72:261–9.
17. Destefano LA. Greenman's principles of manual therapy. 4th ed. Philadelphia, PA: Lippincott Williams and Wilkins, a Wolters Kluwer business, 2011:300–326.
18. Chaitow L, Wilson E, Morrissey D, Mcpartland J. Positional release techniques. 3rd ed. London: Elsevier health sciences, 2007.
19. Selkow NM, Grindstaff TL, Cross KM, Pugh K, Hertel J, Saliba S. Short-term effect of muscle energy technique on pain in individuals with non-specific lumbopelvic pain: A pilot study. J Man Manip Ther 2009;17(1):14–8.
20. Wilson E, Payton O, Donegan-Shoaf L, Dec K. Muscle energy technique in patients with acute LBP: A pilot clinical trial. J Orthop Sports Phys Ther 2003;33:502–12.
21. Schenk RJ, Adelman K, Rousselle J. The effects of muscle energy technique on cervical range of motion. J Man Manip Ther 1994;2:149–55.
22. Schenk RJ, Macdiarmid A, Rousselle J. The effects of muscle energy technique on lumbar range of motion. J Man Manip Ther 1997;5:179–83.
23. Joseph MD, Arthur JN. The effect of muscle energy technique on disability and pain scores in individuals with LBP. J Sport Rehabil 2012;21(2):194–8.
24. Lewis C, Flynn TW. The use of strain–counterstrain in the treatment of patients with LBP. J Man Manip Ther 2001;2:92–8.
25. Naik PP, Heggannavar A, Khatri SM. Comparison of muscle energy technique and positional release therapy in acute low back pain–RCT. Indian J Physiother Occup Ther 2010;4(2):32–6.
26. Sheikh SA, Chorsiya V. Strain–counterstrain technique for immediate relief of trapezitis in sitting job professionals. Int J Sci Res 2013;2(6): 411–2.
27. Klein R, Bareis A, Schneider A, Linde K. SCS to treat restrictions of the mobility of the cervical spine in patients with neck pain — A sham-controlled randomized trial. Complement Ther Med 2013;21:1–7.
28. Burns SA, Foresman E, Kraycsir SJ, Egan W, Glynn P, Mintken PE, Cleland JA. A treatment-based classification approach to examination and intervention of lumbar disorders. Sports Health 2011;3(4):362–72.
29. Norkin CC, White DJ. Measurement of Joint Motion: A Guide to Goniometry. 4th ed. Philadelphia, PA: F. A. Davis Company, 2009.
30. Yadav H. Goyal M. Efficacy of muscle energy technique and deep neck flexors training in mechanical neck pain — a randomized clinical trial. Int J Ther Rehabil Res 2015;4(1):52–66.
31. Mahajan R, Kataria C, Bansal K. Comparative effectiveness of muscle energy technique and static stretching for treatment of subacute mechanical neck pain. Int J Health Rehabil Sci 2012;1(1): 16–21.
32. Narain A, Singh J, Bhowmik S. To compare the effect of core stability exercises and muscle energy

techniques on low back pain patients. IOSR J Sports Phys Educ 2013;1(2):9–15.
33. Patil PN, Basavaraj C, Metgud S, Khatri S. Effectiveness of muscle energy technique on quadrates lumborum in acute low back pain — randomized controlled trial. Indian J Physiother Occup Ther 2010;4(1):54–8.
34. Franke H, Fryer G, Ostelo RWJG, Kamper SJ. Muscle energy technique for non-specific low-back pain. The Cochrane Database Syst Rev 2015;27(2): CD009852.
35. Ellythy MA. Efficacy of muscle energy technique versus strain counter strain on low back dysfunction. Bull Fac Phys Ther 2012;17(2):29–35.
36. Sharma D, Sen S. Effects of muscle energy technique on pain and disability in patients with SI joint dysfunction. Int J Physiother Res 2014; 2(1):305–11.
37. Mullai D, Sareen A, Arora T. Comparative analysis of muscle energy technique and conventional physiotherapy in treatment of sacroiliac joint dysfunction. Indian J Physiother Occup Ther 2011; 5(4):127–30.
38. Moore SD, Laudner KG, McLoda TA, Shaffer MA. The immediate effects of muscle energy technique on posterior shoulder tightness: A randomized controlled trial. J Orthop Sports Phys Ther 2011; 6(4):400–7.
39. Narayan A, Jagga V. Efficacy of muscle energy technique on functional ability of shoulder in adhesive capsulitis. J Exerc Sci Physiother 2014; 10(2):72–6.
40. Smith M, Fryer G. A comparison of two muscle energy techniques for increasing flexibility of the hamstring muscle group. J Bodyw Mov Ther 2008;12(4):312–7.
41. Rajadurai V. The effect of muscle energy technique on temporo mandibular joint dysfunction: A randomized clinical trial. Asian J Sci Res 2011;4:71–7.
42. Nambi GS, Sharma R, Inbasekaran D, Vaghesiya A, Bhatt U. Difference in effect between ischemic compression and muscle energy technique on upper trepezius myofascial trigger points: Comparative study. Int J Health Allied Sci 2013;2:17–22.
43. Lewis C, Souvlis T, Sterling M. Strain-counterstrain therapy combined with exercise is not more effective than exercise alone on pain and disability in people with acute LBP: A randomised trial. J Physiother 2011;57:91–8.
44. Brose SW, Jennings DC, Kwok J, et al. Sham manual medicine protocol for cervical strain–counterstrain research. PM & R 2013;5(5):400–7.
45. Okhovatian F, Mehdikhani R, Naimi SS. Comparison between the immediate effect of manual pressure release and strain–counterstrain techniques on latent trigger point of upper trapezius muscle. Clin Chiropr 2012;15(2):55–61.
46. Ibáñez-García J, Alburquerque-Sendín F, Rodríguez-Blanco C, et al. Changes in masseter muscle trigger points following strain–counterstrain or neuromuscular technique. J Bodyw Mov Ther 2009;13 (1):2–10.
47. Küçükşen S, Yilmaz H, Sallı A, Uğurlu H. Muscle energy technique versus corticosteroid injection for management of chronic lateral epicondylitis: Randomized controlled trial with 1-year follow-up. Arch Phys Med Rehabil 2013;94(11):2068–74.
48. Wong CK, Straincounter strain: Current concepts and clinical evidence. Man Ther 2012; 17(1):2–8.
49. Lenehan KL, Fryer G, McLaughlin P. The effect of muscle energy technique on gross trunk range of motion. J Osteopath Med 2003;6(1):13–8.
50. Vela LI, Haladay DE, Denegar C. Clinical assessment of low-back-pain treatment outcomes in athletes. J Sport Rehabil 2011;20(1):74–88.

Research Paper

Hong Kong Physiotherapy Journal
Vol. 38, No. 1 (2018) 53–61
DOI: 10.1142/S1013702518500063

Hong Kong Physiotherapy Journal
http://www.worldscientific.com/worldscinet/hkpj

Clinical assessment of balance using BBS and SARAbal in cerebellar ataxia: Synthesis of findings of a psychometric property analysis

Stanley John Winser[1,*], Catherine M Smith[2], Leigh A Hale[2], Leica S Claydon[3] and Susan L Whitney[4,5]

[1]*Department of Rehabilitation Sciences, Hong Kong Polytechnic University, Hong Kong*

[2]*School of Physiotherapy, University of Otago, New Zealand*

[3]*Department of Allied and Public Health, Anglia Ruskin University, UK*

[4]*School of Health and Rehabilitation Sciences, Department of Physical Therapy University of Pittsburgh, USA*

[5]*Rehabilitation Research Chair at King Saud University, Saudi Arabia*

[*]*stanley.j.winser@polyu.edu.hk*

Received 24 August 2016; Accepted 19 July 2017; Published 4 April 2018

Background: In the previous psychometric analysis paper in our series for identifying the core set of balance measures for the assessment of balance, we recommended the Berg Balance Scale (BBS) and balance sub-components of the Scale for the assessment and rating of ataxia (SARAbal) as psychometrically sound measures of balance for people with cerebellar ataxia (CA) secondary to multiple sclerosis.
Objective: The present study further examined the suitability of BBS and SARAbal for the assessment of balance in CA with regard to psychometric property strength, appropriateness, interpretability, precision, acceptability and feasibility.
Methods: Criteria to fulfill each factor was defined according to the framework of Fitzpatrick *et al.* (1998). Based on the findings of our previous psychometric analysis, each criterion was further analyzed.

[*]Corresponding author.

Results: The psychometric analysis reported good reliability and validity estimates for the BBS and SARAbal recommending them as psychometrically sound measures; they fulfilled both criteria for appropriateness and interpretability, the measures showed evidence for precision and acceptability, and they were found to be feasible in terms of the time and cost involved for the balance assessment.
Conclusion: We have provided evidence for the use of the BBS and SARAbal for the assessment of balance among people with CA.

Keywords: Balance; cerebellar ataxia; multiple sclerosis; psychometric analysis.

Introduction

Poor balance and gait difficulties are hallmarks of health conditions that result in cerebellar ataxia (CA).[1] Assessment of balance and gait in CA is challenging as there are no standardized measures of balance available. Previously, a series of studies by our research group recommended a set of core measures. A systematic review[2] and a Delphi survey[3] reported the Berg Balance scale (BBS), the Timed Up and Go (TUG) test, posture and gait sub-component of the International Co-operative Ataxia Rating Scale (PG-ICARS) and the gait, stance and sit sub-components of the Scale for the Assessment and Rating of Ataxia (SARAbal) as appropriate measures of balance in CA.[2,3] Further, a psychometric property analysis was done to estimate constructs of reliability and validity of these four measures among people with CA secondary to multiple sclerosis in New Zealand and the United States of America. The study aimed at proposing the best outcome measures based on the findings of the psychometric analysis. The BBS and SARAbal were recommended as the optimal measures of balance in people with CA secondary to multiple sclerosis.[4]

Fitzpatrick *et al.* reported eight factors to be addressed while selecting an outcome measure for clinical trials.[5] In the process of choosing a standardized set of measures for balance in people with CA, these eight factors were considered. The present study therefore aimed to examine the psychometric properties, appropriateness, interpretability, precision, acceptability and feasibility of the BBS and SARAbal for people with CA based on the findings of the psychometric property analysis done by our research team earlier.[4]

Methods

This paper examined eight factors in light with Fitzpatrick's framework of evaluating a suitable outcome measure for clinical trials and clinical practice.[5] The findings of the present study were based on the outcomes of a psychometric property analysis of four outcome measures of balance tested in people with CA secondary to multiple sclerosis.[4] For the present study, we grouped reliability, validity and responsiveness as psychometric properties.[4] The factors are analyzed and their definitions are listed in Table 1.

Each factor was analyzed based on the set criteria outlined as follows.

Key findings of the psychometric analysis of the BBS and SARAbal were summarized to report the reliability and validity of these measures in people with CA. The detailed methodology and results of this psychometric property analyses are published elsewhere.[4,6] The other reported factors including appropriateness, interpretability, precision, acceptability and feasibility we based on the experience gained during the data collection and interpretation of results of our previous psychometric analysis study. To summarize, 60 participants aged 18–65 years with CA secondary to multiple sclerosis were recruited. Data were collected at four outpatient units in New Zealand and the United States of America. All included participants underwent balance assessment using the BBS, TUG, SARAbal and PG-ICARS. The participants were assessed on a single occasion and during the assessment, a video recording was done. The video recording was later used to estimate the intra-rater and inter-rater reliabilities. The Barthel Index, the Expanded Disability Status Scale (EDSS), the full scales of the ICARS and the SARA were also assessed and disease duration was recorded. The EDSS was completed by a neurologist. To investigate the intra-rater and inter-rater reliabilities, a repeat assessment was performed by the same physiotherapist (intra-rater) or a second physiotherapist (inter-rater) from the video recording.

Table 1. Descriptors of the factors analyzed.

Factor	Descriptor
Psychometric properties	Common term that includes reliability, validity and responsiveness of the outcome measures
Appropriateness	Described as how suitable the contents of the instrument are for use in people with CA[5]
Interpretability	Indicates how meaningful are the scores obtained from the outcome measures[5]
Precision	Defined as the accuracy of the instrument in categorizing sub-groups and distribution of numerical value
Acceptability	Defined as the level to which the outcome measure is tolerable for its use in people with CA[5]
Feasibility	Described as the ease of use of the outcome measure in terms of administering it, and the associated financial cost[5]

In this study, appropriateness was analyzed based on two criteria: (i) to judge whether the contents of the outcome measure suit the target population and (ii) if the recommended set of outcome measures has a combination of a condition-specific tool and a generic tool for the assessment of balance. Interpretability was analyzed based on two criteria: (i) to determine how meaningful the obtained scores were, using the BBS and the SARAbal and (ii) to determine if the outcome measures have established normative data. Precision was analyzed based on two criteria: (i) to determine if the instrument is able to discriminate between two known sub-groups within the collected samples and (ii) the accuracy of distribution of numerical values assessed using Rasch analysis or estimation of unidimensionality of the testing items using factorial analysis. Acceptability was determined by estimating the response rate of the participants to the items of the outcome measures. In general, the lesser the missing items, the better the acceptability.[5] Feasibility was assessed by observing the ease of use, cost involved for the assessment, time taken to complete and training required for the assessor to complete the balance assessment using the two outcome measures. The criteria were organized into a tabular column and the reviewer marked either "yes" if the criteria were met or "no" if the criteria were not met or "unclear" if the answer was ambiguous. Each of the criterion was independently reviewed by two authors (SW and CS) and discrepancies in findings were discussed. A third reviewer (LC) was involved for unresolved discrepancies in the findings between the first two reviewers or if the reviewers marked "unclear" for the criteria.

Balance measures

The BBS is a performance-based measure of balance[7] and has been reported to be the most commonly used balance tool by physiotherapists.[8] The BBS is a five-point ordinal scale scored between 0 and 4 for each task and has 14 tasks in total. The highest total score a participant may obtain is 56. This measure is interpreted as better balance with higher scores. Normative scores for the BBS have been established among community dwelling older adults.[9] This measure has good inter-rater (ICC = 0.96) and test retest (ICC = 0.94) reliabilities and low standard error of measurement (SEM).[10] The BBS is found to have acceptable concurrent validity in assessing balance and poor in discriminating between fallers and non-fallers in people with multiple sclerosis.[11]

The SARA is an ataxia severity rating measure.[12] It consists of eight items among which gait, sitting and the standing sub-components are related to balance. The full scale is scored out of 40. The three sub-components of balance are scored out of 18 (SARAbal). Scoring of the eight sub-components do not have equal weighting, with scores ranging between eight for the "gait" sub-component and four for the "heel-shin glide". The higher the score obtained, the worse the condition. The SARA has high test re-test reliability (ICC = 0.90), inter-rater reliability (ICC = 0.97) and internal consistency ($\alpha = 0.93$).[12] Structural validity has been reported,[13] satisfactory convergent validity when correlated with other ataxia rating scales[12] and adequate responsiveness has been demonstrated.[14] The testing has been done and conducted with both genetic and acquired forms of cerebellar disorders.

Results

The review of criteria for each factor resulted in 100% agreement between the reviewers and therefore the third reviewer was not approached. The reliability and validity of the measures were found to be strong and the responsiveness was not estimated. A summary of the findings on the

psychometric properties of the BBS and the SARAbal are highlighted in Table 2. For appropriateness, the measures met both the criteria. With regards to interpretability, off the two required criteria, both the measures met the first criteria whereas the BBS met the second criteria and SARAbal did not. The first criteria for precision were met by both the measures however, the second criteria were not established as Rasch analysis and factor analysis were outside the scope of the psychometric analysis. Both the measures met the criteria for acceptability and in addition, they were found to be feasible.

Discussion

This study aimed at identifying the suitability of using the BBS and SARAbal for the clinical assessment of balance in people with CA. The framework of Fitzpatrick *et al.*[5] was used to address eight independent factors for this recommendation. We have provided evidence for most of the factors and in addition, recommendations for future research for strengthening the present findings have been provided.

Psychometric properties of the measures of balance

The BBS and SARAbal reported good intra-rater, inter-rater reliabilities and internal consistency.[4] The criterion validity was found to be good for both the measures ($\rho S > 0.80$). The measures were correlated against disease duration, disease severity and functional independence to determine construct validity and correlation was moderate ($\rho S > 0.55$). The measures were correlated against ataxia severity rating scales to estimate convergent validity which was found to be good. The study participants were sub-divided into assistive walking device users and non-users. The ability of the measures of balance to differentiate between users and non-users of assistive devices was studied to determine the discriminant validity. The balance scores showed a statistically significant difference between the scores of assistive device users and non-users showing evidence for discriminant validity. In summary, both the BBS and SARAbal have good reliability and acceptable validity for the assessment of balance among people with CA secondary to multiple sclerosis. The structural validity and responsiveness of the measures of balance were not determined.

Appropriateness of the measures of balance

A straightforward method to determine if the contents of the outcome measure suit the target population is to obtain feedback from end users, the clinicians. The psychometric analysis involved testing four balance measures of which three were endorsed by experts through the Delphi survey done earlier by our research team.[3] In the Delphi survey, neurologists and physiotherapists involved in research and clinical practice of CA were interviewed. They were asked to indicate the most appropriate measure of balance they might use to quantify balance deficits relating to CA. The internet-based survey went on for two rounds and the participants came to a consensus on the use of the BBS, TUG and SARAbal as the most appropriate choice of assessment tool. Two of the measures recommended as the core set were those endorsed by the clinical experts in the Delphi study providing evidence for appropriateness.[3]

Secondly, it is recommended that an appropriate set of patient outcome measures should have one condition-specific measure and a generic measure.[5] A condition-specific measure identifies changes that are in close relation or "proximal" to the disease such as difficulty in performing tandem walking in CA and the generic measure identifies changes that are slightly less proximal or "distal" to the health condition,[18] such as altered stepping secondary to coordination deficits in CA. Among the core set of measures, the SARAbal is condition-specific and the BBS is a generic measure of balance.[2]

Interpretability of the measures of balance

In order to identify a meaningful score, the most significant approach may be to relate the scores achieved to the minimal clinically important difference (MCID).[5] The MCID is described as the smallest difference in the score following an intervention that the patient perceives as beneficial.[19] Since the psychometric analysis did not involve a repeat assessment, where arguably a change in score could be expected, determining the MCID score was not possible. However, we established the

Table 2. Definition, accepted statistical analysis, interpretation and findings of the psychometric properties considered.

Psychometric property	Description	Statistical analysis	Interpretation	Results
Reliability				
Internal consistency	Defined as the degree of interrelatedness between the test items within each outcome measures considered.[15]	Cronbach alpha	There are no universal guidelines for interpreting reliability, in general, higher the value towards 1, greater the reliability. We interpreted as follows: $\alpha > 0.80$: good, α between 0.5 and 0.79: moderate, $\alpha < 0.50$: poor	$\alpha = 0.94$ (BBS) $\alpha = 0.72$ (SARAbal)
Inter-rater reliability	Defined as the proportion of variation in the scores of the participant done by two different investigators.[16]	Continuous scores: ICC Dichotomous/ nominal/ordinal scores: kappa (κ) or weighted kappa	ICC > 0.80: good, ICC between 0.5 and 0.79: moderate, $A < 0.50$: poor	ICC = 0.97 (BBS) ICC = 0.96 (SARAbal)
Intra-rater reliability	Defined as the proportion of variation in the scores of the participant done by the same investigator with an interval of 7–10 days.[15]	Same as inter-rater reliability		ICC = 0.99 (BBS) ICC =0.98 (SARAbal)
Validity				
Criterion validity	Defined as the degree to which the scores of the measure under investigation are an adequate reflection of a "gold standard".[16]	Spearman or Pearson correlation co-efficient. Since the outcome measures considered were ordinal, we used the Spearman correlation co-efficient (ρS). Since "'gold standard" was not available for balance assessment, we correlated the measures of balance (BBS, TUG, PGICARS and SARAbal) against each other.	$\rho S > 0.80$: good, ρS between 0.5 and 0.79: moderate, $\rho S < 0.50$: poor	BBS versus TUG: −0.88 PGICARS: −0.80 SARAbal: −0.92 SARAbal versus BBS: −0.92 TUG: 0.72 PGICARS: 0.92
Hypothesis testing	Defined as the degree to which the scores of the measures under investigation are consistent with the hypotheses.[16] Convergent, divergent, external and construct validity are grouped under hypothesis testing.	Spearman correlation co-efficient (ρS).	Same as above	
Convergent validity	Indicates that two measures examining similar underlying phenomenon will provide similar results. For example, high correlation can be anticipated between the results of two outcome measures assessing balance.	Spearman correlation co-efficient (ρS). The measures of balance were correlated with two ataxia rating scales (ICARS and SARA)	Same as above	BBS versus ICARS: −0.76 SARA: −0.82 SARAbal versus ICARS: 0.79 SARA: 0.85

Table 2. (*Continued*)

Psychometric property	Description	Statistical analysis	Interpretation	Results
External validity	Defined as the degree to which the outcome measure under investigation correlates with other instruments or other constructs, for example ADL, disease severity or disease duration.	Spearman correlation co-efficient (ρS). The measures of balance were correlated with ADL status, disease duration and disease severity. ADL was assessed using BI and disease severity using the EDSS.	Same as above	BBS versus EDSS: −0.78 BI: 0.55 Disease duration: −0.61 SARAbal versus EDSS: 0.76 BI: −0.44 Disease duration: 0.58
Discriminant validity	Defined as the ability of the outcome measures to differentiate between two-known groups within the study population.	Group differences of scores between users and non-users of assistive walking devices were considered for establishing discriminant validity. We used Mann–Whitney U test.	Statistically significant difference ($p < 0.05$) in the scores between groups was considered evidence for discriminant validity.	Mean, SD and p value BBS ADU: 34.6 (11.8) ADNU: 52.19 (4.43) $p <$ 0.01 SARAbal ADU:7.0(2.8) ADNU: 1.71 (1.37) $p < 0.01$
Cut-off score, sensitivity and specificity for assistive walking device use	Sensitivity is an indication that the outcome measure is capable of identifying certain trait that is really present in the given population. Specificity is an indication that the outcome measure is capable of identifying the lack of certain trait that is really absent in the given population.	Receiver operating characteristics (ROC) curve was constructed to determine the cut-off score, sensitivity and specificity of the measures to predict the users of an assistive walking device. In addition, to determine and quantify which measure had a better predictive ability, the "Area Under the Curve" (AUC) was used.	The examiner makes a logical decision based on the needs for the cut-off score. In this case, the score needs to precisely identify an assistive device user more than identifying a non-user. Thereof, the sensitivity was kept high and constant at 90% and the corresponding cut-off score and the highest specificity at 90% of sensitivity were derived.	BBS: cut-off < 44 out of 56 sensitivity 90% specificity 94% SARAbal: cut-off > 5 out of 18 sensitivity 90% specificity 100%
Responsiveness				
Responsiveness	Described as the ability of the outcome measure to detect changes over time.[16]	Can be determined using different approaches. Some commonly adopted analysis include ROC (distribution-based approach) or relating the change of score to "Global Rating of Change" score (anchor-based approach).[17]		Responsiveness was not estimated.

Notes: α — Cronbach's alpha, ICC — intra class correlation co-efficient, ρS — Spearman's Rho, BBS — Berg Balance Scale, SARAbal, gait, sit and stance sub-component of the SARA, PGICARS — Posture and gait sub-component of the ICARS, SARA — Scale for the Assessment and Rating of Ataxia, ICARS — International Co-operative Ataxia Rating Scale, ADl — activities of daily living, BI — Barthel Index, EDSS — Expanded Disability Status Scale, ADU — assistive device user, ADNU — assistive device non-user SD — standard deviation, p — level of significance.

minimal detectable change (MDC) for the BBS and the SARAbal.

The MDC is described as the smallest change that an outcome measure detects due to a notable change in the participants' performance. The established MDC is a reflection of the SEM for the measures of balance and could be considered as a "proxy" for the MDC. The term "proxy" in statistics refers to a value that is probably not in itself of any great interest, but from which a variable of interest can be obtained. The MDC was estimated using a data-driven method proposed by Wyrwich *et al.*[20] The Cronbach alpha of the measures of balance was used to estimate the SEM that reflected the MDC. Therefore, the derived MDC provides meaningful information on the expected change in score that may be perceived to be clinically meaningful for the patient following intervention. Future studies may use the obtained MDC as reference scores for reporting their results.

The second method of assessing interpretability is to compare the scores with normative data in a way that the difference in the score reflects the magnitude of difference between the tested sample and an age-matched healthy peer. The BBS has established normative data among community dwelling healthy older adults.[9] Being condition-specific and relatively new, the SARA does not have established normative data. Future studies are recommended to establish the normative scores for the SARAbal among healthy older adults.

Acceptability of the measures of balance

The response rate to the outcome measures was high for the psychometric analysis and there were no missing items in our data providing evidence for acceptability.[5] Acceptability can also be demonstrated by determining the floor and ceiling effect of the tool. These estimates report on the level of ease to complete the items i.e., were the contents of the tool too easy or too difficult or tolerable for the tested population? Determining the acceptability was outside the scope of the psychometric analysis; however, based on the findings of the psychometric analysis, the answer to this question may be partially resolved. Of the 60 participants, only one (2%) had difficulty in completing all four assessments due to fatigue providing some evidence for acceptable floor effect. The participants were able to complete all four tests. Eight (13%) participants obtained full score for BBS and five (8%) for the SARAbal. However, we hesitate to comment on the question "were the contents too easy to complete?" Future studies are recommended to estimate the floor and ceiling effect for these measures of balance.

Precision of the measures of balance

The psychometric property analysis estimated discriminant validity by sub-dividing the participants into assistive device users and non-users. Mann–Whitney U test was used to determine the group differences between the two known groups (assistive device users and non-users). The findings of this analysis revealed a statistically significant ($p < 0.01$) difference between the two groups for both the measures of balance providing evidence for precision.[4] Secondly, it is recommended that the precision could be derived by estimating the unidimensionality of the measures under consideration. However, unidimensionality estimation was outside the scope of the psychometric analysis. Therefore, we recommend future studies to conduct Rasch analysis or factorial analysis to provide evidence for unidimensionality for these measures in future.

Feasibility of the measures of balance

Based on the experience gained during data collection, the two measures of balance took 15–20 min to complete. They did not require the use of sophisticated equipment and are available at free of cost. In addition, formal training is not needed to perform these tests (the measures include instruction). However, the examiners who conducted these tests were qualified physiotherapists and therefore, the feasibility of administration is limited to qualified physiotherapists. With regard to patient safety, it is recommended that the assessment room is well-lighted, surface is non-slippery, and adequate rest breaks are given between the assessment sessions. There were no adverse events documented during data collection providing evidence for feasibility of the measures.

Generalizability of the findings

The findings of the present study are based on the outcomes of a psychometric analysis conducted earlier. As reported, the psychometric property

analysis recruited people with CA secondary to multiple sclerosis. The recruited sample was heterogeneous in terms of disease course of multiple sclerosis which enables the generalizability of findings to all types of multiple sclerosis. In addition, the sample was homogenous in terms of the type of lesion. The included participants with multiple sclerosis were restricted to primary cerebellar impairment. Therefore, these recommendations may be considered for people with other types of cerebellar ataxic lesions.

Conclusion

The findings of this study suggests that the BBS and SARAbal are psychometrically sound, appropriate, interpretable, precise, acceptable and feasible for the assessment of balance in people with CA and multiple sclerosis. Future studies are warranted to estimate the structural validity, responsiveness, MCID, plus floor and ceiling effect for these measures to strengthen the present findings.

Conflict of Interest

The authors declare that there is no conflict of interest relevant to the study.

Funding/Support

This research was funded by the University of Otago, New Zealand Doctoral Scholarship, School of Health and Rehabilitation Research, University of Pittsburgh, USA and Division of Health Science, University of Otago, New Zealand, travel grants, Maurice and Phyllis Paykel Trust (MPPT) fund Physiotherapy New Zealand, Otago Branch Educational Fund, Physiotherapy New Zealand's Neurology Special Interest Group Grant, School of Physiotherapy, Research fund, and was partially and financially supported by King Saud University, through Vice Deanship of Research Chairs, Rehabilitation Research Chair.

Author Contributions

Dr. Stanley John Winser contributed to structuring study design, write up for funding, subject recruitment, data collection, data review, data analysis, data interpretation, project management, writing the manuscript and revising the manuscript. Dr. Catherine Smith contributed to write up for funding, data review, data interpretation, project management and writing the manuscript. Prof. Leigh A Hale contributed to write up for funding, data interpretation, project management and writing the manuscript. Dr. Leica S Claydon contributed to write up for funding, data review, data interpretation, project management and writing the manuscript. Prof. Susan L Whitney contributed to data interpretation, project management and writing the manuscript.

References

1. Palliyath S, Hallett M, Thomas SL, Lebiedowska MK. Gait in patients with cerebellar ataxia. Mov Disord 1998;13(6):958–64.
2. Winser SJ, Smith CM, Hale LA, Claydon LS, Whitney SL, Mehta P. Systematic review of the psychometric properties of balance measures for cerebellar ataxia. Clin Rehabil 2015;29:69–79.
3. Winser SJ, Smith C, Hale LA, Claydon LS, Whitney SL. Balance outcome measures in cerebellar ataxia: A Delphi survey. Disabil Rehabil 2015;37:165–70.
4. Winser SJ, Smith C, Hale LH, et al., Psychometric properties of a core set of measures of balance for people with cerebellar ataxia secondary to multiple sclerosis. Arch Phys Med Rehabil 2016; in press.
5. Fitzpatrick R, Davey C, Buxton MJ, Jones DR. Evaluating patient-based outcome measures for use in clinical trials. Health Technol Assess 1998;2:1–74.
6. Winser SJ, Smith C, Hale LH, et al., Balance assessment in multiple sclerosis and cerebellar ataxia: Rationale, protocol and demographic data. Phys Med Rehabil Int 2014;1(5):6.
7. Berg K, Wood-Dauphinee S, Williams JI. The balance scale: Reliability assessment with elderly residents and patients with an acute stroke. Scand J Rehabil Med 1995;27(1):27–36.
8. Korner-Bitensky N, Wood-Dauphinee S, Teasell R, et al., Best versus actual practices in stroke rehabilitation: Results of the Canadian national survey. Stroke 2006;37:631.
9. Steffen TM, Hacker TA, Mollinger L. Age-and gender-related test performance in community-dwelling elderly people: Six-minute walk test, Berg balance scale, timed up & go Test, and gait speeds. Phys Ther 2002;82(2):128–37.
10. Cattaneo D, Jonsdottir J, Repetti S. Reliability of four scales on balance disorders in persons with multiple sclerosis. Disabil Rehabil 2007;29:1920–5.
11. Cattaneo D, Regola A, Meotti M. Validity of six balance disorders scales in persons with multiple sclerosis. Disabil Rehabil 2006;28(12):789–95.

12. Schmitz-Hübsch T, du Montcel ST, Baliko L, et al., Scale for the assessment and rating of ataxia: Development of a new clinical scale. Neurology 2006;66(11):1717–20.
13. Bürk K, Mälzig U, Wolf S, et al., Comparison of three clinical rating scales in Friedreich ataxia (FRDA). Mov Disord 2009;24(12):1779–84.
14. Lee YC, Liao YC, Wang PS, Lee IH, Lin KP, Soong BW. Comparison of cerebellar ataxias: A three-year prospective longitudinal assessment. Mov Disord 2011;26(11):2081–7.
15. Portney LG, Watkins MP. Reliability of measurements. In: Foundations of Clinical Research Application to Practice. 3rd ed. New Jersey, USA: Julie Levin Alexander, 2009:77–96.
16. Mokkink LB, Terwee CB, Patrick DL, et al., The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. J Clin Epidemiol 2010;63 (7):737–45.
17. Portney LG, Watkins MP. Statistical measures of validity. In: Foundations of Clinical Research Application to Practice. 3rd ed. New Jersey, USA: Julie Levin Alexander, 2009:620–25.
18. Brenner MH, Curbow B, Legro MW. The proximal–distal continuum of multiple health outcome measures: The case of cataract surgery. Med Care 1995:AS236–44.
19. Jaeschke R, Singer J, Guyatt GH. Measurement of health status: Ascertaining the minimal clinically important difference. Control Clin Trials 1989;10 (4):407–15.
20. Wyrwich KW, Tierney WM, Wolinsky FD. Further evidence supporting an SEM-based criterion for identifying meaningful intra-individual changes in health-related quality of life. J Clin Epidemiol 1999;52(9):861–73.

Research Paper

Hong Kong Physiotherapy Journal
Vol. 38, No. 1 (2018) 63–75
DOI: 10.1142/S1013702518500075

Hong Kong Physiotherapy Journal
http://www.worldscientific.com/worldscinet/hkpj

Symptoms-modifying effects of electromotive administration of glucosamine sulphate among patients with knee osteoarthritis

Ayodele Teslim Onigbinde[1,*], Adegbenga Rotimi Owolabi[2], Kamil Lasisi[3], Sarah Oghenekewe Isaac[1] and Adeoye Folorunsho Ibikunle[1]

[1]*Department of Medical Rehabilitation, Faculty of Basic Medical Sciences College of Health Sciences, Obafemi Awolowo University Ile-Ife, Osun State, Nigeria*

[2]*Department of Medical Pharmacology and Therapeutics Faculty of Basic Medical Sciences, College of Health Sciences Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria*

[3]*Department of Physiotherapy, Ladoke Akintola University Teaching Hospital Osogbo, Osun State, Nigeria*

[*]*ayotesonigbinde@yahoo.co.uk*

Received 22 August 2016; Accepted 19 July 2017; Published 27 April 2018

Background: Most trials on symptom-modifying effects of glucosamine are limited to administration through oral route with dearth of empirical data on the use of electromotive force.
Objective: The study determined the effects of glucosamine sulphate (GS) iontophoresis (IoT) on radiographic parameters of patients with knee osteoarthritis (OA).
Methods: Fifty-three patients were randomly assigned to three groups. About 1 g each of GS was administered using IoT and cross-friction massage (CFM) for participants in groups 1 (IoT) and 2 (CFM), respectively. Group 3 ((Combined therapy) CoT) received 1 g of GS using both IoT and CFM. Interventions were twice a week for 12 weeks. Analysis of variance (ANOVA) was used to analyze the data ($p < 0.05$).
Results: After 12 weeks, the medial joint space width (JSW) of the CFM group was significantly higher than that of IoT and CoT groups ($p = 0.005$ and $p = 0.004$). Lateral JSW of IoT group was significantly higher than both CFM ($p = 0.001$) and CoT groups ($p = 0.01$). There were significant decreases in pain intensities;

[*]Corresponding author.

increase in knee flexion and physical functions across the groups ($F = 9.33, p = 0.01; F = 3.23, p = 0.01$; $H = 4.97, p = 0.01$, respectively).
Conclusion: It was concluded that there were significant decreases in the degenerative changes at the knee joint.

Keywords: Osteoarthritis; glucosamine; electromotive administration; degenerative changes.

Introduction

Osteoarthritis (OA) is the most common arthritis with about 3.8% affecting the knee and hip joints.[1] Approximately 10% and 18% of men and women, respectively, present with multifarious symptoms and radiological evidence in more than 50% of people over 65 years of age.[2,3] There is an increasing prevalence of OA with resultant decrease in functional capacities of patients.[4] The earliest signs of knee OA are narrowing of the medial compartment of the joint, sub-chondral sclerosis, cystic changes in the articular surfaces, and spur formation on the tibia spine.[5] The measurement of the distance between the distal femur and the proximal tibia is the joint space width (JSW) and it is an indirect way of measuring cartilage thickness. The JSW is reproducible for the assessment of progressive knee cartilage degenerations, and evaluation of disease-modifying effects of therapies.[6,7] The diagnosis of OA is based on the combination of typical mechanical pain symptoms and physical findings in the joints. OA has traditionally been diagnosed with radiographs that demonstrate JSW and osteophytes.[8]

The main goal of managing OA includes alleviation of pain and improving functional abilities and main drugs of choice are non-steroidal anti-inflammatory drugs (NSAIDs), but the oral and injectables are not without potential hazards. The adverse effects include gastrointestinal disorders and reduction in body immunity, particularly in the elderly.[9] In view of this, there is an increasing quest in medical technology towards establishing safer and effective means of delivering medications beside these common methods. Hence, drug administration using electromotive forces (iontophoresis (IoT) and phonophoresis) are being considered as alternatives in clinical physiotherapy practice. Although, pharmacokinetic parameters of most of these drugs have not been analytically established after administration through the use of electromotive forces, the successes attached to the findings are clinical indications in which the medications are delivered in sufficient amount to the targeted tissues.[4,10,11] In IoT, there is percutaneous absorption through three main pathways: the intercellular (paracellular) pathway between the conneocytes along the lamellar lipids, the intracellular (transcellular) pathway through the cells or the appendageal (shunt) pathway via hair follicles, sweat ducts and secretary glands.[12] Patients with OA should receive a combination of non-pharmacologic and pharmacologic treatment.[13] Amongst drugs which have been speculated to be disease-modifying are glucosamine and chondroitin, but the magnitude of their effects remains unclear and controversial. The effectiveness of administration of glucosamine on slowing progression of OA is still shrewd with speculation.[14] The evidence that it can modify the structure of joints is still early and inconclusive. Some clinical trials have shown that glucosamine may prevent or slow down the loss of cartilage rather than re-growing it.[15,16] Speculation still surrounds the effectiveness of topical application of glucosamine sulphate (GS) cream using massage to alleviate pain and slow down degenerative changes in patients with OA and it appears that there is inadequate data on the electromotive administration of glucosamine. However, it is unknown if electromotive force will drive in more GS to hasten pain relief and also reduce joint degenerative changes faster than massage, hence, this study is needed.

The primary aim of the study was to investigate the effect of GS IoT on selected radiographic parameters (JSW, inter-condylar thickening (ICT) tibia width, pain intensity, range of motion (ROM) and physical function in patients with knee OA. It was hypothesized that there would be no significant difference in the selected radiographic parameters, pain intensity, ROM and physical activity of patients with knee OA among patients who received GS through cross-friction massage

(CFM) only, IoT only; and a combination of both CFM and IoT in administering GS.

Methods

Participants

The 53 participants were patients with knee osteoarthritis, receiving treatment at the Out-Patient Physiotherapy Clinic of a Nigerian University Teaching Hospital in South West Nigeria.

Research design

This study was a randomized controlled trial (pre-test and post-test) experimental design.

Inclusion and exclusion criteria

The major inclusion criteria were that the participants must have knee OA with history not less than three months. There must also be radiological evidences of grade III on Kellegren classification. Excluded from the study were patients with history of knee surgery or replacement, patient with neuromuscular and musculoskeletal diseases; cardiac disorder, those using cardiac pacemaker, on intra articular steroid therapy within two months before the commencement of this study and participants with impaired skin sensation.

Sampling techniques

A total of 60 participants were recruited for the study with 20 in each group using purposive sampling technique. The sample size for this study was predetermined considering standard normal deviation to be 1.96, 0.02° of accuracy, power estimate of 80% and knee OA prevalence of 60% in adults. The probability of Type I error is considered as level of significance. The sample size was computed to be 18 participants per group but to give room for attrition, 20 participants were recruited for each group totaling 60 participants for the study. They were randomly assigned to three groups using fish bowl technique. Sixty separate slips, labeled groups 1, 2 and 3 with 20 for each group were mixed and pooled into a box. Each patient was instructed to pick a slip without looking into the box. Whatever group was picked would be the group that the patient was allotted. The flow chart is presented in Fig. 1.

Instruments

The instruments and test items included bathroom weighing scale, a modified height meter, an electrical stimulator (Model: Endomed 582, India), 70% alcohol and GS cream (glucosamine 8% w/w), (Urah). Amongst the test items are the following: a 10-point visual analogue scale (VAS), a plastic semi-circle Goniometer (Model E-Z ReadTM), Western Ontario and Mcmaster University — WOMAC OA index Questionnaire, X-ray film report, pointing divider, Vernier caliper and magnifying lens (Roger Bacon, Model No AC099).

Procedure for data collection

Ethical approval was obtained from the Health Research and Ethics Committee, Institute of Public Health, Obafemi Awolowo University, Ile Ife. All the patients consented to participate in the study. Participants in group 1 (IoT) received only 1 g (2 Finger-Tip Unit (FTU)) of GS cream which was administered via IoT. Group 2 (CFM) participants also received 1 g (2 FTU) of GS only, but it was administered using CFM while group 3 (combined therapy (CoT)) participants had interventions using 1 g of GS cream through both IoT and CFM.

A 10-point VAS was used to rate the pain. The VAS had been established to be reliable and effective in assessing knee pain arising from OA.[17] Pain intensities were rated on three occasions: on active and passive knee flexions, and on patellar grinding. The active knee flexion was measured in prone lying position using a standard procedure. Physical function was assessed using the WOMAC OS Questionnaire.[18] The physical function subscale was used to assess functional abilities of patients in this study. There are 17 items on the physical function sub-scale, it was rated on a 5-point Likert scale, ranging from 0 to 4 whereby "0 = none and "4 = extreme". The minimum obtainable score was "0" indicating best physical function while the maximum obtainable was "68" indicating poor physical function. The obtained score for physical function was divided by total possible score and multiplied by 100 and reported in percentage. Lower value depicts better physical function performance.

The JSW and inter-condylar thickening (ICT) were measured using standard procedures adopted by Deep *et al.*[19] and Lequesne.[20] The JSW was also measured manually using the method described by

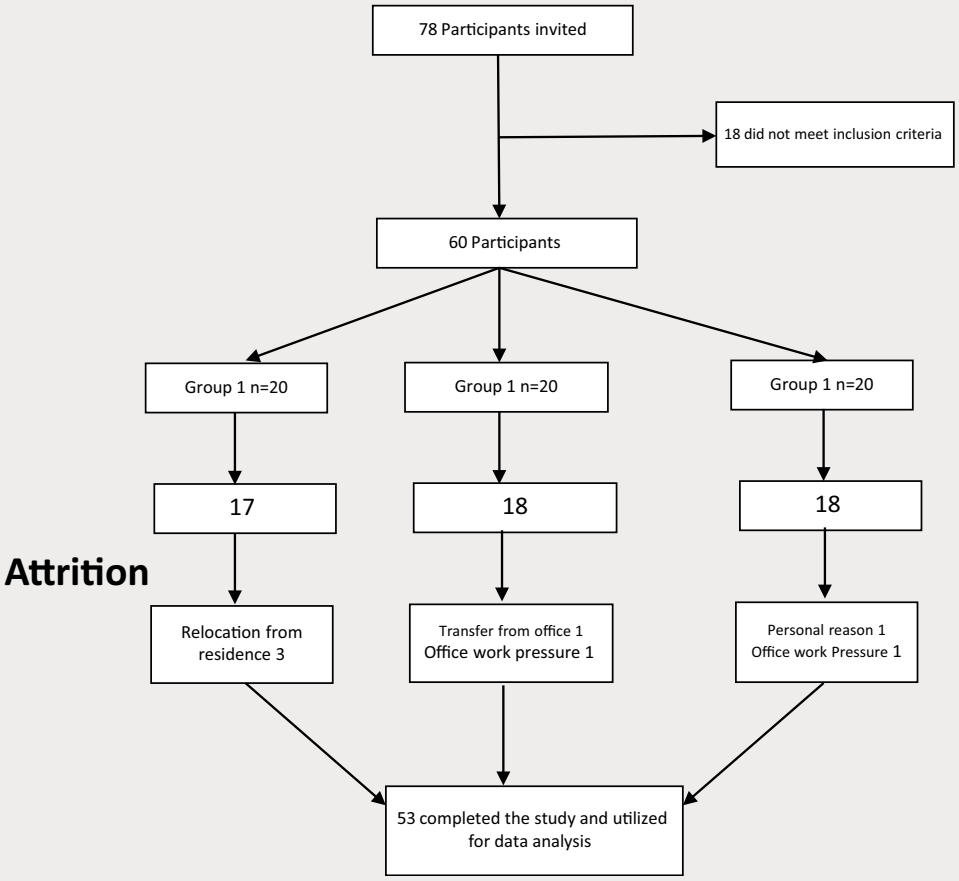


Fig. 1. Flowchart for recruitment.

Lequesne.[20] Using the anteroposterior view of the X-ray film of each patient, the horizontal distance between the superior tip of the lateral and medial condyles of the tibial was divided into two while the lateral JSW was measured at the mid point of the first half and the medial JSW was measured at the mid point of the second half. The dividing pointer was used to prick the two inter-bone distances on the radiograph with the aid of a magnifying lens and then pricked a sheet of paper. The caliper was used to measure the inter-bone distance between the pricks.[20] The ICT on the X-ray film was measured manually as the distance between the tip of the anterior and posterior margins of the inter-condylar eminence used the method described by Lequesne, and the points of the caliper were used to measure inter-margin distance with the aid of a magnifying lens. The tibia width was measured from the superior tip of the lateral tibia condyle to that of the medial horizontally using pointing divider and vernier caliper with the aid of magnifying lens. Prior to this, the reliability of the method was determined by using five X-ray films of patients with knee OA. The test–re-test interval was one week. The Pearson's product moment correlation reliability coefficiency obtained for the method of measuring the tibial width was found to be 0.87.

About 1 g of GS was placed on positive electrode (being positively charged) for patients in the IoT group.[21,22] An electrical stimulator machine (Model: Endomed 582, India) was used to deliver GS through the skin with the aid of electrodes. The Galvanic current mode in the Electrical Stimulator (Endomed 582) was used. The dose applied was 2 mA-min ($2\,\text{mA} \times 20\,\text{min}$) for each subject in groups 1 and 3.[23] The active (positive) electrode was placed on the side where the participants experienced higher pain intensity (that is medial or lateral side of the knee joint). The pain intensity

was ascertained using valgus and varus ligamentous stress tests; and appley's compression tests. The skin areas where electrodes were fastened were cleansed with methylated spirit (70% alcohol) to minimize the risk of burns.[24] Transarthral electrode placement technique was used. The indifferent electrode was placed on the opposite side for subject in groups 1 and 3. Both electrodes were held in place by an adhesive strap. Each subject had intervention(s) twice a week for 12 weeks.

The intention-to-treat (ITT) principle was adopted in this study but last data measured were not carried forward for the seven patients that dropped out because the attrition happened in the first and second weeks of the protocols. We observed that the recorded data at the time of termination did not differ from the values obtained at baseline, hence, they were excluded from data analysis. The rate of attrition was almost uniform in three groups and the drop-out was not due to increase in severity, symptoms, group assignment or drug side effects. However, all the patients were followed up for another six weeks after the end of the study.

Data analysis

Descriptive statistics were used to summarize the data obtained. Levene's test was used to compare the homogeneity of age, weight, height and body mass index (BMI) across the groups. Repeated Analysis of Variance (ANOVA) was used to compare pain intensity, knee ROM, and selected radiographic parameters across the groups. It was also used to compare within group values at baseline, 6 weeks and 12 weeks. Where between groups, variance was observed at baseline, Analysis of co-variance was used to compare the differences. Post-hoc analysis (LSD) was used to determine the trend of differences in the groups. Kruska–Wallis test was used to compare physical functions across the three groups. Alpha level was set at $p = 0.05$.

Results

The result showed that eight (47.1%) of the participants who received GS IoT only have right knee OA and two (11.8%) are male. The affected sides for other groups are in Table 1. The age and selected anthropometric parameters of patients in IoT, CFM and CoT are presented in Table 2. The Levene's test for homogeneity showed that there was no significant difference in the selected anthropometric parameters.

Table 1. Gender and distribution of affected sides of patients in the three groups.

Groups			*N*	%
IoT	Gender	Male	2	11.8
		Female	15	88.2
	Affected knee	Right	8	47.1
		Left	9	59.9
CFM	Gender	Male	4	22.2
		Female	14	77.8
	Affected knee	Right	10	55.6
		Left	8	44.4
CoT	Gender	Male	4	22.2
		Female	14	77.8
	Affected knee	Right	7	38.9
		Left	11	61.1

Note: 1 = IoT group, 2 = CFM group and 3 = CoT group.

Comparison of radiographic parameters of participants across the groups at baseline, 6th and 12th weeks

The means of JSW on medial side of the knee in the IoT group were 0.54 ± 0.08, 0.55 ± 0.07 and 0.59 ± 0.09 at baseline, 6th and 12th weeks, respectively. There was no significant difference in the medial JSW across the three groups at baseline and 6th week, but there was significant difference at the 12th week. ($F = 6.00, p = 0.01$). There was significant difference in lateral JSW and ICT across the three groups at baseline ($F = 4.34, p = 0.02$). Other mean values are presented in Table 3. There was significant difference in lateral JSW across the three groups at baseline ($F = 4.34, p = 0.02$). At the 6th week, there were no significant differences in all the selected parameters. However, at the 12th week, there were significant differences in the medial and lateral JSW compared to baseline and 6th week ($F = 6.00, P = 0.01$ and $F = 12.32$, $p = 0.001$, respectively) (Table 3).

Table 2. Comparison of anthropometric parameters and onset duration of participants across the three groups.

	IoT		CFM		CoT		Levene (p) sig
	Mean	SD	Mean	SD	Mean	SD	
Age	63.53	11.35	49.78	13.19	58.11	9.91	0.35
Weight	80.47	9.49	75.78	8.47	76.00	9.08	0.62
Height	1.52	1.61	0.96	0.49	1.63	0.86	0.73
BMI	35.57	4.13	29.55	4.01	28.39	4.76	0.93
Duration	11.47	7.80	8.72	6.17	11.11	7.28	0.26

Note: 1 = IoT group, 2 = CFM group and 3 = CoT group.
*Levene Test for Equality of Variances.

Table 3. Comparison of radiographic parameters of all the participants at baseline, 6th and 12th weeks in the three groups.

		Group 1		Group 2		Group 3			
		Mean	SD	Mean	SD	Mean	SD	F	P
Medial JSW	Baseline	0.54	0.08	0.49	0.15	0.51	0.11	0.72	0.49
	6th week	0.55	0.72	0.52	0.17	0.51	0.10	0.49	0.62
	12th week	0.59	0.09	0.79	0.30	0.58	0.15	6.00	0.01
Lateral JSW	Baseline	0.82	0.14	0.73	0.17	0.68	0.11	4.34	0.02*
	6th week	0.81	0.17	0.82	0.26	0.11	0.68	2.73	0.08*
	12th week	0.84	0.16	0.57	0.18	0.68	0.13	12.32	0.001*
ICT	Baseline	1.05	0.39	0.94	0.19	1.08	0.36	3.97	0.03*
	6th week	1.19	0.39	0.94	0.19	1.02	0.31	2.99	0.06*
	12th week	1.24	0.42	0.94	0.19	1.13	0.35	3.60	0.04*
Tibia width	Baseline	6.71	1.38	7.47	0.62	6.84	1.09	2.54	0.09
	6th week	6.76	1.33	7.41	0.62	6.83	1.12	1.83	0.17
	12th week	6.66	1.34	7.42	0.61	6.78	1.13	2.57	0.09

*Analysis of co-variance.

The result of the post-hoc analysis (LSD) at baseline showed that there were no significant differences in the baseline parameters excluding the lateral JSW between CoT and IoT; and between ICT of participants in IoT and CFM groups (Table 4). The medial JSW of participants in CFM group was significantly higher than that of participants in IoT and CoT groups ($p = 0.005$ and $p = 0.004$, respectively) at the 12th week, (Table 5). The lateral JSW of IoT group was significantly higher than that of CFM group ($p = 0.001$) and that of CoT group ($p = 0.01$), but that of later was higher than that of the former ($p = 0.04$) (Table 5).

Comparison of pain intensity and ROM of participants at baseline, 6th and 12th weeks

The mean of pain intensity on active knee flexion was 4.94 ± 1.30 on a 10-point rating scale (VAS) for participants in IoT group (GS IoT) at baseline. The mean pain intensities on active knee flexion at 6th and 12th weeks are also presented in Table 6. The result of ANOVA showed that there were significant differences in pain intensities on active and passive knee flexion; and patellar grinding within the IoT group participants ($F = 43.00$, $p = 0.001$, $F = 53.54$, $p = 0.001$; and

Table 4. Result of post hoc (LSD) analysis of baseline radiographic parameters of all the participants across the three groups.

	I	J	Mean difference $(I-J)$	P
Medial JSW	1	2	0.05	0.24
		3	0.03	0.45
	2	3	0.02	0.67
Lateral JSW	1	2	0.84	0.08
		3	0.14	0.05
	2	3	0.06	0.24
ICT	1	2	0.31	0.01
		3	0.17	0.13
	2	3	−0.14	0.20
Tibia width	1	2	−0.76	0.08
		3	−0.14	0.70
	2	3	0.62	0.09

Note: 1 = IoT group, 2 = CFM group and 3 = CoT group.

$F = 12.81, p = 0.001$, respectively). The mean pain intensities on active and passive knee flexion; and patellar grinding for CFM and CoT groups are presented in Table 6. The post-hoc analysis (LSD) showed that the pain intensity on active knee flexion on a 10-point rating scale (VAS) at the 6th week of IoT group participants was significantly lower than that of baseline ($p = 0.001$), with further decrease at 12th week ($p = 0.001$). Similarly, the pain intensity on active knee flexion at 12th week for IoT participants was significantly lower than that of 6th week ($p = 0.001$). The same trends were observed on passive knee flexion and patellar grinding at 6th and 12th weeks, ($p = 0.001$) (Table 7). The mean ROM (active knee flexion) was 107.35 ± 12.18 at onset for participants in the IoT group while at the 6th and 12th weeks, the mean of ROMs was 114.06 ± 10.80 and 122.94 ± 0.81, respectively. The result of ANOVA showed that there was significant difference in ROM within IoT group participants ($F = 9.11$, $p = 0.001$) (Table 6).

Table 5. Result of post hoc (LSD) analysis of radiographic parameters of all the participants across the three groups after 12th week.

	I	J	Mean difference $(I-J)$	P
Medial JSW	1	2	−0.20	0.005
		3	0.01	0.94
	2	3	0.21	0.004
Lateral JSW	1	2	0.27	0.001
		3	0.15	0.01
	2	3	−0.11	0.04
ICT	1	2	0.30	0.01
		3	0.11	0.32
	2	3	−0.18	0.10
Tibia width	1	2	−0.75	0.14
		3	−0.12	0.73
	2	3	0.63	0.08

Note: 1 = IoT group, 2 = CFM group and 3 = CoT group.

For participants in the CFM group, the mean pain intensities on active and passive knee flexions were $4.72 \pm 2.22, 3.39 \pm 1.65$ and 1.83 ± 1.15, respectively, on a 10-point rating scale (VAS) at baseline, 6th and 12th weeks. The result of ANOVA showed that there were significant differences in pain intensities on active and passive knee flexions at baseline, 6th and 12th weeks within the CFM group participants ($F = 12.59$, $p = 0.001$; $F = 15.55, p = 0.001$, respectively) (Table 6). The post hoc analysis (LSD) showed that the pain intensity on active knee flexion at 6th week for CFM group participants was significantly lower than that of baseline ($p = 0.025$) while at the 12th week, it was also significantly lower than at baseline ($p = 0.001$). Similarly, the pain intensity on active knee flexion at 12th week for the CFM group was significantly lower than at 6th week ($p = 0.009$). The result of post hoc analysis (LSD) showed that the ROM at 12th week of CFM group was significantly higher than that of baseline ($p = 0.001$) (Table 8).

The result showing comparison of mean of pain intensities and ROMs for other groups are presented in Table 6. The result of the post hoc analysis (LSD) showed that the pain intensity on active knee flexion on a 10-point rating scale (VAS) at 6th week of CoT group participants was significantly lower than that of baseline ($p = 0.001$) and also the pain intensity on active knee flexion on a 10-point rating scale (VAS) at 12th week in CoT group was significantly lower than that of baseline ($p = 0.001$). Similarly, the pain intensity on active knee flexion on a 10-point rating scale (VAS) at 12th week in CoT group was significantly lower than that of 6th week ($p = 0.01$). Other post hoc analysis (LSD) results are shown in Table 9.

There was significant difference in pain intensity on active knee flexion on a 10-point pain rating scale across the three groups (VAS) ($F = 9.33$, $p = 0.01$) and same trend was found for passive

Table 6. Comparison of pain intensity and ROM of participants at baseline, 6th and 12th weeks within the groups.

			Baseline		6th week		12th week			
			Mean	SD	Mean	SD	Mean	SD	F	P
IoT	Pain intensity	OAKF	4.94	1.30	2.94	0.97	1.77	0.66	43.00	0.001*
		OPKF	6.41	1.33	3.77	0.97	2.94	0.66	53.54	0.001*
		OPG	3.88	1.50	1.88	1.32	2.24	0.75	12.81	0.001*
	ROM	OAKF	107.35	12.18	114.06	10.80	122.94	8.81	9.11	0.001*
CFM	Pain intensity	OAKF	4.72	2.22	3.39	1.65	1.83	1.83	12.59	0.001*
		OPKF	5.83	1.98	4.00	1.65	2.83	1.15	15.55	0.001*
		OPG	3.83	1.58	3.33	1.09	3.00	0.91	2.11	0.130
	ROM	OAKF	104.22	17.25	113.89	14.24	121.61	10.18	6.78	0.002*
CoT	Pain intensity	OAKF	6.83	1.02	3.39	1.04	2.50	0.92	93.79	0.001*
		OPKF	7.33	1.37	4.12	1.15	3.06	1.06	61.58	0.001*
		OPG	5.67	1.65	3.39	1.38	2.56	0.78	26.84	0.001*
	ROM	OAKF	97.33	14.38	102.28	10.25	116.00	11.69	11.27	0.001*

Notes: ∗Significant at $p < 0.05$.
OAKF: On Active Knee Flexion, OPKF: On Passive Knee Flexion, OPG: On Patellar Grinding, 1 = IoT, 2 = CFM and 3 = CoT.

Table 7. Post hoc analysis (LSD) of pain intensity and ROM of all the participants at baseline, 6th and 12th weeks within IoT group.

		I	J	Mean changes $(I - J)$	P-value
Pain intensity	OAKF	1	2	2.00	0.001*
			3	3.18	0.001*
		2	3	1.18	0.001*
	OPKF	1	2	2.65	0.001*
			3	3.47	0.001*
		2	3	0.82	0.020*
	OPG	1	2	2.00	0.001*
			3	1.65	0.001*
		2	3	−0.35	0.410
ROM	OAKF	1	2	−6.71	0.070
			3	−15.59	0.001*
		2	3	−8.88	0.020*

Notes: *Significant at $p < 0.05$.
1 = Baseline, 2 = 6th week and 3 = 12th week, OAKF: On Active Knee Flexion, OPKF: On Passive Knee Flexion, OPG: On Patellar Grinding.

Table 8. Post hoc analysis (LSD) of pain intensity and ROM of all the participants at baseline, 6th and 12th weeks within CFM group.

		I	J	Mean changes $(I - J)$	P
Pain intensity	OAKF	1	2	1.33	0.030*
			3	2.89	0.001*
		2	3	1.56	0.001*
	OPKF	1	2	1.83	0.001*
			3	3.00	0.001*
		2	3	1.17	0.040*
	OPG	1	2	0.50	0.230
			3	0.83	0.050*
		2	3	0.33	0.420
ROM	OAKF	1	3	−9.67	0.050*
			3	−17.34	0.001*
		2	3	−7.72	0.110

Notes: *Significant at $p < 0.05$.
1 = Baseline, 2 = 6th week and 3 = 12th week, OAKF: On Active Knee Flexion, OPKF: On Passive Knee Flexion, OPG: On Patellar Grinding.

knee flexion and patellar grinding at baseline for participants in the three groups (Table 10). The post hoc analysis (LSD) showed that the pain intensity on active knee flexion for IoT group participants was significantly lower than that of CoT group ($p = 0.001$) and CFM group ($p = 0.001$). Similar trends were also observed for passive knee flexion and on patellar grinding (Table 11).

Comparison of physical function of participants across the three groups at baseline, 6th and 12th weeks

The physical function of participant in IoT group at baseline was 28.31 ± 6.19 on a WOMAC scale.

Table 9. Post hoc (LSD) analysis of pain intensity and ROM of all the participants at baseline, 6th and 12th weeks within CoT group.

		I	*J*	Mean changes (*I* – *J*)	*P*
Pain intensity	OAKF	1	2	3.44	0.001*
			3	4.33	0.001*
		2	3	0.89	0.010*
	OPKF	1	2	3.17	0.001*
			3	4.28	0.001*
		2	3	1.11	0.008*
	OPG	1	2	2.28	0.001*
			3	3.11	0.001*
		2	3	0.83	0.060
ROM	OAKF	1	2	−4.94	0.230
			3	−18.67	0.001*
		2	3	−13.72	0.001*

Notes: *Significant at $p < 0.05$.
1 = Baseline, 2 = 6th week and 3 = 12th week, OAKF: On Active Knee Flexion, OPKF: On Passive Knee Flexion, OPG: On Patellar Grinding.

The physical functions of participants in the CFM and CoT groups are presented in Table 12. The result of Kruskal–Wallis showed that there were significant differences in physical function among the participants across the three groups at baseline ($H = 4.97$, $p = 0.01$). The physical functions of participants in IoT, CFM, CoT groups at the 6th week are presented in Table 12. There were also significant differences in physical functions among the participants across the three groups at 6th and 12th weeks ($H = 9.19$, $p = 0.01$; $H = 3.23$, $p = 0.01$, respectively) (Table 12).

Discussion

Topical delivery of medication permits the avoidance of first pass metabolism by the liver and it also by-passes the gastric system providing higher levels and quicker tissue saturation.[11,25] It is widely acknowledged that transdermal delivery improves patient compliance.[25] Levene's test was used to determine if the three groups have equal variances. Comparability across samples is called homogeneity of variance. The result of Levene test in this study confirmed that the anthropometric parameters of patients in the three groups were comparable in age, weight, height and (BMI), hence differences observed in this study could not be attributed to the parameters. Chronicity of diseases could also affect the outcome of interventions, however, there was no significant difference in the duration of onset of knee OA of patients in the three groups.

Measurement of changes in JSW is currently the gold standard in evaluation of structured modifying drugs in OA.[26] This current study evaluated both medial and lateral JSWs because OA may

Table 10. Comparison of pain intensity and ROM of all the participants across the three groups after 12th week.

		IoT		CFM		CoT			
		Mean	SD	Mean	SD	Mean	SD	*F*	*P*
Pain intensity	OAKF: Base	4.94	1.30	4.72	2.22	6.83	1.04	9.34	0.001*
	6th	2.94	0.97	3.39	1.65	3.35	1.06	0.66	0.520
	12th	1.76	0.66	1.83	1.15	2.50	0.92	3.33	0.040*
	OPKF: Base	6.41	1.33	5.83	1.98	7.33	1.37	4.07	0.020*
	6th	3.77	0.97	4.00	1.65	4.12	1.17	0.33	0.720
	12th	2.94	0.66	2.83	1.15	3.06	1.06	0.23	0.780
	OPG: Base	3.88	1.50	3.83	1.58	5.67	1.65	7.84	0.001*
	6th	1.88	1.32	3.33	1.09	3.35	1.41	7.51	0.001*
	12th	2.23	0.75	3.00	0.91	2.56	0.78	3.86	0.030*
ROM	AKF: Base	107.35	12.18	104.22	17.25	97.33	14.38	2.12	0.130
	6th	114.06	10.80	113.89	14.24	01.53	10.04	6.27	0.004*
	12th	122.94	8.81	121.61	10.18	116.00	11.69	2.26	0.120

Notes: *Significant at $p < 0.05$.
OAKF: On Active Knee Flexion, OPKF: On Passive Knee Flexion, OPG: On Patellar Grinding, Base: Baseline.

Table 11. Post hoc (LSD) analysis of pain intensity and ROM of all the participants across the three groups at baseline.

		I	J	Mean changes $(I-J)$	p
Pain intensity	OAKF	1	2	2.19	0.690
			3	−1.89	0.001*
		2	3	−2.11	0.001*
	OPKF	1	2	0.58	0.290
			3	−0.92	0.090
		2	3	−1.5	0.010*
	OPG	1	2	0.05	0.930
			3	−1.78	0.002*
		2	3	−1.83	0.001*
ROM	OAKF	1	2	3.13	0.530
			3	10.01	0.050*
		2	3	6.89	0.170

Notes: *Significant at $p < 0.05$.
1 = IoT, 2 = CFM, 3 = CoT, OAKF: On Active Knee Flexion, OPKF: On Passive Knee Flexion, OPG: On Patellar Grinding.

involve either medial and lateral tibiofemoral or patellafemoral compartments according to the localization of cartilage deterioration.[27] At baseline, the three groups were comparable in medial joint space and tibial widths. At the 6th week, there were no significant changes in all the radiographic parameters. However, at the 12th week (after three months), there were diffused effects of different interventions on JSWs. There was significant increase in the medial joint space when massage was used to administer GS cream while there was a significant increase in lateral joint space when GS cream was administered through the process of IoT. The combined therapies improved the lateral joint space that makes use of CFM technique only. In knee OA, tight muscle increases the compression of joint while tightening of quadriceps, hamstring and calf muscle results in poor coordination and slower reaction time.[28] The tightening of quadriceps, hamstring, calf muscle and poor flexibility associated with knee OA may likely have a combined closing effect on the 1knee joint space. The administration of GS cream through massage might have loosened and relaxed soft tissues at the knee joint; and these might be the reason for the increased medial joint space at the knee joint. The use of massage is an age-old process that involves stimulations of tissues by rhythmically applying both stretching and pressure.[29]

CFM had been reported to stimulate blood flow and also breaks down cross-bridge; and the frictional pressure is applied at right angle thereby stretching apart the musculo-tendinous tissues.[30] The stretching and pressure at the knee joint might improve the flexibility of the quadriceps and hamstring muscles which subsequently open up the joint space of the knee in patients with OA. Flexibility is related to the extensibility of musculotendinous units that cross a joint. Onigbinde *et al.*[31] reported that transdermal massage of glucosamine was very effective in improving hamstring flexibility and increasing knee flexion ROM among patients with knee OA. The reported improvement in medial joint space might be attributed to the contributions of the manipulative effects of CFM and transdermal application of GS cream which both improve flexibility. This study corroborated that of Reginster *et al.*[32] who also observed an increase in the JSW in patients with OA. Also, Dahmers and Schiller[33] reported the increase in medial compartment of tibia femoral joint space following the administration of GS after 12 weeks of

Table 12. Comparison of physical function of participant across the three groups at baseline, 6th and 12th weeks.

	Physical function							
	IoT Mean ± SD		CFM Mean ± SD		CoT Mean ± SD		H	P
Baseline	28.31	6.19	34.08	10.82	37.96	9.50	4.97	0.010*
At 6th week	17.85	4.98	22.70	5.83	23.37	6.64	9.19	0.010*
At 12th week	11.27	2.64	16.61	6.63	14.82	8.23	3.23	0.010*

Notes: *Significant at $p < 0.05$.
IoT: iontophoresis, CFM: cross-friction massage, CoT: combined therapy.

intervention. Also, in a recent study, Durmus *et al.*[34] evaluated the effect of GS on the cartilage repair, and found an increase in the medial JSW.

This study observed that at baseline, the ICT of patients who had intervention using CFM was significantly lower than that of those who received GS IoT only at baseline, however, after 12 weeks of intervention, the ICT remained lower for the former. There was no significant difference in the tibia width across the three groups at baseline, 6th and 12th weeks. This implied that there was no progression in the degeneration of bone margins of the tibia condyle after three months. The within groups assessment showed that knee OA patients who received GS via CFM only had increased lateral JSW at 12th week than at baseline. Also, the lateral JSW at 12th week was significantly higher than that at baseline and 6th week. The significant increase in the medial and lateral JSW of the knee joints corroborated the findings of Reginster *et al.*[32] This study observed no significant difference in the medial JSW, lateral JSW, ICT and tibia width of patient who received GS IoT only and similar trend was observed for patients who had both glucosamine through IoT and massage. The clinical implication of this is that there was neither regression nor progression in degenerative changes in the radiographic features of patients who received either IoT only or combined interventions. Besides, it is also suggestive of the importance of using plain radiograph to monitor progress made in the management of knee OA using JSW, ICT and tibia width as indices for outcome measures.

This study rated pain intensities on active and passive movements; and during patellar grinding. It was observed that after 12 weeks of interventions, the administration of glucosamine via IoT significantly reduced the pain intensity on active knee flexion and patellar grinding. The pain intensity experienced by patients who had CoT was significantly higher at baseline compared to that of those who received massage only. However, after 12 weeks, there was no significant difference between levels of intensities between the groups. This implied that combination of GS IoT and massage was more effective in managing pain associated with knee OA. This corroborated the reported decrease in pain intensity of patient with knee OA after administration of GS.[22,26] This current study further lent credence to the effectiveness of administration of GS in alleviating pain in patient 6 with knee OA as reported by Graig.[26] and Reginster *et al.*[32] Furthermore, Onigbinde *et al.*[11] reported that the administration of 1 g of GS cream was effective in alleviating pain experienced by knee OA patients. GS IoT has been severally observed to modulate and significantly reduce pain immediately after use.[11,35]

There was significant increment in knee flexion at six weeks of interventions across the groups. However, after 12 weeks of intervention, there was no significant difference in the ROMs. This implied that patients who had CoT might have reached a plateau in ROM at the 12th week. This current finding supported the report of Onigbinde *et al.* who observed that patients who had GS IoT had significantly better active knee flexion compared with those who had the topical medication through massage because the duration of their intervention was also within six weeks.[11] However, within the groups, there was significant increase in active knee flexion. This is in consistent with findings of Onigbinde *et al.* who also reported that there was an increase in the ROM of patient with knee OA following the administration of GS.[22]

OA of the knee is the most common cause of chronic disability among the elderly worldwide.[36] The degree of flexibility of the quadriceps and hamstring group of muscles contributes to smooth and precise ambulatory functions. Most subjects with OA usually experience functional limitations in activities of daily living.[37] The current findings on physical functions showed that after 12 weeks of intervention, there was significant improvement across the groups, but participants in the IoT group showed improved physical function compared to the other groups. This corroborated the previous study that showed that GS alleviates pain and subsequently improves the physical functions of patients.[22] Also, Braham *et al.* reported that glucosamine supplementation provides degree of pain relief and further improved the function in persons who experience regular knee pain, which may be caused by prior cartilage injury and/or OA.[22,38]

Conclusion

We concluded that at the 12th week, there were significant decreases in the degenerative changes at the knee joints of patients with knee OA. The administration of GS using IoT alone significantly increases the lateral JSW than other interventions while CFM only significantly increases the medial JSW. However, none of the three interventions was

superior in their effects on ICT and degeneration of tibia bone margin after 12 weeks. Also, GS administration through CFM alleviated pains, increased active and passive knee flexion better than the use of IoT alone or combination of both interventions. Furthermore, the administration of GS using IoT only increased the physical functions than CFM or combination of both interventions.

Conflict of Interest

There was no conflict of interest in this study.

Funding/Support

There was no external financial support for the study. The cost of clinical trial was met by the investigators.

Author Contributions

Onigbinde Ayodele Teslim contributed in developing the concept, data collection and analysis, script preparation, revising the manuscript and editing. Owolabi Adegbenga Rotimi contributed to data collection, analysis, script preparation, revising the manuscript and editing. Lasisi Kamil contributed to data collection, analysis, script preparation, revising the manuscript and editing. Sarah Oghenekewe Isaac contributed to data collection, script preparation and editing. Ibikunle Adeoye Folorunso contributed to data collection, script preparation and editing.

References

1. Bridges SL. National institute of arthritis and musculoskeletal and skin diseases. Arthritis Res Ther 2000;2(1):0003. Available at:www.niams.nih.gov/health_info/osteoarthritis/default.asp.ref-NIH2015_2-6.
2. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. Bull World Health Organ 2003;81:646–56.
3. Royal Australian College of General Practitioners RACGP. Guideline for the non-surgical management of hip and knee osteoarthritis. 2009. Available at:www.racgp.org.au/download/documents/guidelines/musculoskeletal.
4. Onigbinde AT, Oluukola AF, Adenike F, Oniyangi S, Olaitan OL. An assessment of hamstring flexibility of subjects with knee osteoarthritis and their age matched control. Clin Med Res 2013;2(6):121–5.
5. Sellam J, Berenbaum F. The role of synovitis in pathophysiology and clinical symptoms of osteoarthritis. Nat Rev Rheumatol 2010;6(11):625–35.
6. Beattie K, Duryea J, Pui M, O'Neill J, Boulos P, Webber CE. Minimum joint space width and tibial cartilage morphology in the knees of healthy individuals: A cross-sectional study. BMC Musculoskelet Disord 2008;9:119–26.
7. Hilliquinb P, Pessisc E, Costed J, Maugetc D, Azriab A, Chevrotc A. Quantitative assessment of joint space width with an electronic caliper. Osteoarthr Cartil 2002;10(7):542–6.
8. Braun HJ, Gold GE. Diagnosis of osteoarthritis: Imaging. Bone 2011;51(2):278–88.
9. Writer Staff. Acupuncture treatment specialist. 2007. Available at: http//acupuncture-treatment-specialists.com articles acupuncture-articles-id 501.htm/acupuncture-articles1d502.htm.
10. Onigbinde AT, Adedoyin RA, Johnson O. Effect of physical therapy intervention on pharmacokinetic variables. Niger J Med Rehabil 2006;2(19):1–5.
11. Onigbinde AT, Adedoyin RA, Olaugun MOB, Ojoawo OA, Akinpelu AO, Onibokun A. Efficacy of glucosamine iontophoresis in the management of knee osteoarthritis. Niger Med Pract 2008;54(3):66–9.
12. Uitto O, White S. Electrosmotic pore transport in human skin. Pharmacol Res 2003;20:646–52.
13. Lozada CJ, Pace SSC. Osteoarthritis Treatment and Management. 2015. Available at: emedicine.medscape.com/article330487-treatment.
14. Reginister J, Bruyere O, Lecart M, Henroitin Y. Glucosamine and chondroitin sulphate. Am Coll Rheumatol 2009;25:1160–5.
15. The Glucosamine Osteoarthritis Resource Centre. Glucosamine and Osteoarthritis. 2005. Available at: http://www.glucosamine osteoarthritis.org/glucosamine/Glucosamine for-arthritis.html.
16. McAlindon E, LaValley P, Guhlin J. Glucosamine and chondroitin for treatment of osteoarthritis: A systematic quality assessment and meta-analysis, Jama 2000;283(11):1483–4.
17. Adedoyin RA, Olaogun MOB, Fagbeja OO. Effect of interferential current stimulation in the management of osteoarthritis knee pain. Physiotherapy 2002;88(8):493–9.
18. Salaffi F, Leardini G, Canesi B, et al. Reliability and validity of the Western Ontario and McMaster Universities [WOMAC] osteoarthritis index in Italian patients with osteoarthritis of the knee. Osteoarthr Cartil 2003;11:551–60.
19. Deep K, Norris M, Smart C. Radiographic measurement of joint space height in non-osteoarthritic

tibiofemoral joints. J Bone Joint Surg Br 2003;85-B:980–2.
20. Lequesne M. Quantitative measurement of joint space during progression of osteoarthritis: Chondrometry, In: Kuettner K, Goldberg V, eds. Osteoarthritic Disorders. Vol. 30, Rosemont: American Academy of Orthopaedic Surgeons, 1995:427–44.
21. Glucosamine derivative and liposome containing the same as membrane constituent. Available at: http://www.patentstorm.us/patents/5304380-description.html. US patent, 5304380, 1994.
22. Onigbinde AT, Talabi E, Okulaja I, Dominic O. Comparative efficacy of cycle-ergometry exercise and glucosamine sulphate iontophoresis in pain management of subjects with sub-acute knee osteoarthritis. Med Sport 2011;7(1):1517–21.
23. Tiziano M. Iontophoresis in pain management. Pract Pain Manage 2014. Available at: www. Practical Pain Management.com.
24. Gazelius B. Iontophoresis theory. 2001. Available at: http//www.perimed.se.
25. Asia–Pacific Biotec News. Transdermal drug delivery. 2007:336–99. Available at: http://www.asiabiotech.com/publication/apbn/11/english/preserved-docs.
26. Graig W. Glucosamine and chondrition for osteoarthritis. Work Safe BC Evid Based Pract Group 2013;1(6):700–3.
27. Carrillon Y. Imaging knee osteoarthritis. In: Bonnin M, Chambat P, eds. Osteoarthritis of the Knee. Paris: Springer Verlag, 2008:3–14.
28. Gaya MWU, Mshelia BS. Protecting the health of athletes. 2000;1(1):7–13.
29. Watt J. Massage for Sports. 1st edn. Crowood Press, Limited. Available at: amazon.co.uk.
30. Natural Treatment and Exercises for Osteoarthritis. Natural treatment and exercises for osteoarthritis pain relief. 2009. Available at: www.massage for osteoarthritis_natural treatments and exercises for osteoarthritis pain relief.
31. Onigbinde AT, Adesina D, Tarimo N, Ojoawo A. Comparative effects of a single treatment session using glucosamine sulphate and methyl salicylate on pain and hamstring flexibility of patients with knee osteoarthritis. Am J Health Res 2014;2(5–1):40–4.
32. Reginster J, Bruyere O, Lecart M, Henroitin Y. Naturocetic (glucosamine and chondroitin sulphate) compounds as structure-modifying drugs in the treatment of Osteoarthritis. Curr Opin Rheumatol 2003;15(5):651–5.
33. Dahmers S, Schiller RM. Glucosamine. Am Fam Physician 2008;1578(4):471–6.
34. Durmus D, Alayli G, Bayrak IK, Canturk F. Assessment of the effect of glucosamine sulphate and exercise on knee cartilage using magnetic resonance imaging in patient with knee osteoarthritis. J Back Musculoskelet Rehabil 2012;25:275–84.
35. Gangarosa LP, Ozawa A, Okhido M, Shimomura Y, Hill JM. Iontophoresis for enhancing penetration of dermatologic and antiviral drugs. J Dermatol 1995;22(11):865–75.
36. Guccione A, Felson D, Anderson J. The effects of specific medical conditions on the functional limitations of elders in the Framingham Study. Am J Public Health 1994;83(3):351–8.
37. Netter FH, Freyberg R. Rheumatics' diseases. In: Nelder FH, ed. The Gba Collection of Medical Illustrations. Gmmit SFA: Ciba-Geigy Corporation, 1990:178–81.
38. Braham R, Dawson B, Goodman C. The effect of glucosamine supplementation on people experiencing regular knee pain. Br J Sports Med 2003;37(1):45–9.