Osteoarthritis which is a degenerative joint disease affecting the articular cartilage, bone and soft tissues around the joint is a highly prevalent condition worldwide with an incidence of 20.4% at the University Teaching Hospital and Levy Mwanawasa Teaching Hospital in Zambia. It has no known effective intervention due to its poorly understood pathogenesis. Combined interventions of Manual Therapy and Conventional Physiotherapy are significant in restoring function, quality of life, reducing disability, drug consumption and surgery in individuals with knee OA. This study evaluated the emerging optimistic evidence on the effectiveness of manual therapy, established the possible factors associated with it and assessed its impact on physical function and quality of life in patients with knee osteoarthritis. This study was a single-blinded RCT involving 6 male and 24 female participants with bilateral knee osteoarthritis aged between 30-85 years at University Teaching Hospital and Levy Mwanawasa Teaching Hospital. Participants were randomized using unlabelled opaque envelopes to a conventional group (n=15) and intervention group (n=15). The conventional group received a treatment protocol of hot packs, Transcutaneous Electrical Nerve Stimulation and exercise therapy, while those in the intervention group received the same protocol combined with manual therapy twice per week for 5 weeks giving 10 treatment sessions. Short Form 36 questionnaire (SF-36), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Six-minute walk test questionnaire (6-MWT) and Visual Analogue Scale (VAS) were tools used for data collection before and after treatment. Data was entered in SPSS imported into Microsoft Excel and analyzed using STATA software version 13. Paired t-test mean values of group effect for VAS, 6-MWT, WOMAC and SF-36 Questionnaire were compared at week 0 and week 5. There was an improvement in all mean values; VAS (2.4), 6-MWT (195.75), WOMAC (51) and SF-36 (307.9) to 1.5, 276.3, 30 and 542.2 respectively. The difference between conventional and interventional groups was statistically significant for the WOMAC and SF-36 Questionnaire (p = 0.0102 and p = 0.0085). Differences were not significant for 6-MWT (p = 0.1678) and VAS (p = 0.2893). Adding manual therapy to conventional physiotherapy is more effective in reducing knee pain, improving walking distance, physical function and quality of life in patients with knee osteoarthritis. The effects of manual therapy on knee osteoarthritis were sustained up to 2 weeks after treatment.

Keywords: Conventional therapy, Knee Osteoarthritis, Manual therapy, Physiotherapy.

1. Introduction

Osteoarthritis (OA) remains a major public burden and renders great socioeconomic costs on individuals, families, communities as well as governments [34, 44]. Knee OA is directly linked to activity limitations such as walking, climbing stairs, self-care and participation restriction. It is also responsible for costs of expenses on visits to physicians as well as time lost from employment due to persistent pain, muscle weakness, joint stiffness and impaired proprioception [27], [37]. A study by Murray and colleagues [55] ranked OA as the 5th among all forms of disability worldwide while Chu et al. and others [16] projected OA to be the 4th leading cause of years lived with disability by 2020. Evidence from the studies clearly demonstrates an increase in the prevalence and burden of OA over the past years [6], [9], [46]. Osteoarthritis affects people of all age groups and its prevalence is highly associated with an increase in age. Osteoarthritis is estimated at 80% in individuals over the age of 65 years [11], [19]. The present global prevalence of OA is approximately 1.37% of the world’s population of whom 9.6% affected are men and 18% are women. As the world’s population continues to age, it is projected that OA will affect at least 130 million individuals (1.78%) around the globe by the year 2050 [22], [39]. The prevalence rate of knee OA in the African region is estimated to be 20.2% in males and 30.2% in females aged over 45 years. In Ghana, a prevalence rate of 8% of OA has been reported among all adult population [13], [26], [43]. Akinpelu and colleagues [4] estimated that one out of every five Nigerian adults aged 40 years and older have symptomatic knee osteoarthritis. The authors further reported a point prevalence of symptomatic knee OA at 16.3% for adults aged above 30 years and 20.6% for those above 40 years in Nigeria. A systematic review and meta-analysis by Usenbo and others [45], reported OA as the most prevalent form of arthritis in South Africa, at 55.1% among adults aged over 65 years with the highest prevalence of 33.1% for knee osteoarthritis. There is a paucity of literature on the prevalence of OA in Zambia. However, a study by Mulla and colleagues [36] at Zambian Italian Orthopaedic Hospital (ZIOH) then and now St John Paul II Orthopaedic Mission Hospital (SJP2)
in Lusaka Zambia found OA to have been a primary diagnosis in 46 patients on whom joint replacement operations were performed. Currently, available therapies used in the management of knee OA are unable to remit the underlying disease process of the disease [1], [22], [54]. Therefore, treatment of knee OA is limited to reducing symptoms and slowing or stopping the progression of the condition [35], [38], [48]. The common physiotherapy management approach for knee OA in Zambia mostly include moist heat in-form of hot packs, TENS and exercise therapy. This approach has been in practice for a long time with little research evidence of its effectiveness. Evidence-based practice improves health care delivery and helps in providing more effective health services to patients hence the need to embrace it in this world of evolving treatment protocols [12], [31]. Despite the emerging optimistic evidence from a number of studies conducted on the effectiveness of manual therapy as an adjunct therapy on knee OA, there is very limited evidence for its use in Zambia [2], [30], [38], [49]. Although there is optimism in the benefits of MT when used as an adjunct to conventional physiotherapy, most Randomized Controlled trials (RCTs) conducted to evaluate its effects have reported contradictory findings in patients with knee OA. This has been attributed to the poor methodological quality of the studies [2], [23], [41]. The current study evaluated the effects of MT as an adjunct to conventional physiotherapy on knee pain, physical function and quality of life in patients with knee osteoarthritis.

2. Materials and Methods

This study was a single RCT that tested the effects of Manual Therapy (MT) as an adjunct to Conventional Physiotherapy (CP) of moist heat in-form of hot packs, TENS and exercise therapy. The study was conducted at the University Teaching Hospital (UTH) and Levy Mwanawasa Teaching Hospital (LMTH) in Zambia. To have a representative sample, the population of this study included male and female adults aged 30 to 85 years with bilateral knee OA. This study was a 5 weeks single-blinded controlled trial with 10 treatment sessions of approximately 1 hour 35 minutes to 2 hours twice per week. The study had 2 weeks follow up after treatment to assess the sustained effects of the treatment. The following steps demonstrate the order in which the study was carried out and how data was collected.

Patient Recruitment

Participants eligible for the study were recruited through the orthopaedic surgeons at the two selected hospitals on initial contact. The orthopaedic surgeons screened and referred 42 patients with knee OA to the physiotherapy departments at the two respective institutions. Out of the 42 patients enrolled, 12 patients did not meet the inclusion criteria and were excluded leaving a total of 30 patients. All study participants were requested to sign a written consent after being fully informed about the treatment procedure and assure them that involvement in this trial was not going to affect their potential future treatments.

Baseline Measures

Participant’s variables and baseline parameters such as knee pain, physical function and quality of life were recorded for 2 consecutive weeks using the appropriate measuring tools shown in table 1. Measurements were conducted by physiotherapists blinded to the subject’s treatment group and were not involved in the treatment of the patients. All patients who had difficulty in self-administration of WOMAC and SF-36 assessment questionnaires because they could not read and write were helped by their caregiver or by a person blinded to the purpose of the tools.

Randomization and Blinding

Patients were then randomized to an intervention group or a control group using thirty un-labelled opaque envelopes. The intervention group consisted of 15 participants 10 at UTH and 5 at LMTH. Patients in the intervention group received CP of moist heat in-form of hot packs, TENS, ET and a program of Maitland joint mobilization to the patella-femoral and Tibio-femoral joints. The conventional group also consisted of 15 participants, 10 at UTH and 5 at LMTH and patients received CP of moist heat in form of hot packs, TENS and ET only. Participants were not blinded to the interventions they received. To avoid influence on the results during evaluation the control and intervention groups were requested to come on different days. Outcome assessors did not provide any intervention and were blinded to treatment group allocation. The statistician was also blinded to group assignment during the analyses.

Consort Guideline

The study included participants with grade 1 to 3 Kellgren-Lawrence radiographic confirmed bilateral knee OA [29]. Patients who scored 3 out of 10 knee pain or greater on the VAS with activity intervention at baseline. Those who consented were able to ambulate at least 30 meters on an even surface with or without a walking device and were able to perform physical exercises with minimal support. The study excluded individuals with uncontrolled hypertension, severe cardiopulmonary disease, mentally challenged, Severe osteoporosis, rheumatoid arthritis, knee infection, a history of neurological disorders affecting lower limb function such as stroke, neoplastic disorder and hip or knee arthroplasty. Those who underwent arthroscopy surgery in the past 3 months before the study and individuals with previous fractures to the lower limbs in less than 2 years before the study. Patients with altered skin sensation at L3-S2 dermatomes and loss of proprioception of big toe were also excluded.
Data Collection Tools
Table 1 shows the data collection tools that were used in this study being VAS, 6-MWT, WOMAC and SF-36 Questionnaire.

<table>
<thead>
<tr>
<th>Measuring tool</th>
<th>Scale</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Analogue Scale (VAS)</td>
<td>0 to 10, 0 being the least pain and 10 the most severe pain</td>
<td>Knee pain</td>
</tr>
<tr>
<td>Western Ontario and McMaster index questionnaire (WOMAC)</td>
<td>24 questions (5 relating to pain, 2 to stiffness &amp; 17 to function) on a 5-point scale: 0 = none, 1 = slight, 2 = moderate, 3 = severe, 4 = extreme.</td>
<td>Physical function</td>
</tr>
<tr>
<td>6-Minute Walk Test (6-MWT)</td>
<td>The test was performed on a flat surface 16 meter in length.</td>
<td>Functional capacity</td>
</tr>
<tr>
<td>SF-36 Questionnaire</td>
<td>All questions that address each specific area of functional health status are scored on a scale from 0 to 100, with 100 representing the highest level of functioning possible.</td>
<td>Quality of life</td>
</tr>
</tbody>
</table>

Statistical Methods
Data was analyzed using STATA version 13. Statistical results to describe each group’s categorical variables were expressed as counts and percentages and continuous variables as mean, standard deviation (SD), median and interquartile range. Graph boxes, histograms and tables were used to present this data. The P-value of less than 0.05 was taken as significant for testing treatment effects. Assumptions of normality were checked using the Shapiro-Wilk test and a two-sample t-test with equal variances was used to compare the intervention and the conventional groups for their pre and post mean differences to determine treatment effects separately. Pearson’s correlation and Chi-square were run to assess the association between age, height, weight, body mass index, duration of OA and 6-MWT after administering the two treatment types. Correlation tests were also run between all demographic variables and the 8 subscales of the SF-36 questionnaire.

Study flow chart
Figure 1: Study flow chart.

Treatment Program
The treatment program comprised of two groups being the control group and intervention group. All participants attended 10 treatment sessions of approximately 1 hour 35 minutes to 2 hours twice per week for 5 weeks. The interventions were provided at the respective institutions by registered physiotherapists who have been in practice for 2 years or more and working full time at the three institutions. Manual scripts of Standard Operating Procedures (SOPs) for an exercise and manual therapy programs (Appendix 1 and 2) were provided to each therapist for reference to standardize the treatment. Therapists were audited on adherence to therapy protocols occasionally by the data monitoring committee which consisted of two independent physiotherapists.

Expected Outcome Measures
The study measured change in VAS score, 6-MWT distance and physical function as an expected outcome which impact on the quality of life. The VAS, 6-MWT, WOMAC score and SF-36 questionnaires were used to measure the outcomes at baseline and 5 weeks.

3. Results
The study involved 30 participants of both sexes with ages ranging from 36 to 79 years. Six (20%) of the study participants were males and 24 (80%) were females. The mean age for males was 64 ±12.52 while for females the mean age was 57.7 ±12.86. The mean body mass index in kilograms per square meter (kg/m²) for males was 31.5 ± 5.44 and 33.5 in females ± 5.78. Females on average lived many years with knee OA than males with the mean of 4.17 and ±3.54 compared to the mean for females of 4.29 and ±2.53.
Pain levels on Knee OA using VAS
A paired t-test was run on a sample of 30 knee OA patients to determine if there were differences in the level of pain after administering two treatment types. Both conventional and intervention groups consisted of 15 randomly assigned participants with a mean value of VAS 2.4 (.51), t-value = 0.001 and p = 1.000 at baseline. At week 5 the conventional group had a mean of 1.6 (.51) and the intervention group had a mean of 1.4 (.51), (p = 0.289). Although the difference was not statistically significant the results showed that participants in the intervention group had lower pain levels 1.00 (00) compared to participants in the conventional group 0.8 (00). See table 2.

Table 2: Pre and post mean (SD) values on VAS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-Mean Value</th>
<th>Post-Mean Value</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-knee pain VAS Score at week 0</td>
<td>2.4 (.51)</td>
<td>2.4 (.51)</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>Post-knee pain VAS Score at week 5</td>
<td>1.6 (.51)</td>
<td>1.4 (.51)</td>
<td>2</td>
<td>0.080</td>
</tr>
</tbody>
</table>

Six-Minute Walk Test Scores
In table 3 when 6-MWT was conducted on 30 participants with knee OA, the pre mean values of 184 (75.53) m and 207.47 (105.49) in meters (m) were found for conventional and intervention groups respectively. The post mean value at week 5 increased to 250 (80.72) m in the conventional group and 302.67 (119.30) m in the intervention group (t-test = 1.4161, df = 28, p = 0.1678). The mean difference of 95.2 (13.81) m noted in the intervention group was not statistically significant (p = 0.1678) however, the 15 participants in the intervention group demonstrated greater improvement in the distance covered compared their 15 counterparts in the conventional group.

Table 3: Means of pre and post 6-MWT scores in the conventional and intervention groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-Mean</th>
<th>Post-Mean</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-MWT Score</td>
<td>184 (75.53)</td>
<td>207.47 (105.49)</td>
<td>1.4161</td>
<td>0.1678</td>
</tr>
<tr>
<td>6-MWT Score</td>
<td>250 (80.72)</td>
<td>302.67 (119.30)</td>
<td>1.4161</td>
<td>0.1678</td>
</tr>
</tbody>
</table>

Correlation between 6 min walk test and some osteoarthritis knee determinants
A Pearson’s correlation test conducted on 30 knee OA patients, revealed no association on the variables (age, height, weight, BMI, knee pain, duration of knee OA) and performance on the 6-MWT. However, correlation results established a moderate positive relationship between height on weight and BMI (r = 0.5349, p = 0.002, r = 0.7248, p = 0.0001) indicating that as height increases, weight also tends to increase. The age demonstrated a moderate positive correlation with duration of knee OA (r = 0.5583 p = 0.0013) because older patients live many years with knee OA. See table 4.

Table 4: Correlation between 6-MWT and osteoarthritis knee determinants.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Outcome</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
<th>BMI</th>
<th>Duration of OA</th>
<th>Knee pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.0507</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.7902</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>-0.0423</td>
<td>-0.0207</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.8242</td>
<td>0.9135</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>-0.0763</td>
<td>0.1287</td>
<td>0.5349*</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.6886</td>
<td>0.4980</td>
<td>0.0023</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>-0.0870</td>
<td>0.2275</td>
<td>-0.1771</td>
<td>0.7248*</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.6474</td>
<td>0.2267</td>
<td>0.3490</td>
<td>0.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of OA</td>
<td>-0.2452</td>
<td>0.5583*</td>
<td>-0.1287</td>
<td>0.3670*</td>
<td>0.5294*</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1916</td>
<td>0.0013</td>
<td>0.4977</td>
<td>0.0460</td>
<td>0.0026</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee pain (VAS)</td>
<td>-0.2542</td>
<td>0.1330</td>
<td>-0.2144</td>
<td>-0.0205</td>
<td>0.1396</td>
<td>0.2120</td>
<td>1.0000</td>
</tr>
<tr>
<td></td>
<td>0.1753</td>
<td>0.4834</td>
<td>0.2552</td>
<td>0.9145</td>
<td>0.4618</td>
<td>0.2608</td>
<td></td>
</tr>
</tbody>
</table>

Key: OA: Osteoarthritis, BMI: Body mass index, VAS: Visual analog scale (*) represents significant relationship at p<0.05
Group Effect on WOMAC

In table 5, the WOMAC questionnaire was administered to the 30 participants with knee OA to assess their pre (week 0) and post (week 5) level of physical function. The pre mean WOMAC score was 45 (10.30) for the conventional group and 58.4 (14.42) for the intervention group \( (p = 0.0067) \). Post WOMAC scores after 10 treatment sessions reduced to 25.07 (1.59) and 35.6 (3.48) at \( (p = 0.0102) \) for conventional and intervention groups respectively resulting in a clinically significant difference of 22.80 (10.94) in the intervention group. This difference was statistically significant \( (p = 0.0102) \) showing that participants in the intervention group had a satisfactory outcome.

**Table 5: Results of Group Effect on WOMAC**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conventional (N=15)</th>
<th>Intervention (N=15)</th>
<th>df</th>
<th>Between Group Difference (95% CI)</th>
<th>T Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre WOMAC Score at week 0</td>
<td>45 (10.30)</td>
<td>58.4 (14.42)</td>
<td>28</td>
<td>-13.4 (22.77)</td>
<td>2.928 9</td>
<td>0.006 7</td>
</tr>
<tr>
<td>Post WOMAC Score at week 5</td>
<td>25.07 (1.59)</td>
<td>35.6 (3.48)</td>
<td>28</td>
<td>-10.53 (18.37)</td>
<td>2.753 8</td>
<td>0.010 2</td>
</tr>
</tbody>
</table>

Mean Values of Group Effect on 8 Sub-scales of SF-36 Questionnaire

In table 6, the SF-36 questionnaire was used to assess the quality of life in patients with knee OA at week 0 (baseline) and at 5 weeks after 10 treatment sessions. The low scores in the 5 subscales of the SF-36 questionnaire at baseline demonstrated that patients with knee OA have reduced quality of life. Role limitations due to physical functioning sub scale had the lowest mean of 10.40 (10.49) in the conventional group as well as in the intervention group (15.87 (8.28). At week 5 all the 8 sub scales of SF-36 questionnaire showed a statistically significant difference \( (p = 0.0001) \) indicating that quality of life had improved at 5 weeks. The values in the table are pre = baseline (week 0), post = outcome (week 5 after 10 treatment sessions) mean (SD) and p-values for the 8 subscales of the SF-36 questionnaire.

**Pearson’s correlation for SF-36 Sub scales**

In table 7, when Pearson’s correlation was run at significant level \( p < 0.05 \) it revealed that sex had a moderate positive correlation of \( (r = 0.699, p = 0.001) \) suggesting that being male or female has an impact on the general health participants (figure 4.8). There was a weak negative correlation \( (r = -0.418, p = 0.038) \) between age and pain explained by the theories that patient’s perception of pain reduces as they grow older because they tend to adapt to the pain and also due to a decrease in pain receptor. Height had a weak positive correlation \( (r = 0.471, p = 0.017) \) on energy and fatigue implying that as height of a patient increased, fatigue levels also increased. The test also revealed a low negative correlation \( (r = -0.497, p = 0.0114, r = -0.419, p = 0.037) \) between duration of knee OA, social functioning and pain. The longer the duration of knee OA the less affected the social life which could probably have resulted from adaptation to chronic knee pain. Level of education weakly affected the emotional wellbeing in patients with knee OA \( (r = -0.398, p = 0.0487) \) demonstrating that psychological status of patients with higher education levels were less affected compared to patients with low education.

**Table 6: Results of Group Effect on SF-36 Questionnaire sub scales.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conventional (N=15)</th>
<th>Intervention (N=15)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Physical functioning</td>
<td>34.47 (28.26)</td>
<td>33.93 (21.79)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Post- Physical functioning</td>
<td>63.70 (28.10)</td>
<td>74.30 (23.80)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pre-Rule limitations due to physical health</td>
<td>10.40 (10.49)</td>
<td>15.87 (15.28)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Post-Rule limitations due to physical health</td>
<td>59.40 (41.30)</td>
<td>57.70 (38.60)</td>
<td>0.0085</td>
</tr>
<tr>
<td>Pre-Rule limitations due to emotional problems</td>
<td>19.13 (26.88)</td>
<td>36.60 (29.28)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Post-Rule limitations due to emotional problems</td>
<td>65.10 (30.20)</td>
<td>80.00 (21.10)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pre-Energy/Fatigue</td>
<td>41.60 (20.85)</td>
<td>41.07 (22.78)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Post- Energy &amp; Fatigue</td>
<td>60.10 (20.40)</td>
<td>63.80 (14.60)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pre-Emotional well being</td>
<td>60.47 (15.75)</td>
<td>67.67 (22.21)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Post- Emotional well being</td>
<td>73.80 (15.30)</td>
<td>79.00 (14.90)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pre-Social functioning</td>
<td>51.07 (18.07)</td>
<td>51.80 (27.34)</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

**Key:** EF, Energy/Fatigue; EWB, Emotional Well Being; SF, Social Function; P, Pain; GH, General Health.

4. Discussion

The present study comprised of mostly female participants compared to male participants with an average age of 58 years with age range from 36 to 79 years. In terms of gender, a similar presentation exists in different studies [15], [30], [42]. The higher representation of females could be attributed to the fact that females generally have...
higher BMI which is one of the major determinants of knee OA. It is also believed that extra body weight adds more pressure on joints causing the cartilage between them to wear and tear at a faster rate hence predisposing a joint to OA. Supporting this theory, the mean BMI for participants in this study was much higher with the majority of female participants having a BMI higher than 32-40 kg/m2. A study by Hame and Alexander [24] also linked excess body fat to an increase in the production of Adipokines which trigger inflammation yet another predisposing factor to OA. It has been established in this study that 15 patients with knee OA who were treated with conventional physiotherapy plus manual therapy experienced a marked clinically meaningful though not statistically significant difference in pain levels. This observation was supported by a substantial reduction shown in the mean difference on VAS scores between the baseline and outcome measures after 10 treatment sessions. The non-statistically significant difference in the findings of the present study maybe due to a small sample size of 30 participants used. Both groups had at least more than half participants with moderate knee pain and less than fifty percent with severe knee pain at baseline. Slightly more than half of participants in the intervention group reported mild knee pain at week 5 compared to less than fifty percent who had moderate pain in the intervention. However, no participant had severe knee pain at week 5 in both treatment groups. According to Rhon and others [40], MT is believed to prevent, modulate pain as well as induce a controlled inflammatory response that initiates healing and influences processing of pain. The similar potential mechanisms and the fact that treatment was manually applied to allow the therapists to focus on the specific structures that produced pain for each patient could have contributed to a reduction in pain seen in patients in the intervention group in the present study. The results from this study agree with those reported by Salamh and colleagues [41] from a systematic review and meta-analysis of 12 clinical trials which revealed that adding MT to a usual treatment showed a standard meaningful difference for the pain of (SMD = 0.073). Furthermore, MT as an adjunct to conventional physiotherapy in this study confirmed a greater reduction in pain (SMD = 1.00) supporting recommendation of combined interventions for knee osteoarthritis [2], [20], [23]. Knee pain in patients with knee OA is usually implicated in restrictions of functional performance and mobility resulting in slower walking speeds and a faster decline in gait speed over time. A 6-MWT was used to assess the functional capacity of participants at baseline and compare the scores at week 5 after administering the two interventions of conventional therapy and conventional therapy plus MT to determine the treatment effects [14], [32]. Six-minute walk test has been used extensively in several studies due to its high validity of 85% and reliability 90% [10]. Participants are allowed to walk at a self-regulated pace and also to take a rest when necessary during the test making it safe and viable even in patients with knee OA. However, the paucity of literature on reference values limits its application in African countries including Zambia. The current study, therefore, adopted a quadratic prediction model for individuals with musculoskeletal limitations which predicts that the population studied should walk 303.51 m during the 6-MWT as a reference value [51]. Nevertheless, there was no significant difference between the pre and post outcome measures (p = 0.1678) however, a clinically meaningful mean difference of -95.2 ±13.81 m) was noted in the intervention group. Use of foreign 6-MWT reference values could have had an impact on obtaining results due to geographic variations and different ethnicity hence the need to establish reference values for a Zambian population. Participants in the intervention group had significant change in distance covered between baseline and week 5. About 66.67% of participants in the intervention group had a low score ranging from 96-240m at baseline compared to 53.33% at week 5. Participants in this study had way below average initial functional capacity which could have been the reason why the difference was not statistically significant for manual therapy in improving 6-MWT performance at 5 weeks. The low initial functional capacity could have been due to a large number of participants 21 (70%) having a duration of 3-10 years lived with knee OA suggesting that patients had a longer duration of symptoms which could have led to restricted mobility, slower walking speeds and a decline in gait speed. It is logical to assume that longer duration of symptoms signifies weakness in muscles of the lower limb, impaired knee biomechanics and proprioception factors which affect mobility. Similarly, Rodrigues da Silva and colleagues [51]. found no improvement in 6-MWT performance and attributed the result to the fact that volunteer participants included in their study had a pre mean 6-MWT of 368.6 ±9.15 indicating an initial aerobic capacity above the predicted values of 303.51 meters. Contrasting the current findings, Ciolac and colleagues [17]. noted a substantial improvement of 22.6% in walking distance after 13 weeks of resistance training in patients with knee OA. Initial functional capacity of participants in Ciolac’s study [17] was 270 m which was more close to the reference value suggesting better functional capacity and also the duration of treatment of 13 weeks was longer compared to 5 weeks. There was no correlation between Knee OA determinants and 6-MWT contrasting findings from previous studies by Ateef and others [10]. who reported a negative correlation between age, BMI and pain. Conley and others [18]. found similar results with a minor difference to those reported by Ateef [10]. The authors found a moderate negative association between pain and functional performance (r = -0.527, p = 0.001). However, the current results showed that weight had a moderate positive correlation on height (r = 0.5349, p = 0.002) and BMI had a strong positive correlation on height (r = 0.7248, p = 0.001). Bones make up around 15% of a person’s total body weight a reason why taller people weigh more than shorter people of the same body built. Duration of knee OA had a moderate positive correlation on age and BMI. This rationale is valid because OA is a degenerative condition that worsens with time therefore patients become inactive as the condition worsens probably due to persistent pain. Inversely increased BMI places extra joint loading resulting in more damage to the joint and more pain. Contrary to findings of the current study Correia de Faria Santarém and colleagues [21], reported a significant negative correlation between BMI (r = -0.5) and 6-MWT. Physical function and quality of life are both enhanced by a minute reduction in pain. Patients in the intervention group in this

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study showed statistically significant mean difference results in physical function measured by the WOMAC. The probable explanation for the results could have been due to the earlier clinical reduction noted on VAS scores. Previous RCTs by Ahmad [3], Fitzgerald [23], and Courtney [53] demonstrated similar beneficial effects of MT on the 3 domains of WOMAC (pain, stiffness and function) in patients with knee OA, but have not elucidated the specific possible mechanisms rather than proposing that the effects could be derived from the increased extensibility of collagen, optimized joint lubrication and reduction in muscle tone around the knee and other related body regions resulting in improved joint function and joint mobility [5], [9], [16], [25]. The present study used a 5-point Likert scale total range of 0 to 96 with five response levels for each item. The response levels signify different degrees of intensity (0 = none, 1 = mild, 2 = moderate, 3 = severe, or 4 = extreme). The final score for the WOMAC was determined by combining scores for pain, stiffness, and function such that scores range from 0 to 96 for the total WOMAC where 0 represented the best health status and 96 the worst possible status. In this context, an improvement is attained by a reduction in the overall score in that the higher the score, the poorer the function. A clinically meaningful importance difference of 12 points used in rehabilitation intervention for knee osteoarthritis was adopted as a reference to determine the efficacy of an intervention in this study [42]. This study showed a statistically significant difference in results demonstrated by a decrease in the overall WOMAC scores from 58.4 (14.42) to 35.6 (3.48) with a mean difference of 22.80 (10.94), p = 0.0102. A mean difference of 22.80 noted in the intervention group surpassed the 12 points reference value suggesting that changes in the scores depended on a treatment group assignment. These results are consistent with that of previously published trials [5], [9], [30], [50], where similar improvements were noted in the mean values in patients with knee OA after administering MT. In this regard, graded MT techniques plus a supervised exercise program involving neuromuscular control exercises and balancing exercises such as the one utilized in this study should be employed to help address these deficits in patients with knee OA. Furthermore, the current study achieved these positive outcome effects in 10 treatment sessions contrasting 12 to 16 clinical visits reported in most of the previous studies [8]. Quality of life of participants assessed by SF-36 questionnaire in the present study improved substantially between baseline and week 5. Participants in the intervention group had a much higher score compared with participants in the control group. Findings of the current study suggested that role limitations due to physical functioning domain is the mostly affected in patients with knee OA because it had the lowest mean at baseline. However, these results are in contrast with those of Alrushud and colleagues [7], who found role limitation due to emotional problems to be the most affected domain when they compared the impact of knee OA on the quality of life among Saudi elders. The authors further reported that pain influenced the mood of participants contributing to mental health being the most affected domain. The present study, however, showed that patients were less affected by psychological factors compared to physical health a possible factor which could have resulted from social-economic variations. Most patients in this study were from low social places of Lusaka compared to patients in Alrushud’s study who came from the highest social place Saudi Arabia. The significant improvements noted in the intervention group demonstrated that a manual therapy protocol used in the current study may be employed to improve quality of life in patients with knee OA. This finding is supported by Sit [42], who observed improvement in the scores for quality of life measured by EuroQol-5D questionnaire with the minimal clinically important difference of 0.03 points following patella mobilization therapy. Gender had a moderate positive correlation on the general health of patients suggesting that being male or female has an impact on the general well-being of participants. There was a weak positive correlation between height, energy and fatigue implying that as the height of a patient increase, fatigue levels also increased. The test also revealed a low negative correlation between duration of knee OA, social functioning and pain. The longer the duration of knee OA the less affected the social life which could probably have resulted from adaptation to chronic knee pain. Level of education weakly affected the emotional well-being in patients with knee OA demonstrating that psychological status of patients with higher education levels was less affected compared to patients with low education. Contrasting this finding, Kawano and others [28], found patients with higher education level to have better functional capacity when they were compared to patients with a basic level of education. A weak negative correlation was noted between age and pain explained by the theories that patient’s perception of pain reduces as they grow older because they tend to adapt to the pain and also due to a decrease in pain receptor. This finding was contrary to Quedraogo and colleagues [52], who found patients with over 60 years of age to have a decrease in pain tolerance in their study to assess the impact of knee OA on quality of life using a Knee Hip Quality of Life (OAKHQOL) questionnaire. All outcome measures for participants in the intervention group were constantly better than for participants in the conventional group throughout the entire study showing that the observed improvements were mainly attributable to the addition of MT intervention. Conventional physiotherapy adequately addressed the symptoms common in patients with osteoarthritis of the knee, but MT provided an additional effect as demonstrated in the results. All participants sustained the treatment effects up to 2 weeks after the conclusion of a clinical trial. More studies with a longer-term follow-up of 3, 6, 12,18 and 24 months could be enlightening in this area [2], [25], [42].

**Conclusions**

This study has shown that adding manual therapy to conventional physiotherapy is more effective than conventional therapy alone in reducing knee pain, improving walking distance, physical function and quality of life in patients with osteoarthritis of the knee as demonstrated by improvement in the VAS, 6-MWT, WOMAC and SF-36 questionnaire scores. Therefore, manual therapy should be embraced as an adjunct to a comprehensive rehabilitation program of conventional therapy in everyday practice when managing patients with knee OA.
Limitations
The inclusion criteria of the study covered a broad age range from 30 to 85 but failed to group them according to the duration of knee OA and radiographic profiles which could have impacted on the results obtained. The study sample size of 30 participants was too small to generalize the results. The treatment duration of 5 weeks and follow-up of 2 weeks was short to establish long term effects of manual therapy. The reference values for 6-MWT were adopted from a foreign country which has had an impact on obtaining results due to geographic variations and different ethnicity.

5. Declaration

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Author Contribution
All authors conceptualized the study. SC, BC and MM wrote the manuscript. All authors read through the final manuscript and approved it for submission for publication.

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Appendix 1

Manual Therapy Protocol Description

The therapist achieved at least one set of grade III or IV each session. Caution with end of range (EOR) techniques for knee flexion was taken as a degenerative meniscus is easily aggravated in this position.

Joint Position.
The therapist selected a joint position for treatment based on their assessment of the irritability of the patient’s condition. Joint position was altered in response to patient reporting or test: re-test findings.

Patient Position.
The therapist modified the patient’s starting position for treatment based on the patient’s condition. Patient position was altered in response to patient inability to achieve the standard position or reporting discomfort.

Dose.
Accessory movements were performed in sets of 30 oscillations. At least 3 sets were performed. The therapist employed the highest dose of mobilization appropriate, with at least one set of grade III, or IV in each session. A maximum of 6 sets was performed if the patient tolerated the technique and responding favorably.

Grade I – small amplitude movement at the beginning of the available range of movement
Grade II – large amplitude movement at within the available range of movement
Grade III – large amplitude movement that reaches the end range of movement
Grade IV – small amplitude movement at the very end range of movement

Lower grades (I + II) are used to reduce pain and irritability (use VAS scores).
Higher grades (III + IV) are used to stretch the joint capsule and passive tissues which support and stabilize the joint so increase range of movement.

Manual Stretches to quadriceps, hamstrings, and gastrocnemius was performed. Dosage was 60 seconds total (1x60s, 2x30s, 3x20s).

Soft Tissue Mobilization (STM) was performed simultaneously with the manual stretching exercises.

Physiological Movements were performed 10-30 times. The number of sets ranged from 3 to 6 according to therapist choice and patient response.

Order of Treatment Techniques. The therapist selected the order of treatment techniques choose to alternate between techniques of accessory movements and physiological movements.

Test-Retest Procedures were performed by the therapist throughout the treatment session as required.

Adding or Dropping of Techniques.
Additional techniques (if indicated) was added as time allowed. The therapist was clear of the response to new techniques. Hamstring and gastrocnemius stretches and soft tissue manipulation (STM) were dropped at follow up sessions if goals had been reached.

Hamstrings Stretches: were discontinued when knee extension motion was 30 degrees or less of 0 degrees’ knee extension with hip positioned at 90 degrees of flexion.
Gastrocnemius Stretches: were discontinued after meeting 10 degrees of ankle dorsiflexion with knee extended and 10 degrees of dorsiflexion with the knee bent.

Patient Safety.
If the physiotherapist considered application of a mandatory technique threatened patient safety they opted not to perform that technique. Wherever possible, they choose an alternative patient position or a variation from the “acceptable variation” category.

Each time this occurred the physical therapist documented this in the patient’s treatment record at the end of the session. The principal investigator (PI) was informed on that day, as soon as it was practically possible. The PI reviewed the case with the therapist, discussing the patient’s history and physical condition with respect to the protocol deviation. Following consultation, the course of future action with respect to the protocol deviation for that patient was
agreed by the therapist and PI. In the event of failure to agree, the PI’s decision prevailed. The PI sought consultation in order to reach a decision, and/or delivered the protocol technique in question for that patient.

**Section 1: Primary Techniques**

**Knee flexion and extension.** All knee flexion and extension techniques were mandatory at the initial session.

**For knee flexion,** AP’s, patellar glides, STM, manual stretches and physiological movements were all included.

**For knee extension,** PA’s, external rotation, STM, manual stretches and physiological movements were all included.

**Acceptable variations included:**
- Patient position (supine/sitting/weight bearing, with or without seat belt)
- Med and lateral glides of tibial-femoral joint, with or without seatbelt
- Varus and valgus stresses, internal or external rotations of tibia, for accessory and physiological movements

**Combining physiologic and accessory movements**

Hip Long Axis Distraction and Caudal/Lateral Glide: These techniques are also mandatory as most people with knee OA have limitations in hip motion that can affect function

1. **Knee Flexion Accessories movements- MANDATORY**

A-P accessory movements.

**Description/ instructions:**
- The patient was in supine. The therapist selected the knee joint position on the basis of pain and irritability.
- The least provocative joint position was in the pain free range.
- If patient response allowed, the knee was flexed to the onset of pain or resistance.
- If patient response allowed, the joint was placed at end of range flex into the restrictive barrier.
- Therapist placed the 1st web space on the proximal tibia. An oscillatory mobilization (Grade 3 or 4) was performed in an anterior to posterior direction on the proximal tibia.
- Tibial rotation was added to most effectively reach the restrictive barrier

**Patellar mobilizations.**

**Description/ instructions:** The patient was in supine with the knee in extension. The joint position was progressed into increasing flexion or weight bearing if the symptoms are easing or minor.
- Oscillatory movements (glides) were produced via the therapist’s thumbs or a cupped hand. The glides were combined with rotation and/or compression to meet the restriction.
- Compression was introduced with caution.
- Medial/Lateral/Caudal/Cephalad were selected on the basis of restriction. If no restriction was detectable caudad/cephalad glides was used.
2. **Physiological movements –MANDATORY**

**Pure Knee Flexion + valgus + tibial internal rotation (+seat belt)**
- The therapist stabilized the patient’s thigh and knee against their body while grasping the patient’s ankle.
- The therapist gently brought the patient’s heel towards the buttock to the restrictive barrier.
- Oscillations were produced in pure flex direction (Grade 3 or 4).
- Valgus stress was added (heel lateral to buttock) (Grade 3 or 4).
- Internal rotation was added simultaneously. Oscillatory mobilizations were performed through a 5-6-inch arc of motion.
- A towel roll was inserted under the knee to enhance the mobilization technique at near end-range of knee flexion.
- Grade V mobilization was optional.

**Pure Knee Flexion + Varus + tibial external rotation + seat belt**
- The therapist stabilized the patient’s thigh and knee against their body while grasping the patient’s ankle.
- The therapist gently brought the patient’s heel towards the buttock to the restrictive barrier. Oscillations were produced in a pure flexion direction. (Grade 3 or 4).
- A seat belt was added to produce a lateral glide of tibia through range if this decreases pain.
- A medial glide of the tibia was produced by placing the seat belt around the femur and manually gliding the tibia medially.
- Varus stress was added (heel to midline) (Grade 3 or 4).

3. **Manual Stretch Knee Flexion MANDATORY**

**Quad stretch, progress to rectus femoris stretch**
- The patient was positioned supine. The therapist stabilized the patient’s thigh and knee against their body while grasping the patient’s ankle. The therapist gently brought the patient’s heel towards the buttock to the restrictive barrier. The stretch was held for 1x60 secs (or 2-30s, 3-20s).
- If no stretch was felt the patient was positioned prone. The therapist stabilized the pelvis and produced a passive flexion stretch by bringing the heel towards the buttock. The stretch was held for 1x60 secs (or 2-30s, 3-20s).
- An alternative position was with the patient lying supine with the involved leg dangling over the edge of the plinth or using the modified Thomas test position. The therapist sat alongside the involved leg and flexed the knee just before the point of patient reported stretch.
- The stretch was held for 1x60 secs (or 2-30s, 3-20s).
4. **Soft Tissue Manipulation (STM) - MANDATORY and performed in conjunction with the quadriceps stretch, Quads/Peripatellar/ITB**

- The patient was positioned supine with leg over the side of the plinth. The patient’s quadriceps were placed on a stretch. The therapist performed an effleurage stroke along the length of the quads. The therapist proceeded from superficial to moderate depth of the effleurage depending on patient tolerance. The technique was delivered for as long as the stretching technique was performed.
- The strokes included the peripatellar area or particular tightness is present, circular massage was concentrated in this area.
- Note: If the patient could not tolerate this positioning the effleurage was performed with the quadriceps on stretch in a position that was tolerable to the patient.
- To address the ITB patient was positioned in side lying in an Ober’s position modified for comfort.

5. **Knee Extension Accessories movements -MANDATORY**

**PA accessories (may include Tibia External Rotation).**

- The patient was positioned prone.
- The therapist selected the joint position on the basis of pain and irritability.
- The least provocative position was with the knee flexed in a pain free range.
- As patient response allowed the knee positioned in more extension at the onset of pain or resistance.
- As patient response allowed the joint was positioned at end of range extension at the restrictive barrier.
- The therapist used their thumb pads or the heel of their hand to impart oscillatory movements in the P-A direction.
- The other hand was used to move the lower end of the tibia parallel with the proximal end

Or: the distal tibia was lifted slightly to combine PA with knee flexed.
Or: the distal tibia was lowered to combine PA with knee extension.
Or: External Rotation may be added.
- The patient was positioned supine. The knee was positioned in flexion and progressed to extension as patient response allows.
- The therapist grasped around the proximal end of the tibia. The thenar eminence of the lateral hand produced an AP movement while simultaneously the fingers of the medial hand produce a PA movement, resulting in a lateral rotation of the tibia on the femur.

6. **Physiological movements -MANDATORY**

**Pure Knee Extension + valgus and varus + seat belt + AP glide.**

- The therapist placed the heels of the hands over the proximal tibia while the lower leg was supported by a towel roll. An oscillatory movement was performed to the restriction of extension.
- Valgus or varus stress was added if it produces a pain response or adds to the restriction.
- A seat belt was used to produce medial or lateral glide of the tibia as previously described.
- An A-P glide was added to the oscillatory movement if it reproduces pain or stretch to the posterior aspect of the knee joint.
7. **Manual Stretch – MANDATORY (Initial Session)**

**Discontinue if goal reached – follow up sessions.**

**Hamstrings stretch** were discontinued when knee extension motion was 30° or less of 0° knee extension with hip positioned at 90° of flexion.
- The patient was positioned supine with knee extended.
- The therapist grasped the involved leg and flexed the hip while maintaining knee extension to the point of stretch.
- The stretch was held for 1x60 secs (or 2-30s, 3-20s).

**Gastrocnemius stretch** were discontinued after meeting 10° of ankle dorsiflexion with knee extended and 10° of dorsiflexion with the knee bent.
- The patient was positioned prone with the knee as close to full extension as possible.
- The therapist grasped the middle of the tibia with one hand to maintain EOR knee extension. The therapist used the thigh to produce dorsiflexion of the ankle while feeling the stretch was felt in the posterior aspect of the calf.
- Note: The supine position was used if the patient could not tolerate the prone position.
- The stretch was held for 1x60 secs (or 2-30s, 3-20s).

8. **Soft Tissue Manipulation (STM) MANDATORY – Initial Session**

**Discontinue if goal reached – follow up sessions.**

**Hamstrings** - when knee extension motion was 30° or less of 0° knee extension with hip positioned at 90° of flexion.
- The therapist performed an effleurage stroke along the length of the hamstrings.

**Adductors:** STM for the adductors was included either in STM for hamstrings or quads and was done in conjunction with gastrocnemius stretching.
- The technique was performed in conjunction with gastrocnemius stretching. The therapist performed an effleaurage stroke along the length of the gastrocnemius making sure to cross the knee joint. The amount of dorsiflexion and depth of STM depended on patient tolerance. The technique was applied for the duration of the stretching technique.
- Note: If the patient could not tolerate this positioning the effleaurage was performed with the gastrocnemius on stretch in a position that was tolerable to the patient.
9. **Hip Distraction Mandatory- Long Axis Distraction and thrust.**

- The patient was positioned supine. The therapist grasped involved leg, above malleoli. The patient’s hip was placed in 15-30° flexion, 15-30 ° abduction, slight external rotation. The therapist performed 3 sets of 30 grade III or IV oscillations. A grade V mobilization was performed once during each set.
- If the subject had knee discomfort with the ankle hand position, then an alternative was to apply the distraction with the hands placed above the knee with the hands placed around the distal femur.
- If the therapist had difficulty applying the distraction force, a figure of 8 belt may be used to assist with supporting and distracting the limb.

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**Section Two.**

**Additional Regional Techniques — 5 Minutes Maximum Per Impairment**

11. **Hip Antero-Posterior Progression (Posterior glide)**

**Indication:** Posterior hip pain on flexion, adduction, internal rotation (FABER). Stiffness (inability to cross midline during FABER TEST).

- The therapist placed the patient’s lower extremity with the hip in a position of flexion, adduction, and internal rotation. The therapist used his/her body to impart an oscillatory, passive mobilizing force to the postero-lateral hip capsule through the long axis of the femur.
- The technique was progressed by adding more flexion, adduction, & / or internal rotation.

12. **Postero - Anterior hip flexion, abduction, external rotation (Anterior glide in low crawl position)**

**Indication:** Anterior hip pain on flexion, abduction, and external rotation (FABER), or anterior hip pain on FABER test.

- Bring the prone lying patient’s hip into varying degrees of flexion, abduction and external rotation.
- Contact the proximal hip and use your body to impart an oscillatory, passive mobilizing force in a posterior to anterior direction.
- Vary the vector of your mobilizing force, dependent on stiffness and the patient’s symptoms.
- If extremely stiff, start with a pillow under the patient’s left trunk to decrease the amount of hip abduction required. Progress to lying flat on the table when able.
- Reassess symptoms and impairments after mobilization

**Stretches**

**Manual gluteus/internal rotator stretch.**

**Indication:** Hip ER <30°, or asymmetric with non-involved limb.

- The patient was positioned supine. The therapist flexed the patient’s knee to 90, flexes and externally rotates the hip to the point of stretch.
- Alternate position was patient prone, with the pelvis stabilized.
- The stretch is held for 1x60 secs (or 2-30s, 3-20s).
Hip external rotator stretch.

**Indication:** Hip IR <30º, or asymmetric with non-involved limb.

- The patient was positioned supine. The therapist flexed the patient’s knee to 90º and ensures that the hip is in neutral or slight adduction. The hip was internally rotated until a stretch was felt at the anterior hip.
- Alternate position was patient prone. (See description of internal rotation in extension)
- The stretch was held for 1x60 secs (or 2-30s, 3-20s).

## Ankle Joint- Rear Foot Distraction Manipulation

**Indication:** Loss of ankle dorsiflexion<10º with knee extension dorsiflexion<10º with knee flexion.  
- The therapists grasped the dorsum of the patient’s foot with interlaced fingers and provide firm pressure with both thumbs in the middle of the planar surface of the forefoot engage the restrictive barrier by dorsiflexing and evertic the ankle & applying long axis distraction. The therapist pronates, everts, dorsiflexes the foot to fine-tune the barrier. The therapist then applied 3 sets of 30 grade III and IV mobilizations.

## AP Talo-Crural Accessory

**Indication:** Loss of ankle dorsiflexion<10º with knee extension dorsiflexion<10º with knee flexion.  
- The therapist used their left hand to firmly stabilize the lower leg at the malleoli. The therapist then grasped the anterior, medial, and lateral talus with your right hand and applies an anterior to posterior oscillatory mobilization force to the talus. (Grade 3 or 4).
- The amount of dorsiflexion can be adjusted to meet restriction allowed by patient response.
- The treatment was progressed into weight bearing in a lunge position on a chair.
- This was reinforced by an anterior glide of the tibia produced by a seat belt.

## Proximal Tibio-Fibular Joint Posterior to Anterior Manipulation

**Indication:** Proximal Tibial Fibular joint - (lateral knee pain, including superior Tib/fib joint).
- The therapist placed their 2nd MCP in the popliteal fossa, then pulls the soft tissue laterally until the metacarpo-phalangeal joint (MCP) is firmly stabilized behind the fibular head.
- The therapist used their right hand to grasp the foot and ankle as demonstrated and externally rotate the leg and flex the knee to the restrictive barrier (the therapist should feel firm pressure from the fibular head over the palmar aspect of your MCP). Once at the restrictive barrier, the therapist applied 5 grade III or IV mobilizations through the tibia (direct the patient’s heel towards his ipsilateral buttock).
Appendix 2
Exercise Program Protocol for Patients with Knee OA
Core protocol exercises included four components namely: Aerobic/warm-up, Strengthening, Stretching and Neuromuscular control. Each participant performed all four components of the program.

**Warm Up**
Cycling was performed up to 10 minutes. Exercise was discontinued if patient reports an increase in pain greater than 2 points on visual analogue scale (VAS).

**Rules for Stopping Exercise**
Presence of angina, heart rate exceeds age-predicted max (220-Age), systolic pressure falls or does not rise with increased load, systolic pressure >260mmHg, diastolic > 115mmHg was applicable, for participants with identified cardiovascular risk.

**Strengthening Exercises**
These were performed with a dose of 3 sets of 10 repetitions with a 3 second hold or until fatigue. Exercise was discontinued if patient reports an increase in pain > 2 points on VAS, however this was avoided by ensuring appropriate starting intensity and resistance.

**EXERCISE 1: Strengthening of knee extensors: Open chain progression.**

**LEVEL 1: Isometric quads set.**
The participant is positioned in long sitting with the knee extended. Therapist instructs the participant to isometrically contract the quadriceps muscles bilaterally as vigorously as possible without reproducing pain. The exercise was performed on each limb.

**Progression:** Progress to level 2 when 3 sets of 10 were performed without difficulty, and the patient performed an activity with ease and good form.

**LEVEL 2: Leg Extensions.**
The participant was initially positioned in sitting in a chair or on treatment table with the exercised leg in approximately 90 degrees of flexion. The therapist instructed the participant to extend the knee to full extension, then slowly lower until the foot returned to rest on the floor.

**Progression:** Progress to level 3 when 3 sets of 10 are performed without difficulty, and the patient performed activity with ease and good form.

**LEVEL 3: Resisted Leg Extensions.**
Progress to Level 3 by looping theraband resistance around the front legs of a chair, then placed the foot and ankle inside the loop. The exercise was then performed by having the subject extend the knee against the theraband. The level of theraband was progressed sequentially by color.

**Progression** was from least to most resistance (red, green, blue, gray, black, gold) When the subject can perform 3 sets of 10 reps without difficulty, using good form, then the resistance was progressed to the next color. When “gold” was achieved, two loops were made (place foot and ankle behind both bands of theraband) of band to further progress the resistance (either drop to lesser resistance color and use 2 loops or use 2 loops of gold if appropriate).
Standing Strengthening of knee extensors 2: Closed chain progression

LEVEL 1: Weight reduced partial squats. 
The participant supporting his/her instructed the knees tracking important that beyond the toes to The exercise was pain. Progression: against the wall.

LEVEL 2: Step-ups. Note: These was added when the subject could perform 3 sets of 10 reps of partial squats with the back against the wall.

The participant stood in front of a step. Started with the 6.5cm step and progressed as tolerated. The patient places the foot of the target limb on the step and brings the body over the foot to stand on the step with an extended knee. The participant was to minimize arm support assistance or push-off assistance from the contralateral limb. Slowly lower until the contralateral foot returned to fully weight-bear on the floor, then return the target limb alongside (i.e. the starting position). The exercise was performed on each limb.

Be sure to provide directions to keep the knee over the 2nd metatarsal and keep the pelvis as level as possible to promote proper alignment and hip control during this task. NB: Hip control is important for knee OA patients.

Progression was from a small low (2-4 inch), then medium (4-6 inch), then high (6-8 inch) step. Note: This can also be done as a lateral step-up to begin with if the subject can’t tolerate the forward step-up procedure. Eventually this should be progressed to forward step up.

Strengthening of Hip Extensors:

LEVEL 1: Supine bridging.
Patient was in supine with knees bent 90°. Patient actively performs a glut contraction while lifting the hips and pelvis off the floor to obtain a bridge position, with the hip in a neutral flex/ext position.

Progression: Patient is progressed to Level 3 when 3 sets of 10 of Level 2 exercise was performed without difficulty and patient is performing activity with ease and good form.

LEVEL 2: Supine unilateral bridging.
Patient was supine with knees bent 90°. Patient actively performs a glut contraction while lifting the hips and pelvis off the floor to obtain a bridge position. Unaffected knee is extended from flexed position and held.
Strengthening of Knee Flexors:

**LEVEL 1: Prone hamstring curls.**
The participant was positioned in prone on the treatment table. The participant flexes the knee from full extension to 90° of flexion, then returns limb to full knee extension position. **Exercise was performed on each limb.** Watch for excess lumbar movement.

**Progression:** Progress to Level 2 when 3 sets of 10 was performed without difficulty, and the patient performed activity with good form.

**LEVEL 2:** Theraband is applied to the distal leg. This done in prone or in standing, whichever was easiest for the patient to set up.

**Progression:** The level of resistance band was progressed sequentially by color. The progression was from least to most resistance (red, green, blue, gray, black, gold) When the subject could perform 3 sets of 10 reps without difficulty, using good form, then the resistance was progressed to the next color. When “gold” is achieved, you may need two loops of band to further progress the resistance (either drop to lesser resistance color and use 2 loops or use 2 loops of gold if appropriate).

**Stretching exercises**
These will be performed each session until goals are met. **Dose:** 1-minute total with 20-60 second hold times.

**Goals:** The following stretches was discontinued when the goal was met:
1. Hamstring stretch discontinued when knee extension motion was 30 degrees or less of 0 degrees’ knee extension with hip positioned at 90 degrees of flexion.
2. Standing calf stretching discontinued after meeting 10 degrees of ankle dorsiflexion with knee extended and 10 degrees of dorsiflexion with the knee bent.
3. Quadriceps stretching discontinued when knee flexion is greater than 90 degrees when the hip was maintained in 0 degrees of extension.

**Calf Muscle Group Stretching:**
Patient assumed a standing position with involved lower extremity placed behind the non-involved.

Patient’s arms are placed on wall and involved knee was kept straight with heel flat to the floor until stretch was felt.

**Hamstring Muscle Group Stretch:**

**Hamstring Stretch:** The participant will lie supine. The participant held the thigh in 90° of hip flexion. The knee was extended as far as possible. Held the limb in the stretched position for 30 seconds. Repeated the exercise 3 times. **Repeat the exercise on your opposite leg.**

Alternative methods included using a strap or towel wrapped around the foot and held by the participant to maintain the stretched position or using the long sitting position to provide the hamstring stretch.
Quadriceps Muscle Group

**Stretch:**
The participant was positioned in either standing or prone. Patient places foot onto chair until stretch is felt or lies prone using a towel or belt to stretch. In some instances, a side lying position may be used in which the subject is instructed to keep the hip in neutral flex/ext while maximally flexing the knee.

**Neuromuscular control exercises:** were chosen from the 3 most challenging exercises the patient can achieve safely. **Dose:** 2 minutes each exercise, 3 exercises. May repeat any exercise more than once, and count the repeat as a new exercise.

**Stairs**
Patient was asked to ascend/descend 3 steps with alternating step pattern to increase strength and functional activity. Used the upper extremity support if needed. Progress was with increased step height.

**Section Two: Additional impairments-based exercises.**
Patients who tested positive for additional impairments at the initial assessment was prescribed the following exercises based on the clinical judgment of the clinician with the dose parameters follow the guidelines listed above for strengthening and stretching.

**Strengthening of Ankle Plantar-Flexors**

**Indication:** If inability to perform 10 unilateral calf raises (with full height and calcaneal inversion) or noticeable muscle atrophy compared to opposite side.

**LEVEL 1: Bilateral calf raise and lowering.**
Patient was positioned in standing with both feet on the step. Patient rises up on toes as high as possible, holding for 3 seconds, then returning to start position.
Progression: Patient is progressed to Level 2 when 3 sets of 10 of Level 1 exercise was performed without difficulty and patient performed activity with good form.

**LEVEL 2: Bilateral calf raise, unilateral lowering.**
Patient was instructed to go up on toes bilaterally and lower only with the involved side with or without use of upper extremity support.
**Progression:** Patient progressed to Level 3 when 3 sets of 10 of Level 2 exercise was performed without difficulty and patient performed activity with good form.
LEVEL 3: Unilateral calf raise, unilateral lowering.  
Patient was instructed to raise up on involved side, lower with involved side with or without use of upper extremity support.

**Strengthening of Hip Abductors**

**Indication:** If unable to perform 10 lateral pelvic tilts while weight-bearing on the test leg (reverse action hip abduction)

**LEVEL 1:** Supine hip abduction.  
Patient lies supine and actively abducts the involved hip through the available ROM.  
**Progression:** Patient progressed to Level 2 when 3 sets of 10 of Level 1 exercise was performed without difficulty and patient performed activity with good form.

**LEVEL 2:** Standing hip abduction.  
Patient was standing and actively abducted the involved hip through the available ROM.  
**Progression:** Patient progressed to Level 3 when 3 sets of 10 of Level 2 exercise was performed without difficulty and patient performed activity with good form.

**LEVEL 3:** Side-lying hip abduction.  
Patient was positioned in side-lying and actively abducted the involved hip through the available ROM.  
Progress to level 4 when the exercise is performed 3 sets of 10 without difficulty and patient is performing activity with good form.

**LEVEL 4:** Reverse action hip abduction in standing.  
Subjects stands on the exercise limb in unilateral support. The pelvis was laterally tilted toward the non-weight bearing limb and then tilted back up to neutral. Neutral position is held for 3 seconds. Repeat the exercise, up to 3 sets of 10 repetitions. A chair or table can be used for balance initially, but the exercise should be progressed to performing without the need for balance support.
Strengthening of Hip External Rotators

Indication: Same as for Hip Abductors.

LEVEL 1: Clamshells.
Patient was positioned in side-lying with knees bent 90°. Patient actively externally rotates the upper leg through the available ROM while maintaining the pelvis in neutral alignment and keeping the feet together. Progression: Patient progressed to Level 2 when 3 sets of 10 of Level 1 exercise was no longer challenging and patient performed activity with ease and good form.

LEVEL 2: Clamshells with resistance.
As above with theraband around the knees to increase resistance. Progression: Patient was increased to Level 3 when 3 sets of 10 of Level 2 exercise was no longer challenging and patient performed activity with ease and good form.

LEVEL 3: Clamshells with increased resistance.
As above with increased level of resistance using theraband.