Quantitative Assessment of Muscle Activity and Joint Load in Braced and Unbraced Osteoarthritis Knee by External Strain Gauge Sensor

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Abstract

Objectives: Altered biomechanics leads to the development of degenerative joint disease. The joint pressure and dynamic loading varies during activities of daily living. The study was undertaken to assess the muscle activation pattern of the medial and lateral knee compartments (tibiofemoral joint) during gait in osteoarthritis subjects without and with knee brace undergoing either exercise therapy or balance therapy. The joint load was assessed by the strain gauge transducer and the weight shift pattern is taken as an indicator for the muscle activation pattern.

Methods: In a prospective design study on 57 male subjects diagnosed osteoarthritis knee with Kellagren-Lawrence scale walked barefooted with and without designed offloader knee brace on a level surface for three minutes. The subjects were allocated in two different study groups i.e. Conventional (exercise therapy) (Control Group, n=31) and Structured Neuromuscular Postural Training (SNPT) group (Balance therapy) (Study Group, n=26). The subjects were sub grouped as pre-elderly (40-60 Years) and elderly (>61 years) group in both. The quantitative assessment of muscle activity and joint loading with and without knee brace was done using designed strain gauge sensor instrument. The pressure changes of strain gauges of muscles around the knee joint viz. vastus medialis (VM), vastus lateralis (VL), semi membranosus / tendinosus (Medial Hamstring) (MH), Biceps Femoris (Lateral Hamstring) (LH), gastro-soleus (GS) and tibialis anterior (TA) muscles during normal gait were observed at baseline and 6 weeks follow up after undergoing exercise therapy or balance therapy treatment as per allocation of study groups. The digital values from MATLAB were recorded and analyzed.

Results: At the end of 6 weeks conventional / SNPT (structured neuromuscular postural training) treatments, medial hamstring muscle activity showed significant difference (p<0.001) in pre-elderly subgroup, while significant difference was seen in vastus laterals (VL), medial hamstring (MH) (p<0.005) and lateral hamstring (LH) muscles (p<0.001) in elderly subgroup.

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Further, the muscle co-contraction has been higher for vastus medialis-medial hamstring (VM-MH) pair compared to vastus lateralis-lateral hamstring (VL-LH) pair without brace at baseline. The application of offloader valgus knee brace significantly increases VL-LH co-contractions in magnitude and decreases in VM-MH co-contractions at 6 weeks follow up.

**Conclusion:** Muscle activity increased in medial hamstring both in pre-elderly and elderly subjects. While, Vastus Laterals and lateral hamstring showed increased activities in elderly subjects. Hence, balance training and the application of off loader knee brace will be helpful to redistribute the load on medial tibiofemoral compartment.

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**Introduction**

Osteoarthritis (OA) is a progressive degenerative joint disease with multifaceted pathological mechanisms involved in articular cartilage and sub-chondral bone. The burden of the disease is nearly 20 percent of the world’s current population and with this prevalence 70 million persons are affected in India (22). OA knee joint assumes a special importance because it is a weight bearing joint and has excessive translatory motion during the activities of daily living. The progression of knee OA is mediated by aberrant biomechanics (5, 17, 20) and can be assessed by using gait analyses by a validated markers of dynamic knee loading such as the peak adduction moment and adduction angular impulse and tibio-femoral rotation (7, 8). Hence, the assessment of load in the knee joint by dynamic methods is reliable.

In recent years, several studies (4, 6, 10, 11) attempted to measure the plantar pressure of normal and abnormal foot during standing and walking by using pedo-barograph. Varieties of instruments were used for measurement of plantar pressure include force-sensing resistors, hydro cells, pedoscope, capacitances, transducers as well as critical light reflectors (2, 3, 9, 14). The selection of viable existing systems for measuring pressure has resulted in producing different results, leading to incorrect interpretation of clinical observations. Hence gait analysis studies implicate dynamic component.

In current practice, the use of gait analysis has been limited due to the fact that accessible gait analysis systems are costly, invasive and require well-controlled laboratory environments with force plate and optoelectronic marker system (21).

Recently the quantitative speed-related changes in muscle function are measured from the muscles around knee joints in sports performance following injury or surgery using EMG signals. The generated muscle activated simulations; can directly compute a muscle’s contribution to joint and center of mass (COM) motion (10, 16). Younger et al (23) used surface muscle pressure (SMP) to estimate muscle force of quadriceps muscles of healthy subjects to study extensor muscle stiffness during gait.

Even though surface electromyography can accurately register electrical activity of muscles during gait, but can not estimate the muscle force. Hence, there is a need to assess the muscle force. To achieve this we have devised a non invasive cost effective, strain gauge sensor instrument to estimate mechanical activity of knee muscles. In addition the usefulness of knee brace was also examined.

Hence, the objective of the study was to assess muscle activity (weight shift) pattern around knee especially VM-MH pair and VL-LH pair in unbraced and braced knee situations in both conventional and SNPT treatment mode of pre-elderly and elderly subjects.

**Methods**

The individuals with radiographically confirmed knee osteoarthritis with Kellagren-Lawrence scale between 41 to 80 years age visiting university hospital
outpatient services of Banaras Hindu University from June 2011 up to May 2014 were considered for the study. Ethical approval was taken from Institute Ethical Committee before starting the data collection. Informed consent was obtained and the subjects were familiarized with the study procedure.

Subjects with sports injury/traumatic knee, inflammatory arthritis, metabolic disorders; specific vestibular, proprioceptive and visual impairment were excluded.

62 Male subjects were allocated in two different study groups i.e. Conventional (n=31) and Structured Neuromuscular postural training (SNPT) (n=26) groups without age differentiation according to treatment modes. The subjects were further sub grouped pre elderly (40-60 Years) and elderly (>61 years) age wise in both study groups as pre-elderly conventional (Gr. 1, n=19), elderly conventional (Gr. 2, n=12), pre elderly SNPT (Gr. 3, n=14) and elderly SNPT (Gr. 4, n=12) for analysis purpose. However, 5 subjects in SNPT group did not complete 6 weeks follow-up in time hence were excluded from the analysis. Thus, study is presented for 57 subjects only.

After checking inclusion/exclusion criteria and obtaining written consent, subjects were examined at entry level. They were evaluated quantitatively using strain gauge sensor for the muscle activation patterns and joint loading of vastus medialis, medial hamstrings, vastus lateralis, lateral hamstrings, gastro-soleus and tibialis anterior muscles. The subjects were asked to walk on a level surface with and without offloader valgus knee brace to investigate the influence of orthosis on the knee alignment. The muscle variables were measured again with brace.

The subjects in either groups (conventional / SNPT) were given one week training of 30 minutes duration in OPD and were advised to carry on at home for same duration.

Conventional treatment includes rest, knee immobilization, quadriceps strengthening, hamstring stretching, isometric and isotonic exercises, massage, and mobilization.

Structured Neuromuscular Postural Training (SNPT) approach emphasized strengthening vastus medialis, stretching hamstring muscles and knee distraction, Frankel’s exercise, Timed Up and Go test (3 metre walk) along with proprioceptive and postural training on Gym ball, balance board and trampoline.

After one week of intervention, the patient were advised to carry on their own as per instructions at home for 5 weeks, twice daily for half an hour.

At the end of the 6 weeks therapy subjects were again evaluated without and with brace. The difference between the values with brace to without brace at initial and 6 weeks follow up provided the effect of brace and treatment.

Instrumentation and tools used

Steel alloy polycentric offloader knee brace designed by us. It has a modular structure to change the alignment based on the patients’ need. It has higher functional range of motion effect due to its polycentric lock compared to generally used monocentric locks. It reduces pressure at knee joint and can be corrected to $10^\circ$ valgus as per the need (Fig. 1). The offloader knee brace can modify axial loading and can be adjusted by the subject to accommodate varus strain.

Data collection procedure

We assessed muscular loading using designed strain guage sensor instrument; with and without offloader valgus knee brace of specific muscles viz. vastus medialis (VM), vastus lateralis (VL), semi membranosus / tendinosus (Medial Hamstrings-MH), Bicep Femoris / Lateral Hamstrings (LH), gastro-soleus (GS) and tibialis anterior(TA) muscles in a three minutes level walk.

Linear strain gauge: 6 mm (1-LAA11K6/350_E) made up of steel alloy was used in the study. The effect of to temperature is manifested as shift in the baseline only, which is compensated according. So, the temperature compensation was not required in the present setup.
The pressure changes of strain gauges in volts are captured by the differential amplifiers, which is then given to Analog to Digital Converter (ADC) of the PIC 18F4550 microcontroller and is finally transferred to the system. The digital values from ADCs are received by MATLAB where final signal processing is done. These values are recorded further and analyzed.

Data decoding and Statistical analysis

MATLAB (ver. 6.1, Math Works Inc.) was used to process data. Data was organized in Excel sheet (2002, Microsoft Corp.), and the statistical analysis was performed using SPSS (ver. 16.0, SPSS Inc.) (Fig. 2)

Muscular load / joint load could be obtained in Newton-meter in muscles GS, LH, MH multiplying digital values with 0.48; VL, VM with 0.622 and TA with 0.5 as correlating values in applied MATLAB.

MATLAB software has been used for the following purposes:

1. Data acquisition.
2. Data processing: The data has been processed to obtain the following statistical parameter:
   (a) Mean (b) standard deviation variance (c) minimum and maximum value of data and range of data. (d) graphical representation of data.
3. Finally based on the statistical value of data analysis and classification is done for quantification of muscular loading in osteoarthritis knee subjects using look up table method.

Six strain gauges were used to pick up the muscular activity at loading (Dynamic Response) of GS, LH, MH, VL, VM, and TA muscles. Muscle activity pattern of lateral compartment (VL-LH pair) / medial compartment (VM-MH) muscles were assessed after conventional therapy / SNPT therapy without brace and with brace in both pre-elderly and elderly group.

Students “t” test (paired or unpaired) was done to examine the efficacy of off - loader valgus knee brace between mean values of muscular loading between without and with bracing in osteoarthritis knee pre elderly and elderly subjects among both conventional and SNPT treatment groups. A significance level of < 0.05 was considered for this analysis.

Results

Demographic characteristics of subjects recruited:

Pre-elderly male conventional Subjects (n=19) – Age, 49.79±5.73 yrs; height, 170.42±5.32 cm; weight, 71.11±8.84 kg and BMI, 24.61±2.02 while of SNPT group (n=14) – Age, 52.57±5.23 yrs; height, 171.57±4.80 cm; weight, 76.21±8.61 kg and BMI, 26.04±2.61. Thus, the groups are comparable.

Elderly male conventional Subjects (n=12) – Age, 67.50±4.58 yrs; height, 169.92±5.05 cm; weight, 71.67±4.81 kg and BMI, 24.96±2.02 while of SNPT group (n=12) – Age, 67.92±5.07 yrs; height, 166.50±6.33 cm; weight, 70.17±7.08 kg and BMI, 25.68±3.32. Thus, the groups are comparable.

BMI of the subjects and treatment (conventional and SNPT) category correlation was not significant (Chi square test \(c^2_1=0.141; \ p=0.041\) for pre elderly and \(c^2_1=0.671; \ p=0.413\) for elderly group).

Muscle activation pattern in lateral compartment of the knee

Pre elderly group

The pre-elderly conventional group muscles LH, VL and GS at 6 weeks have shown increase when braced 1.76±0.25, 0.07±0.03, and 2.38±0.58 volts respectively. While pre-elderly SNPT group muscles LH, VL and GS have shown increase when braced 1.73±0.25, 0.06±0.03, and 2.10±0.27 respectively. The increase was found to be statistically significant (p<0.001) in pre-elderly (Table I).
Muscle activation pattern in lateral compartment of the knee

Elderly group

In elderly conventional group LH, VL and GS have shown increase in volts when braced by 3.55±0.35, 0.11±0.02, and 3.51±0.56 respectively. While, elderly SNPT group, LH, VL and GS have shown increase when braced by 2.21±0.30, 0.07±0.02, and 3.32±0.47 respectively. The increase was statistically significant (p<0.001) in elderly group (Table I).

Muscle activation pattern in medial compartment of the knee

Elderly group

In the elderly conventional group MH, VM and TA when braced have shown decrease by 1.91±0.30, 1.15±0.19 and 0.05±0.02 volts respectively. While, elderly SNPT group MH, VM and TA when braced have shown decrease when braced by 2.40±0.32, 1.25±0.41 and 0.04±0.02 respectively. The decrease was statistically significant (p<0.001) in elderly (Table II).

Thus, the trend with application of brace shows that there was increment in Gastrocnemius, Lateral hamstring and Vastus lateralis values and decrement in Medial hamstring, Vastus Medialis and Tibialis Anterior muscles for both elderly as well as pre-elderly subjects at baseline and 6 weeks follow up.

<table>
<thead>
<tr>
<th>Muscle Variables</th>
<th>Group</th>
<th>Mean±SD (Δ Initial)</th>
<th>Mean±SD (Δ follow up)</th>
<th>Δ change from Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastro-Soleus (GS)</td>
<td>Conven</td>
<td>2.03±1.43</td>
<td>2.38±0.58</td>
<td>0.35±1.47</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>2.07±1.71</td>
<td>2.11±0.27</td>
<td>0.03±1.55</td>
</tr>
<tr>
<td>t (p)</td>
<td></td>
<td>0.07 (0.94)</td>
<td>1.64 (0.11)</td>
<td>0.59 (0.60)</td>
</tr>
<tr>
<td>Lateral Hamstring (LH)</td>
<td>Conven</td>
<td>2.06±0.79</td>
<td>1.76±0.25</td>
<td>0.30±0.84</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>2.09±0.67</td>
<td>1.73±0.26</td>
<td>0.36±0.71</td>
</tr>
<tr>
<td>t (p)</td>
<td></td>
<td>0.13 (0.90)</td>
<td>0.28 (0.80)</td>
<td>0.22 (0.83)</td>
</tr>
<tr>
<td>Medial Hamstring (MH)</td>
<td>Conven</td>
<td>2.12±1.21</td>
<td>1.12±0.23</td>
<td>0.99±1.20</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>2.34±0.58</td>
<td>1.90±0.28</td>
<td>0.43±0.76</td>
</tr>
<tr>
<td>t(p)</td>
<td></td>
<td>0.61 (0.54)</td>
<td>8.63, (&lt;0.001)</td>
<td>1.54 (0.13)</td>
</tr>
<tr>
<td>Vastus Lateralis (VL)</td>
<td>Conven</td>
<td>0.05±0.02</td>
<td>0.07±0.03</td>
<td>0.02±0.04</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>0.06±0.09</td>
<td>0.06±0.03</td>
<td>0.00±0.08</td>
</tr>
<tr>
<td>t(p)</td>
<td></td>
<td>0.52(0.61)</td>
<td>0.81(0.42)</td>
<td>0.94(0.36)</td>
</tr>
<tr>
<td>Vastus Medialis (VM)</td>
<td>Conven</td>
<td>0.53±0.44</td>
<td>0.77±0.26</td>
<td>0.24±0.53</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>0.51±0.63</td>
<td>0.67±0.32</td>
<td>0.16±0.82</td>
</tr>
<tr>
<td>t(p)</td>
<td></td>
<td>0.10 (0.92)</td>
<td>1.00 (0.32)</td>
<td>0.35 (0.73)</td>
</tr>
<tr>
<td>Tibialis Anterior (TA)</td>
<td>Conven</td>
<td>0.04±0.01</td>
<td>0.05±0.02</td>
<td>0.01±0.02</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>0.03±0.04</td>
<td>0.05±0.01</td>
<td>0.02±0.05</td>
</tr>
<tr>
<td>t(p)</td>
<td></td>
<td>1.17 (0.25)</td>
<td>0.29 (0.77)</td>
<td>0.77 (0.45)</td>
</tr>
</tbody>
</table>
Intergroup comparison:

A. Age wise comparison:

The intergroup comparison of treatment groups for muscle variables without brace to brace among pre-elderly and elderly groups shows no statistical significance at baseline indicating the groups are equal in nature and comparable.

While at 6 weeks follow up, statistical significant difference was found for only Medial Hamstring muscle (t=8.63, p<0.001) in pre-elderly groups (Table I) and for Lateral Hamstring, Medial Hamstring and Vastus Lateralis muscles (t=10.08, p<0.001; t=3.80, p=0.001 and t=5.16, p<0.001) in elderly groups (Table II) respectively. This shows that in pre-elderly and elderly group there was decreased significant change in medial hamstring muscle; and increased significant changes were found in lateral hamstring and Vastus lateralis muscles in elderly subjects.

The unbraced loading shows significant difference from baseline to 6 weeks follow up among both the age related pre-elderly and elderly study groups in Medial Hamstring and Vastus Lateralis. In pre-elderly group the significance was (t=2.695, p=0.011; t=2.998, p=0.005) for MH and VL muscles respectively. Similarly for elderly groups, same muscles had the significance (t=2.733, p=0.012; t=2.537, p=0.019). The significant decrease in the MH muscle and increase for VL muscles shows the impact of treatment in both pre-elderly & elderly groups when assessed without brace. Thus the muscle activity changes in MH and VL muscles, both in pre elderly and elderly age group subjects.

B. Without age comparison:

The mean comparison of treatment group without age differentiation for conventional (Gr. 1+2, n=31) and SNPT (Gr. 3+4, n=26) treatment groups narrates that no statistical significance was observed between conventional and SNPT groups for all the muscle variables except MH muscle which was statistically significant when braced (t=2.02, p=0.049) at baseline (Table – III).

The mean difference of different muscle variables at 6 weekly follow up of conventional and SNPT treatment group without age differentiation narrate that there was statistical significance between conventional and SNPT groups for LH, MH and VL muscles at 6 weeks follow up with brace, no brace and difference of brace

### TABLE II: Muscle activation patterns in elderly conventional group (Gr.2) and SNPT group (Gr. 4) at initial and 6 weeks follow up.

<table>
<thead>
<tr>
<th>Muscle Variables</th>
<th>Group</th>
<th>Mean±SD (Δ Initial)</th>
<th>Mean±SD (Δ follow up)</th>
<th>Δ change from Initial</th>
<th>t (p)</th>
<th>t (p)</th>
<th>t (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastro-Soleus (GS)</td>
<td>Conven</td>
<td>3.40±0.72</td>
<td>3.51±0.56</td>
<td>0.11±1.06</td>
<td>1.05 (0.31)</td>
<td>0.68 (0.50)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>2.74±2.09</td>
<td>3.32±0.47</td>
<td>0.58±2.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral Hamstring (LH)</td>
<td>Conven</td>
<td>3.24±1.21</td>
<td>3.55±0.35</td>
<td>0.31±1.17</td>
<td>2.91±1.49</td>
<td>2.21±0.30</td>
<td>0.70±1.30</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>2.10±1.54</td>
<td>3.55±0.35</td>
<td>0.31±1.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial Hamstring (MH)</td>
<td>Conven</td>
<td>3.74±1.32</td>
<td>1.91±0.30</td>
<td>1.82±1.44</td>
<td>2.66±1.60</td>
<td>2.40±0.32</td>
<td>0.25±1.65</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>0.60±0.55</td>
<td>10.08 (&lt;0.001)</td>
<td>2.01 (0.06)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vastus Lateralis (VL)</td>
<td>Conven</td>
<td>0.09±0.04</td>
<td>0.11±0.02</td>
<td>0.02±0.03</td>
<td>0.09±0.02</td>
<td>0.07±0.02</td>
<td>0.02±0.02</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>0.09±0.02</td>
<td>0.07±0.02</td>
<td>0.02±0.02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vastus Medialis (VM)</td>
<td>Conven</td>
<td>0.72±0.46</td>
<td>1.15±0.19</td>
<td>0.43±0.53</td>
<td>1.09±0.50</td>
<td>1.25±0.41</td>
<td>0.15±0.77</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>0.13±0.90</td>
<td>5.16 (&lt;0.001)</td>
<td>3.56 (0.002)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibialis Anterior (TA)</td>
<td>Conven</td>
<td>0.04±0.02</td>
<td>0.05±0.02</td>
<td>0.01±0.03</td>
<td>0.04±0.02</td>
<td>0.04±0.02</td>
<td>0.00±0.03</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>0.04±0.02</td>
<td>0.04±0.02</td>
<td>0.00±0.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibialis Anterior (TA)</td>
<td>Conven</td>
<td>0.32±0.75</td>
<td>1.11 (0.28)</td>
<td>0.55 (0.59)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>0.32±0.75</td>
<td>1.11 (0.28)</td>
<td>0.55 (0.59)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
to no brace respectively. Rest other muscles GS, VM and TA were not significant.

LH muscle shows statistical significance (t=4.30, p<0.001; 4.94, p<0.001; 2.57, p=0.013) at 6 weeks follow up with brace, no brace and difference of brace to no brace respectively. Similarly MH muscle shows statistical significance (t=6.78, p<0.001; 7.09, p<0.001; 6.09, p<0.001) at 6 weeks follow up with brace, no brace and difference of brace to no brace respectively. Further VL muscle shows statistical significance (t=3.39, p<0.001; 3.39, p<0.001; 2.55, p=0.014) at 6 weeks follow up with brace, no brace and difference of brace to no brace respectively (Table IV).

### Impact of Brace

The impact of treatment was assessed comparing without brace values of baseline and 6 weeks follow up. SNPT treatment approach at 6 weeks follow ups was significantly higher in Medial hamstring muscles in pre-elderly while for Medial hamstring and Vastus Medialis muscles in elderly. However, conservative treatment showed significantly better results in Gastrocnemius, Vastus lateralis and lateral hamstring

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Baseline</th>
<th>6 weeks follow ups</th>
<th>t test / p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS</td>
<td>Conventional Gr</td>
<td>Mean±SD (brace)</td>
<td>Mean±SD (no brace)</td>
<td>Δ change (Brace-no brace)</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>11.36±4.04</td>
<td>8.80±3.04</td>
<td>2.56±1.37</td>
</tr>
<tr>
<td>LH</td>
<td>Conventional Gr</td>
<td>Mean±SD (brace)</td>
<td>Mean±SD (no brace)</td>
<td>Δ change (Brace-no brace)</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>11.94±4.20</td>
<td>9.42±3.23</td>
<td>2.52±1.12</td>
</tr>
<tr>
<td>MH</td>
<td>Conventional Gr</td>
<td>Mean±SD (brace)</td>
<td>Mean±SD (no brace)</td>
<td>Δ change (Brace-no brace)</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>10.58±3.79</td>
<td>8.10±2.92</td>
<td>2.47±1.17</td>
</tr>
<tr>
<td>VL</td>
<td>Conventional Gr</td>
<td>Mean±SD (brace)</td>
<td>Mean±SD (no brace)</td>
<td>Δ change (Brace-no brace)</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>0.58±0.26</td>
<td>0.52±0.23</td>
<td>0.06±0.04</td>
</tr>
<tr>
<td>VM</td>
<td>Conventional Gr</td>
<td>Mean±SD (brace)</td>
<td>Mean±SD (no brace)</td>
<td>Δ change (Brace-no brace)</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>4.46±2.43</td>
<td>5.06±2.80</td>
<td>0.06±0.45</td>
</tr>
<tr>
<td>TA</td>
<td>Conventional Gr</td>
<td>Mean±SD (brace)</td>
<td>Mean±SD (no brace)</td>
<td>Δ change (Brace-no brace)</td>
</tr>
<tr>
<td></td>
<td>SNPT Gr</td>
<td>1.44±0.38</td>
<td>1.48±0.39</td>
<td>0.04±0.02</td>
</tr>
</tbody>
</table>

TABLE IV: Muscle activation pattern of different treatment groups at 6 weeks follow-up in all age group combined. An asterisk (*) indicates P<0.05 compared to Conventional group.
Fig. 1: A custom designed polycentric offloader valgus knee brace showing the lateral and posterior view.

Fig. 2: The schematic of indigenous Instrumentation system used for recording the muscle activity. GS, Gastro-Soleus; LH Lateral hamstring; MH Medial hamstring; VL Vastus lateralis; VM Vastus Medialis and TA Tibialis anterior.
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muscles in both age groups. No treatment group was found superior, as SNPT was better for medial compartment muscles and conventional for lateral compartment of knee joint.

Discussion

Clinical significance with application of brace in our study showed that there was increment in Gastrocnemius, Lateral hamstring and Vastus lateralis force while decrement in Medial hamstring, Vastus Medialis and Tibialis Anterior muscles.

Further, the muscle co-contraction has been higher for VM-MH pair compared to VL-LH pair without brace at baseline. Study indicates that vastus medialis-medial hamstring co-contraction were lesser in magnitude than those of vastus lateralis-lateral hamstring pair at 6 weeks follow ups with the application of offloader brace. This expresses an effort to re-distribute loading on the medial compartment of the knee and profound more stability and strength.

This shows an effort to shift the joint load more on lateral side, reducing joint pressure medially in osteoarthritis knee patients. Improvement in the medio-lateral force and the knee joint alignment decreased following use of the knee orthosis is important finding of this study. Weight shift pattern is consistent to the study of McQuade & De Oliveira who found higher muscle activation pattern, co-contraction of quadriceps and hamstring in OA knee subjects than the control group. (11) Our study results do support the concept of Harrington (5) that there is a “direct relationship between angulation, magnitude of load, and the location of load within the knee (13).

The concept of unloading the affected compartment by bracing aims to correct the mechanical axis deviation. The valgus unloader brace reduces the load on the medial compartment applies a corrective torque and relieve pain by the application of an opposing outside valgus moment in relation to the knee (1, 13, 18). This finding may explain the pain relief reported by patients using such braces in clinical studies.

In our study at the end of 6 weeks conventional / SNPT (structured neuromuscular postural training) treatments, muscle activity increased in medial hamstring in both pre-elderly and elderly subjects. While, Vastus laterals and lateral hamstring showed increased activities in elderly subjects. The results of Lyytinen et al, 2010 (12) are in agreement with our study where subjects with knee OA exhibit increased muscle activity in VM muscle compared to control subjects when assessed with surface electromyography (EMG). Treatment protocol on balance parameter in SNPT (structured neuromuscular postural training) is recommended by Robitaille and colleagues (15) who state that structured, group-based exercise programs in natural settings can increase balancing ability among community-dwelling older adults prone to fall (19).

Both intervention groups exhibited improvement in self-reported function and comprehensive rating of muscular changes. However SNPT and conventional treatment groups showed improvements in different parameters of balance and muscle activation.

Conclusion

Our study with off loader brace may be helpful to investigate the interaction and compensation of the knee joint during aging process and age related compensation. The results of this study, suggest that polycentric offloader knee brace redistribute the load laterally thus provide unloading of knee in frontal plane and may increase the dynamic balance in context to demand in osteoarthritis knee. The subjects without it might be at risk of injury and fall due to the balance deficit.

Concluding, non invasive and cost effective sensor in the study was able to assess quantitatively the muscle activation patterns in clinical setting. It was supportive to assess joint loading pattern and kinematic changes in Osteoarthritis subjects. Simultaneously, use of brace has shown decrement on medial compartment and increment on lateral
compartment of knee and its significance in altering joint kinematics, thereby improvising management.

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References