TO EVALUATE THE FOOT CENTER OF PRESSURE AND GAIT PARAMETERS IN PATIENTS WITH GRADE II KNEE OSTEOARTHRITIS USING A PRESSURE MEASURING SYSTEM

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Abstract

Background- Osteoarthritis is a degenerative disorder of joints that involves cartilage destruction, subchondral bone thickening, and new bone formation at the joint surface. The centre of foot pressure is the point of origin of ground reaction force (GRF) which is probably the most important force during locomotor activities. Pressure plate analysis is a test done to measure the forces going through one's feet as they go about their activities like walking, running, lifting loads, and so on. This is used for analysis of gait parameters in patients with OA.

Objectives- To quantify, compare, and correlate the foot COP deviation, pain, clinical scores, disability, and radiographic analysis in normal and grade II Osteoarthritis patients.

Methodology- A total of 45 patients including both male and female were selected out of which 30 were grade II knee OA and 15 were normal subjects (Grade 0). Each patient was assessed for disability using WOMAC, pain using NPRS, walking ability using clinical scores, and gait parameters using a pressure plate.

Results- Data was analyzed using SPSS software. There was a significant relationship between stance time, clinical scores, WOMAC, NPRS and there was a significant correlation between the gait parameters obtained by our method and the clinical evaluation results.

Conclusion- The study concluded that there was a deviation in center of pressure and gait parameters among subjects with grade 2 OA knee.

Keywords- Foot COP, Gait parameters, Grade II knee OA, Pressure measuring system.

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BACKGROUND

Osteoarthritis is a degenerative disorder of joints that involves cartilage destruction, subchondral bone thickening, and the new bone formation(osteophytes) at the joint surface [1]. Osteoarthritis is a very diverse condition with its prevalence, risk factors, clinical manifestations, and prognosis differing according to the joints affected. It commonly affects the knees, hips, hands, and spinal apophyseal joints [2]. In most cases the cause for osteoarthritis is unknown or it may be due to the natural process of aging, obesity, overuse, or heavy physical occupational work which leads to the wearing and tearing of the joint and this is referred to as primary osteoarthritis. Primary OA can represent as generalized, localized or erosive OA [3]. Whereas secondary OA can occur due to several factors such as trauma, or infection [4].

More than 90% of the increasing number of total hip or knee joint replacement operations are being undertaken worldwide due to the precipitating diagnosis of osteoarthritis. OA is more common in women than men, but the prevalence increases dramatically with age. Nearly, 45% of women over the age of 65 years have symptoms while radiological evidence is found in 70% of those over 65 years. OA of the knee is a major cause of mobility impairment, particularly among females. OA was estimated to be the 10th leading cause of nonfatal burden. [5]

Early osteoarthritis can result due to collagen degradation and mechanical disorganization. During joint loading, the reduced lubrication in the joint between the cartilage surfaces will put an effect on the cartilage and change the collagen orientation and organization. It is also possible that due to the wearing and tearing of the articular cartilage surface the tissue thickness gets reduced which also contributes to early OA. [6,7]

Although while walking multiple joints are involved but the most commonly affected joint with OA is the knee joint. [8]. The medial compartment of the tibiofemoral joint is affected more than the lateral compartment. During the weight bearing the loads transferred through the medial compartment are 2.5 times more than the lateral compartment due to the line of force passing medially to the knee while walking. This asymmetry explains a markedly higher prevalence of medial compartment involvement reported in subjects with tibiofemoral OA relative to the lateral compartment. During the load bearing in a developed case of knee OA, the anatomical axis is either shifted medially or laterally further causing a biomechanical stress on the joint ultimately leading to joint disorientation and cartilage destruction. [9,10,11] Individuals with knee osteoarthritis suffer progressive loss of function displaying increasing dependency on walking, stair climbing, and other lower limb activities. [12]

One way to assess the loading pattern over the entire gait cycle is by using a Center of Pressure trace. This is a calculated measurement based on the foot ground contact area and magnitude of pressure for each pressure sample taken during the gait cycle. [13]

The **center of foot pressure** is the point of origin of ground reaction force. The ground reaction force (GRF) is one of the most important forces acting during locomotor activities such as walking, skipping, hopping, jumping, and running. The center of the foot on supporting surface moves along a path during gait and produces a characteristic pattern. In barefoot walking, COP starts at posterolateral edge of the heel at the beginning of stance phase and moves linearly through midfoot area, remaining lateral to midline and then moves medially across the ball of foot with concentration along metatarsal break. The COP then moves second and then first toes of foot during terminal stance of gait cycle.[14]

The best predictors of knee pain were the presence of osteophytes and the Kellgren and Lawrence grading system. [14] The **Kellgren and Lawrence scale** is traditionally and the most commonly used method to assess the severity of knee OA radiographically. [15] The Kellgren and Lawrence classification helps medical professionals make better clinical decisions by identifying which patients would most benefit from surgical treatment. Each radiograph was given a rating between 0 and 4, with higher grades indicating more severe OA.

- Grade 0: No joint space narrowing or reactive changes
- Grade 1: Doubtful joint space narrowing (JSN) and possible osteophytes lipping
- Grade 2: Definite osteophytes and possible JSN
- Grade 3: Moderate osteophytes, definite JSN, some sclerosis, possible bone-end deformity
- Grade 4: Large osteophytes, marked JSN, severe sclerosis and definite bone end deformity [13,14,15]

Need of the study- As a method for evaluation of the severity of osteoarthritis, clinical evaluation is important for the quantification of subjective symptoms, and radiography is necessary for the evaluation of deformity. However, these methods are insufficient for the objective evaluation of improvement in clinical symptoms in dynamic situations such as walking ability. So, in the present study using a pressure measuring system, we are quantifying the gait parameters in patients with knee joint osteoarthritis. [16] These findings widen the understanding of lower limb biomechanics in knee OA and can further provide a firm base in the field of device design and research practices. [10]

OBJECTIVES OF STUDY

1. To quantify gait parameters in grade II knee osteoarthritis.

a) To quantify the foot COP deviation and to correlate pain, clinical scores, disability, and radiographic analysis in normal subjects

b) To quantify the foot COP deviation and to correlate pain, clinical scores, disability, and radiographic analysis in grade II Osteoarthritis patients.

2. To compare the foot COP deviation and clinical scores in normal vs grade II OA patients.
3. To correlate radiographic analysis of grade II osteoarthritis with gait analysis, clinical scores, pain, and disability.

METHODOLOGY

STUDY DESIGN- Non-experimental, descriptive in nature.

SETTING- The study was performed in OPD of DAV Institute of Physiotherapy and Rehabilitation, Jalandhar.

DURATION OF STUDY-Total duration of the study was six months **SAMPLE SIZE-** A total of 45 patients included of which 30 were grade II knee OA and 15 were normal subjects (Grade 0).

SAMPLING TECHNIQUE-Purposive Sampling

SAMPLING CRITERIA- ➢ **Inclusion criteria**

- Subjects - 40-70 years of age.
- Gender – Both male and female.
- Individuals having knee pain.
- Patients who have undergone radiological examination in anteriorposterior and lateral views and meet the K&L criteria of grade II OA.
- Patients should be cooperative and mentally fit.

➢ **Exclusion criteria**

- Subjects with a recent history of lower limb trauma or surgery.
- Subjects with congenital foot deformities.
- Subjects who received intra-articular steroid injections and hyaluronans in the preceding 6 months.
- Subjects who are unable to ambulate without assistance.
- Subjects with any prior arthroplasty or arthroscopy in either knee.
- Subjects with a history of any unstable medical conditions.
- Subjects with a history of orthopedic problems such as rheumatoid arthritis, and soft tissue injuries such as tendinitis, bursitis, and apophysitis.
- Subjects with a history of any neurological disease such as stroke, ataxia, parkinsonism, or tabes dorsalis.

VARIABLES

➢ **DEPENDENT VARIABLES:**

- Pressure Plate for Gait parameters.
- Walking Ability using Clinical scores
- Disability using WOMAC (Western Ontario and McMaster Universities)
- Pain using NPRS (Numeric pain rating scale).

➢ **INDEPENDENT VARIABLES:**

• Grade II Osteoarthritis

PROCEDURE:

Written informed consent was obtained from the subjects at the beginning of the study. The subjects were selected using purposive sampling based on inclusion and exclusion criteria. Further patients were radiographically graded according to Kellgren and Lawrence criteria and divided into two groups: Group A consisting of 15 patients of grade 0, and Group B consisting of 30 patients of grade II knee OA.

Each patient was assessed for disability using WOMAC, pain using NPRS, walking ability using clinical scores, and gait parameters using a pressure plate.

PROCEDURE OF COLLECTING GAIT PARAMETERS:

Barefoot pressure measurement was carried out on the ORTHO-KING PRESSURE PLATE SDP 610. The height, weight, foot size, and age were recorded on the software.

Prior to pressure measurements, subjects were familiarized with the testing procedure and details of the procedure were explained.

Fig-1 Ortho-King Pressure Plate SDP 610

Step I Static bipedal standing feet separated based on their normal style of The subjects were asked to look straight ahead standing and the plantar pressure distribution was while standing barefoot on the platform with both observed.

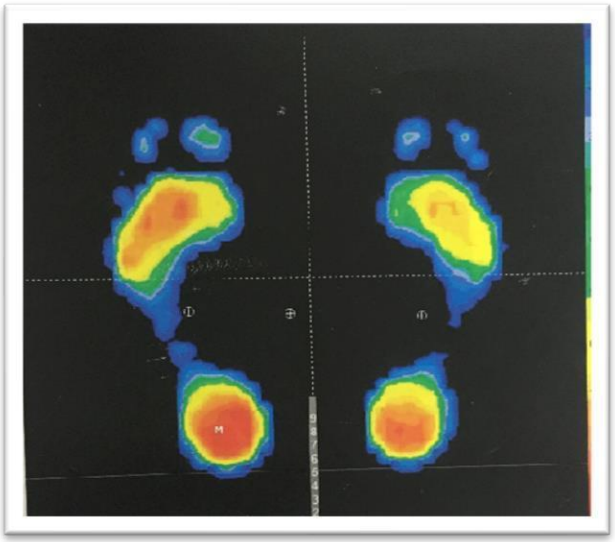


Fig 2-Static Bipedal Stance

Step II Dynamic sampling

The subjects were asked to walk barefoot by keeping the left and right foot alternatively on the pressure plate and the COP trace was recorded while walking.

Here the curve shows the path of the COP

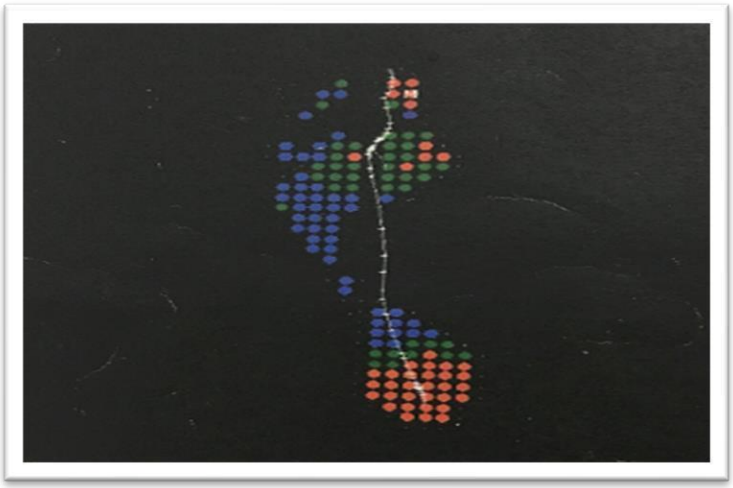


Fig 3.1- Centre of Pressure trace

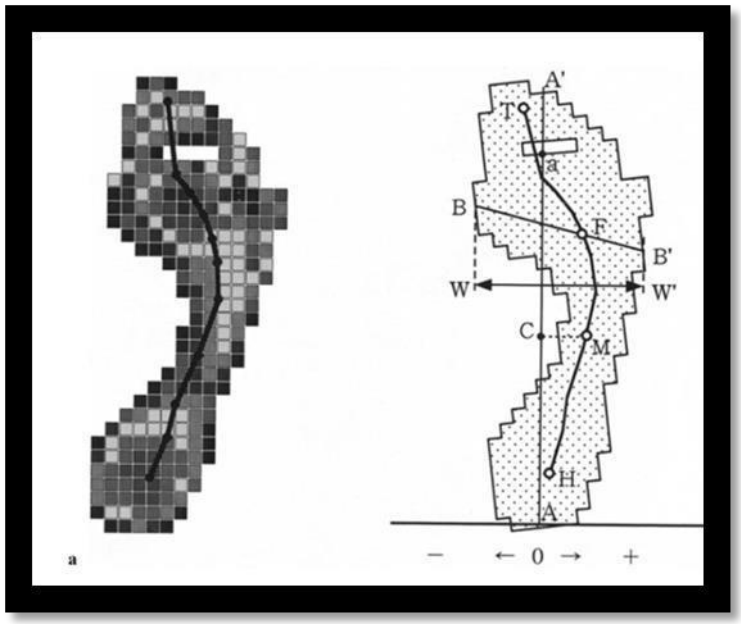
force is divided by stance time.[16]

The measurement method for the location of the COP and gait parameters: The following parameters were calculated:

a) **Stance time:** The duration between heel strike and toe off is calculated as the total stance time.
b) **Percent pre-stance, percent mid-stance, and percent terminal stance phases:** The times of heel strike, foot flat, heel off, and toe off, determined from the sequential instant footprint, and the duration of the pre-stance, percent mid-stance, and percent terminal stance phases are calculated, and the fraction of each to the stance time is determined.
c) **Average vertical force**: The integral of the vertical component of the floor reaction force is divided by stance time.[16]

Location of COP on the footprint: The COP is quantified in the heel, midfoot, forefoot, and toe on the footprint of the combined frame. The location of the COP, expressed as the distance from the axis of the foot that is the line between the mid posterior heel border and the mid tip of the second toe, is corrected by foot width.

Fig 3.2- Centre of Pressure trace of footprint



The curve shows the path of the center of pressure (COP). Measurement method for location of the COP, measured in the heel(H), midfoot(M), forefoot(F), and toe (T), corrected by the foot width (WW'), and quantified as the distance from the axis of the foot (AA'). The COP outside is

expressed as positive, and that inside the axis of the foot is expressed as negative.

Markings in the above figure are labeled as - A, Mid-posterior heel border; A', mid tip of the second toe; a base of the second toe, B, medial edge of the forefoot; B', the lateral edge of the forefoot; C, mid-point between Aa.[17]

Step- III Multiple dynamic acquisition:
Same way the subject is asked to walk three times barefoot by keeping the left and right foot alternatively. This gives us an accurate mean reading of the parameters such as stance time (ms) which includes the phases (pre-stance, mid stance, terminal stance)

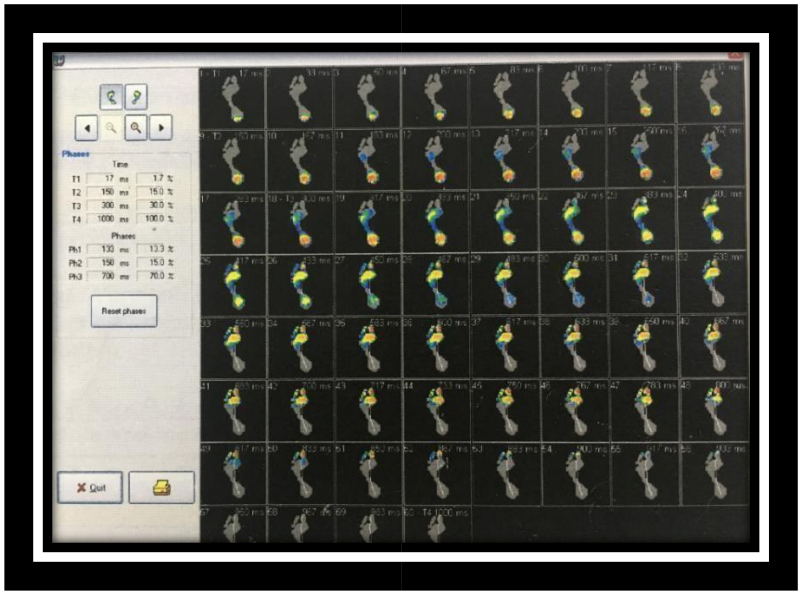


Fig 4:-Multiple dynamic acquisition

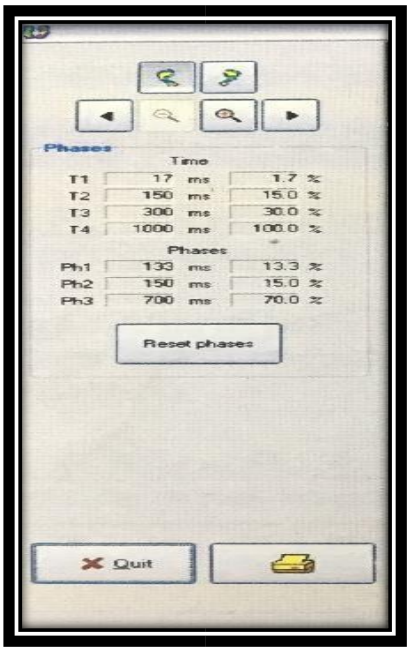


Fig 4.2-Multiple dynamic acquisition results: T4 indicates the total stance time (ms) and the Ph1, Ph2, Ph3 indicates the pre-stance, mid-stance and terminal stance.

RESULT

Data was analyzed using SPSS software. A comparison between two groups was performed to significant difference between the two groups. Statistical tests were used for the analysis of data of osteoarthritis patient and normal subjects. Comparison between the Center of Pressure and gait parameters were done using study the unpaired t-test.

Table No 1: Comparison of Stance time between grade II OA and normal subjects:

Descriptive Statistics and T Test		Mean	SD	N	T Test	df	P Value	Result
STANC E TIME	Grade II Osteoarthrit is Patients	1160.91	267.15	33	2.301	41	0.027	Significant
	Normal Subject	932.00	303.78	10				

Figure No 5:

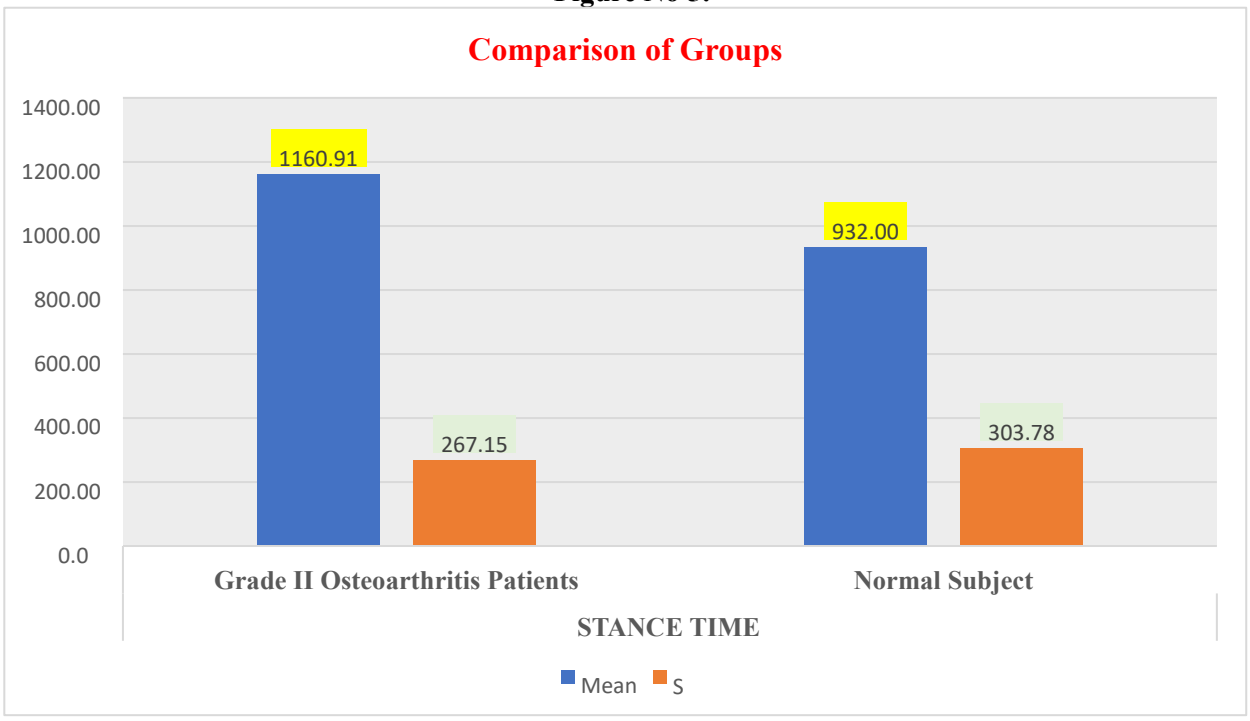


Table No 2: Comparison of % Pre-stance between grade II OA and normal subjects:

Descriptive Statistics and T Test		Mean	SD	N	T Test	df	P Value	Result
% PRESTANCE	Grade II Osteoarthriti s Patients	26.39	7.32	33	0.981	41	0.332	Not Significant
	Normal Subject	29.6 2	13.72	10				

Figure No 6:

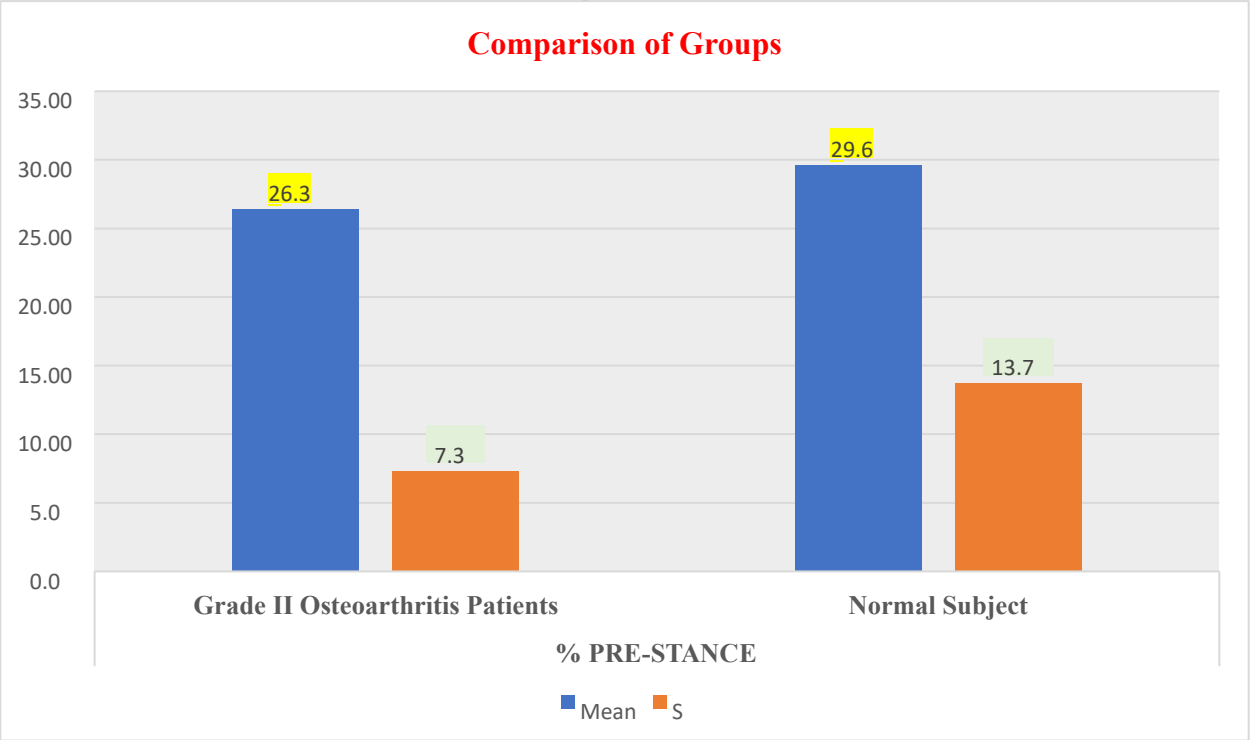


Table No 3: Comparison of % Mid-stance between grade II OA and normal subjects:

Descriptive Statistics and T Test		Mean	SD	N	T Test	df	P Value	Result
% MIDSTANCE	Grade II Osteoarthriti s Patients	47.42	10.30	33	1.169	41	0.249	Not Significant
	Normal Subject	42.32	16.97	10				

Figure No 7:

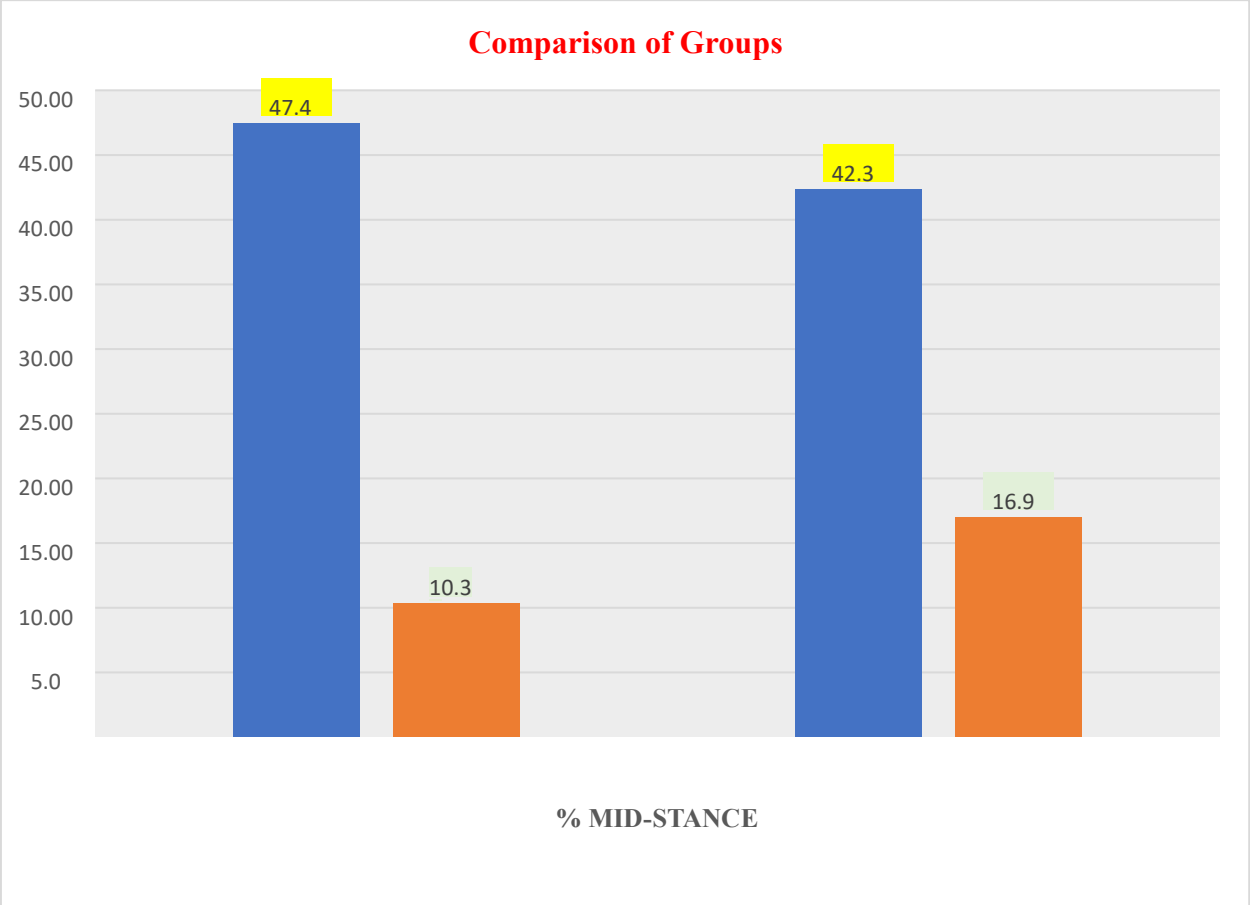


Table No 4: Comparison of % Terminal stance between grade II OA and normal subjects:

Descriptive and T Test	**Statistics**	**Mean**	**SD**	**N**	**T Test**	**df**	**P Value**	**Result**
%TERMIN AL STANCE	Grade II Osteoarthrit is Patients	25.58	9.25	33	1.705	41	0.096	Not Significa nt
	Normal Subject	19.37	12.61	10				

Figure No 8:

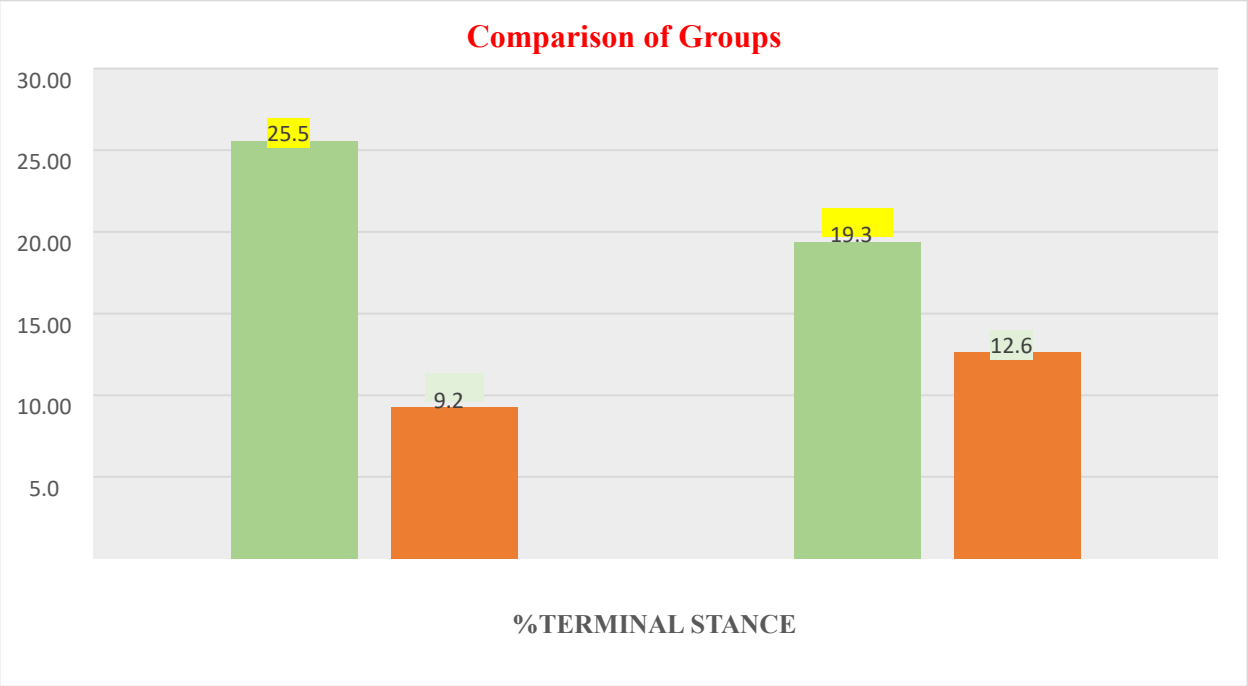


Table No 5: Comparison of average vertical force between grade II OA and normal subjects:

Descriptive Statistics and T Test		Mean	SD	N	T Test	df	P Value	Result
AVF	Grade II Osteoarthritis Patients	72.81	14.75	33	1.364	41	0.180	Not Significant
	Normal Subject	79.54	8.88	10				

Figure No 9:

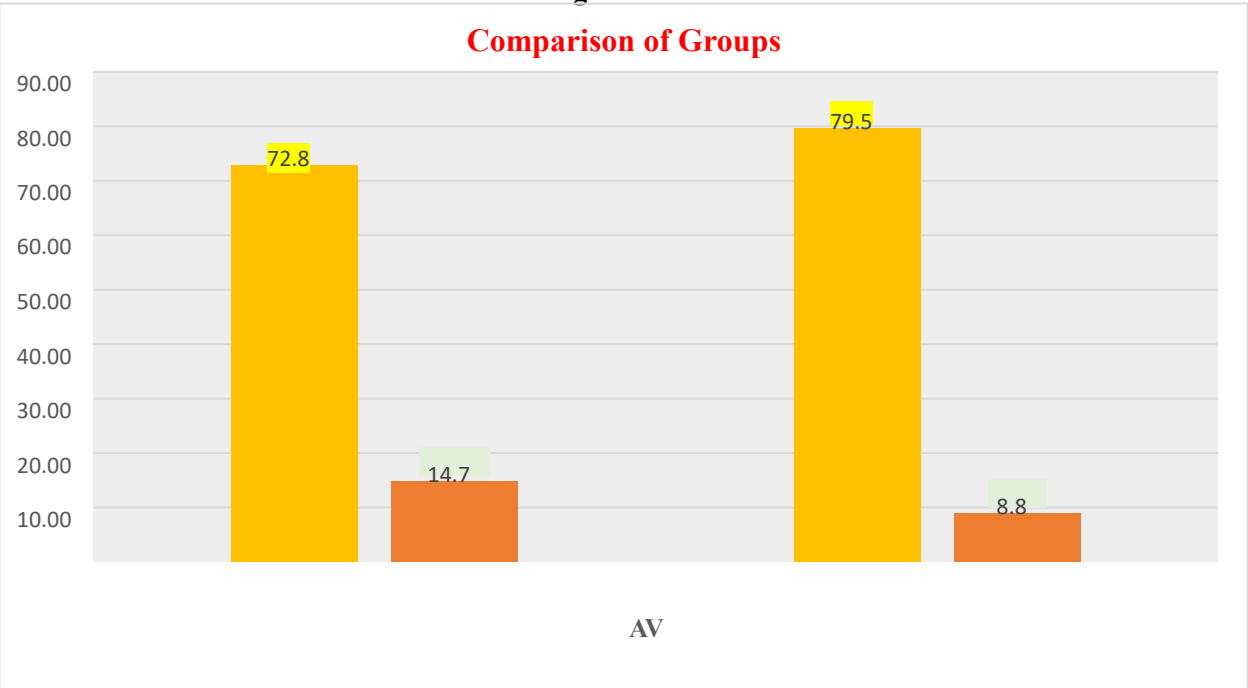


Table No 6: Comparison of heel strike between grade II OA and normal subjects:

Descriptive Statistics and T Test	Mean	SD	N	T Test	df	P Value	Result

HEEL	Grade II Osteoarthritis Patients	-0.02	0.23	33	0.753	41	0.456	Not Significant
	Normal Subject	0.04	0.08	10				

Figure No 10:

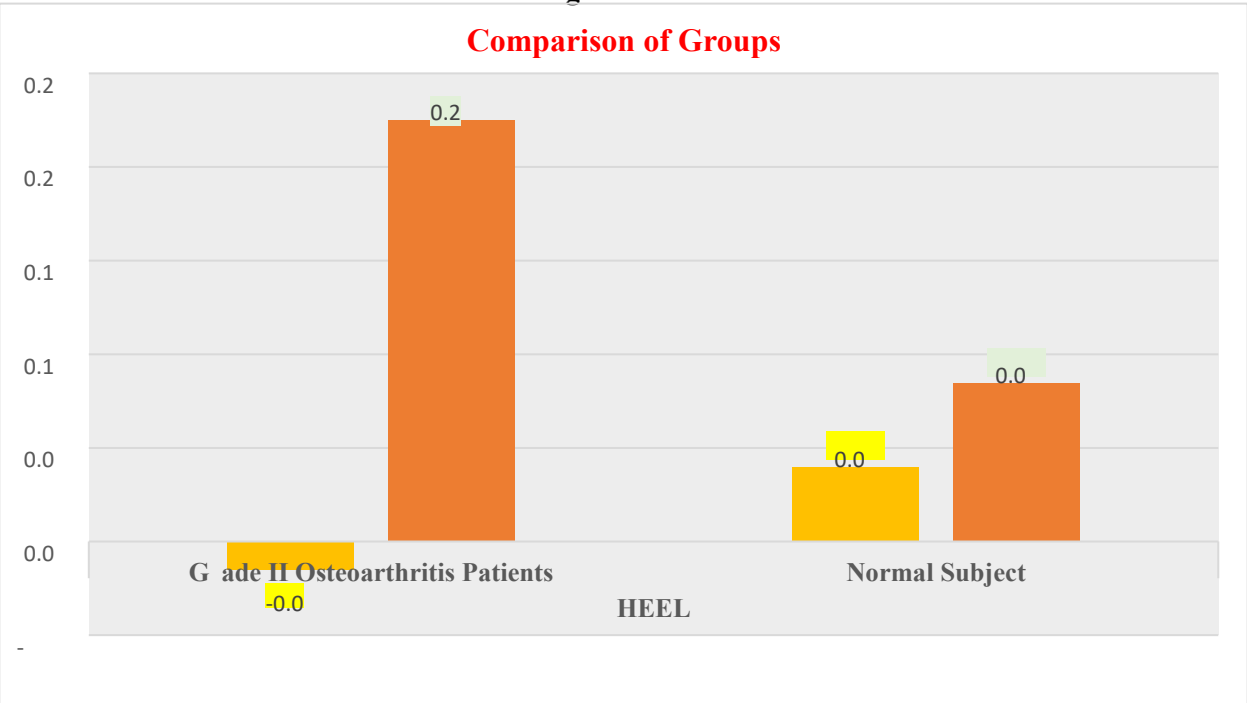


Table No 7: Comparison of mid foot between grade II OA and normal subjects:

Descriptive Statistics and T Test		Mean	SD	N	T Test	df	P Value	Result
MIDFOOT	Grade II Osteoarthriti s Patients	0.44	0.62	33	0.328	41	0.744	Not Significant
	Normal Subject	0.51	0.50	10				

Figure No 11:

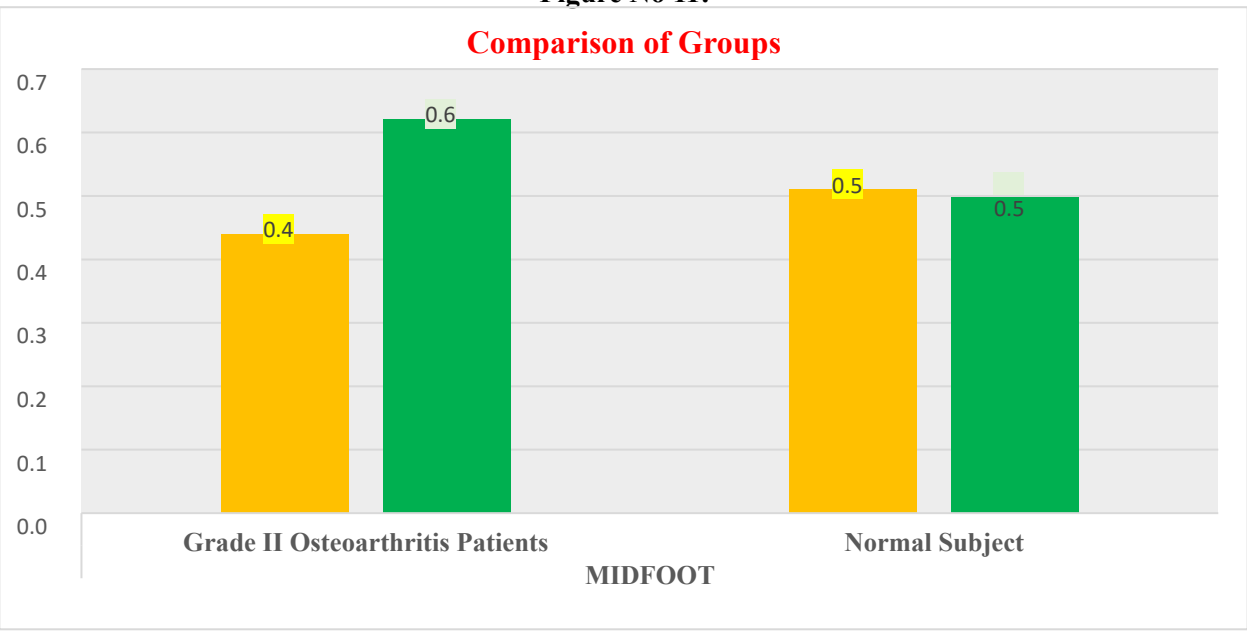


Table No 8: Comparison of forefoot between grade II OA and normal subjects:

Descriptive and T Statistics Test		Mean	SD	N	T Test	df	P Value	Result
FOREFOOT	Grade II Osteoarthritis Patients	0.33	0.46	33	1.838	41	0.073	Not Significant
	Normal Subject	0.65	0.54	10				

Figure No 12:

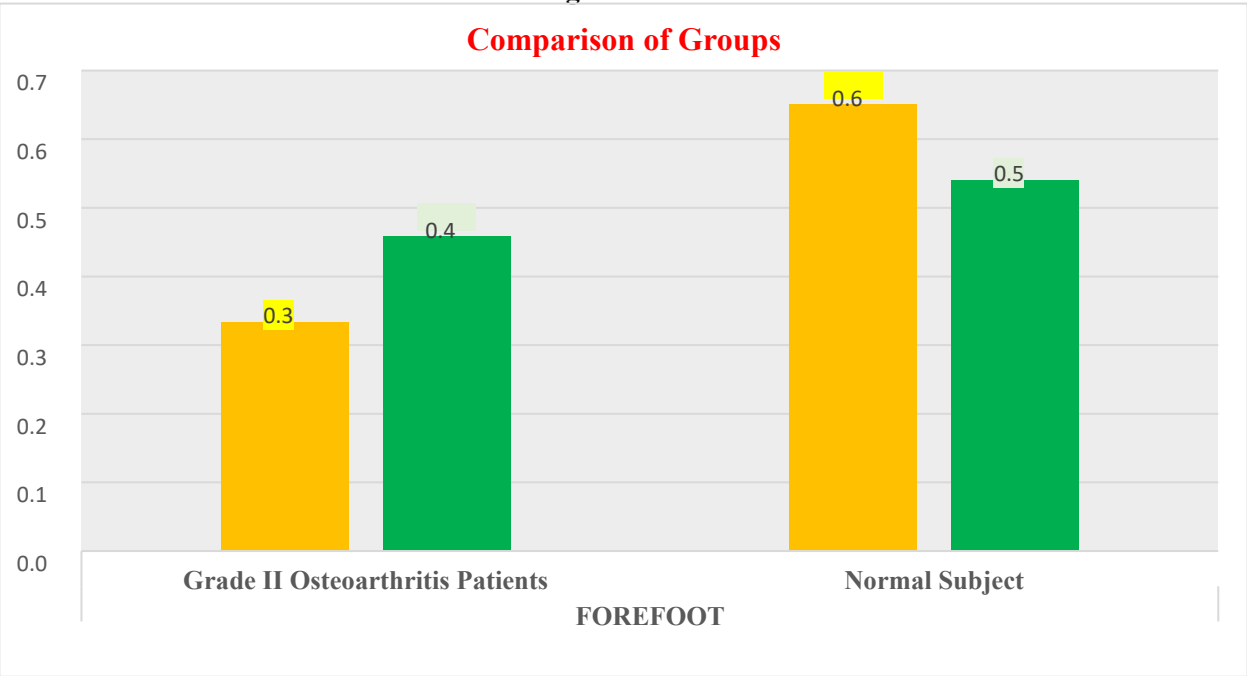


Table No 9: Comparison of toe off between grade II OA and normal subjects:

Descriptive Statistics and T Test		Mean	SD	N	T Test	df	P Value	Result
TOE	Grade II Osteoarthritis Patients	-0.51	0.56	33	0.223	41	0.825	Not Significant
	Normal Subject	-0.55	0.51	10				

Figure No 13:

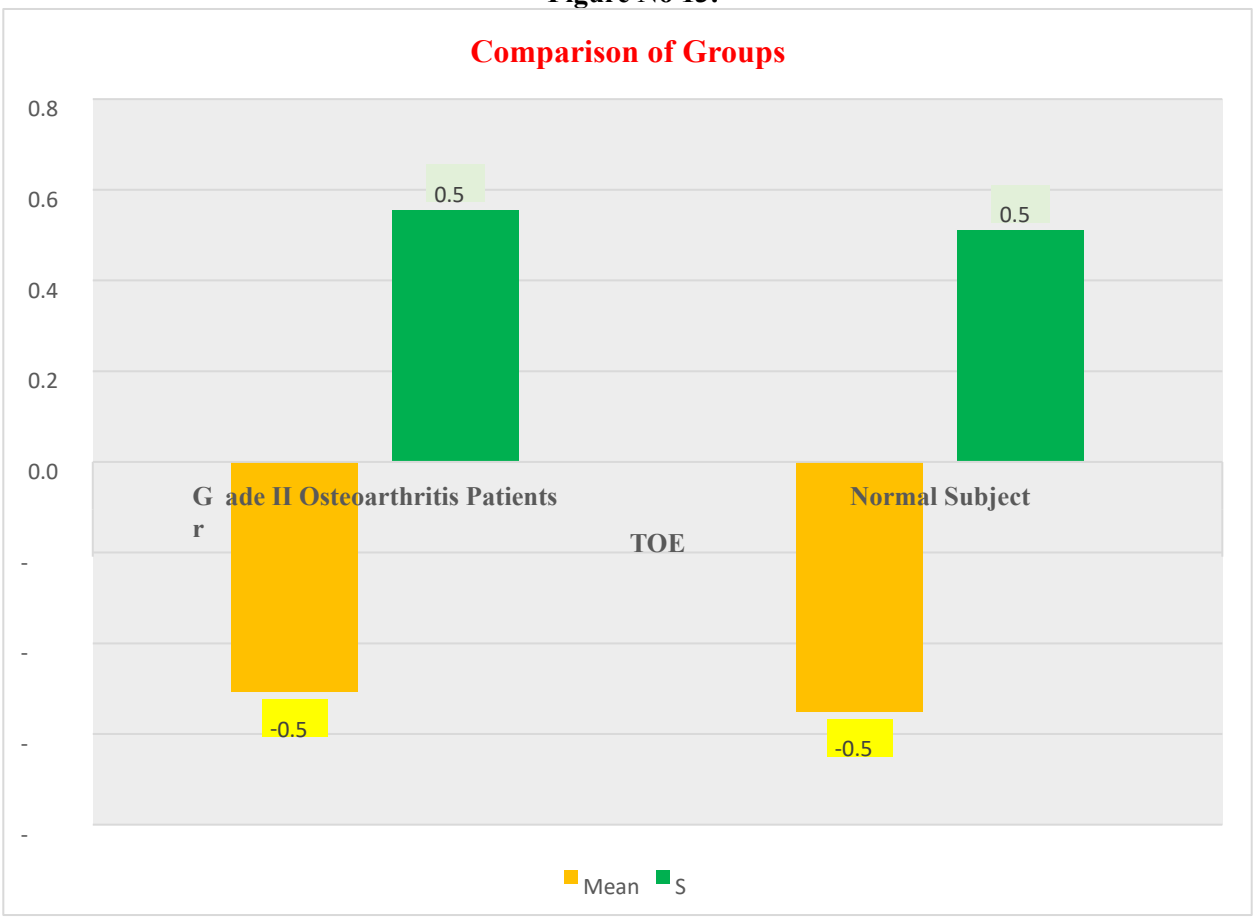


Table No 10: Comparison of clinical scores between grade II OA and normal subjects:

Descriptive Statistics and T Test		**Mean**	**SD**	**N**	**T Test**	**df**	**P Value**	**Result**
CLINICAL SCORES	Grade II Osteoarthriti s Patients	26.21	5.00	33	2.373	41	0.022	Significant
	Normal Subject	30.0 0	0.0 0	10				

Figure No 14:

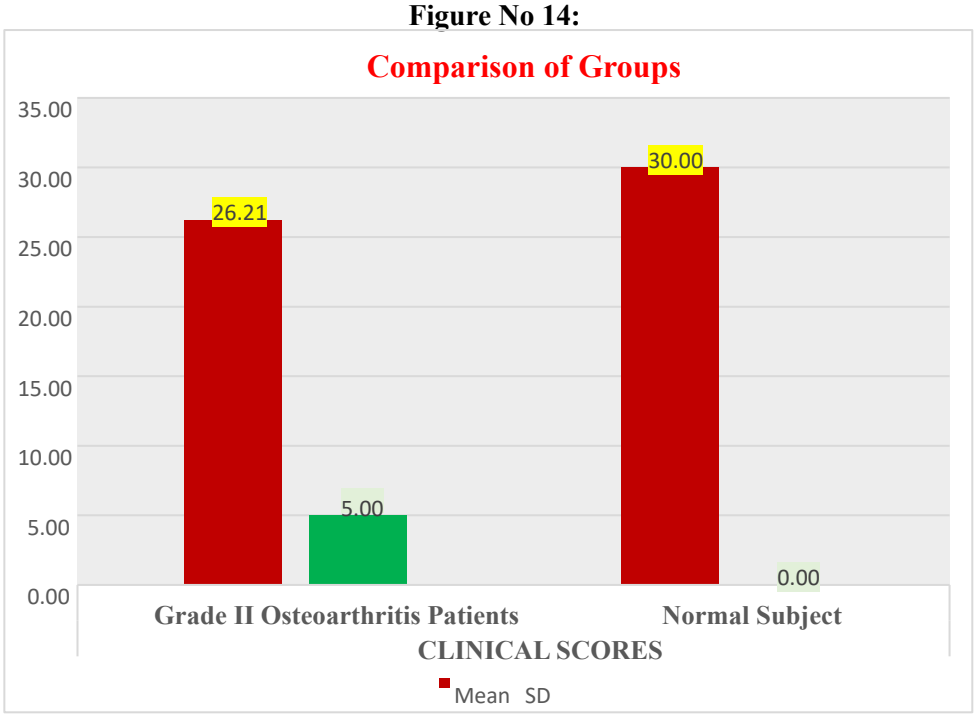


Table No 11: Comparison of WOMAC INDEX between grade II OA and normal subjects:

Descriptive Statistics and T Test		Mean	SD	N	T Test	df	P Value	Result
WOMAC	Grade II Osteoarthriti s Patients	22.82	16.89	33	4.048	41	<0.001	Significant
	Normal Subject	1.00	1.05	10				

Figure No 15:

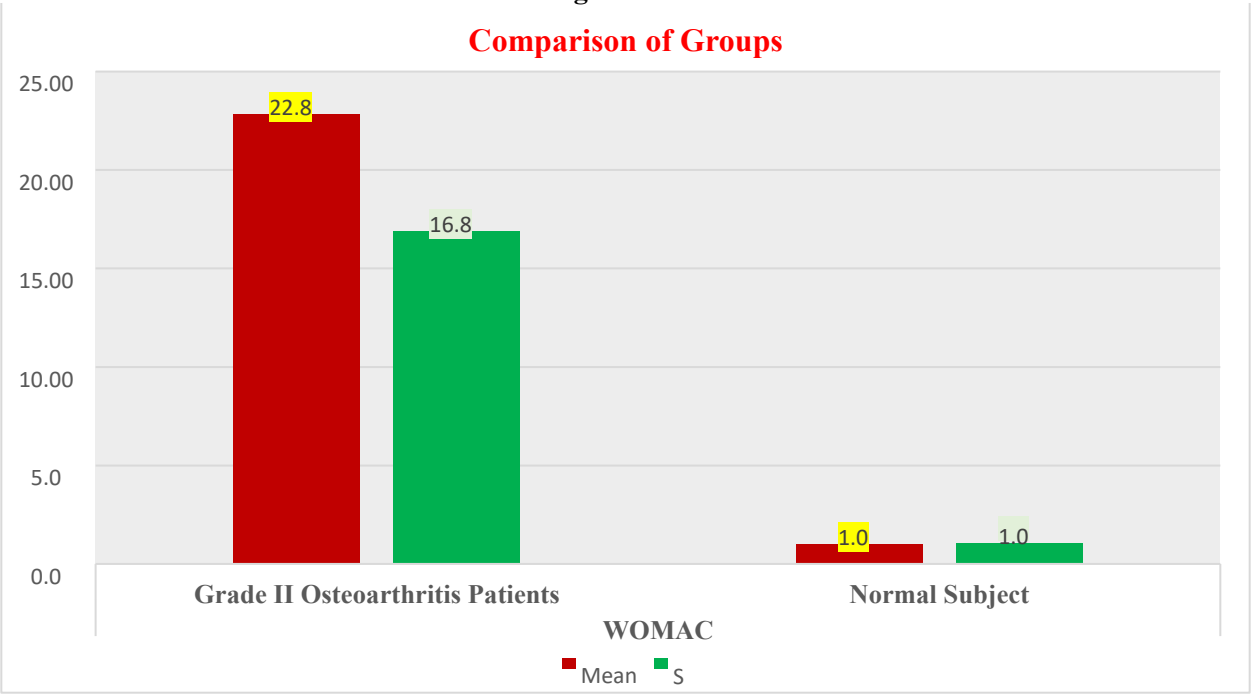


Table No 12: Comparison of NPRS between grade II OA and normal subjects:

Descriptive Statistics and T Test	Mean	SD	N	T Test	df	P Value	Result

NPRS	Grade II Osteoarthritis Patients	3.06	1.06	33	9.064	41	<0.001	Significant
	Normal Subject	0.00	0.00	10				

Figure No 16:

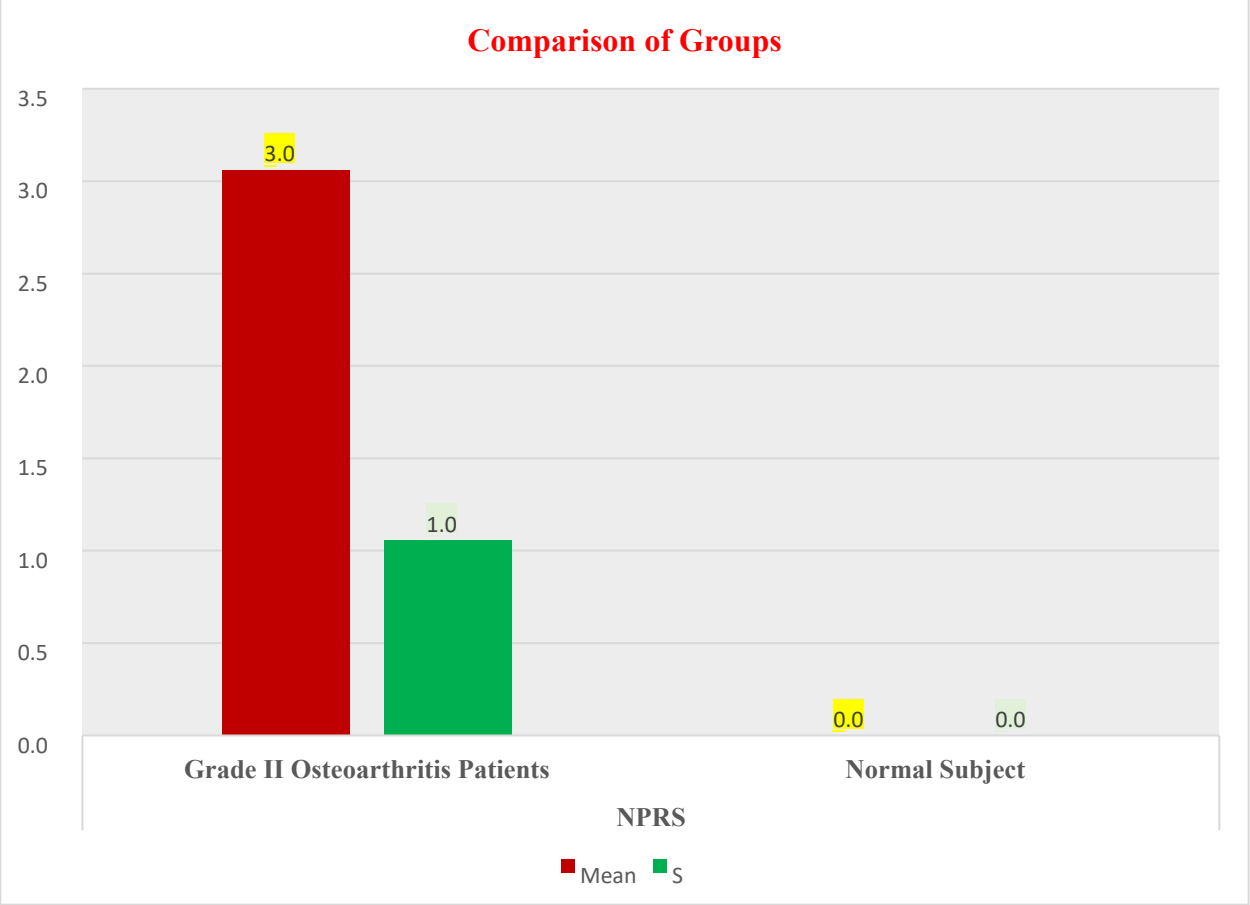


Table No: 13 Overview of parameters in grade II osteoarthritis

Descriptive Statistics	Mean	SD	N
STANCE TIME	1160.91	267.154	33
% PRE-STANCE	26.39	7.323	33
% MID-STANCE	47.42	10.300	33
%TERMINAL STANCE	25.58	9.247	33
AVF	72.81	14.746	33
HEEL	-0.02	0.225	33
MIDFOOT	0.44	0.621	33
FOREFOOT	0.33	0.458	33
TOE	-0.51	0.556	33
CLINICAL SCORES	26.21	5.005	33

WOMAC	22.82	16.892	33
NPRS	3.06	1.059	33
a. Group = Grade II Osteoarthritis Patients			

Correlation Matrix		STANCE TIME	% PRE-STANCE	% MID-STANCE	%TERMINAL STANCE	AVF	HEEL	MIDFOOT	FOREFOOT	TOE	CLINICAL SCORES	WOMAC	NPRS
STANCE TIME	Pearson Correlation												
	P value												
	N												
% PRE-STANCE	Pearson Correlation	-.479**											
	P value	0.005											
	N	33											
% MID-STANCE	Pearson Correlation	0.064	-.509**										
	P value	0.722	0.002										
	N	33	33										
%TERMINAL STANCE	Pearson Correlation	0.331	-0.207	-.724**									
	P value	0.060	0.249	0.000									
	N	33	33	33									
AVF	Pearson Correlation	-0.040	0.109	-0.040	-0.080								
	P value	0.826	0.545	0.826	0.659								
	N	33	33	33	33								
HEEL	Pearson Correlation	-0.101	-0.138	0.303	-0.249	-.369*							
	P value	0.578	0.444	0.086	0.163	0.035							
	N	33	33	33	33	33							
MIDFOOT	Pearson Correlation	.390*	-0.037	-0.050	0.113	-0.323	0.183						
	P value	0.025	0.838	0.781	0.532	0.067	0.307						
	N	33	33	33	33	33	33						
FOREFOOT	Pearson Correlation	-.352*	0.216	-0.209	0.089	-0.265	0.057	0.309					
	P value	0.044	0.228	0.244	0.621	0.136	0.755	0.080					
	N	33	33	33	33	33	33	33					
TOE	Pearson Correlation	0.035	0.176	-0.309	0.214	0.011	-0.258	0.207	.428*				
	P value	0.849	0.328	0.080	0.232	0.952	0.147	0.247	0.013				
	N	33	33	33	33	33	33	33	33				

	N											
CLINICAL SCORES	Pearson Correlation	-.425*	0.250	0.038	-0.249	0.132	-0.039	-.509**	0.064	-0.222		
	P value	0.014	0.161	0.835	0.163	0.465	0.831	0.003	0.725	0.214		
	N	33	33	33	33	33	33	33	33	33		
WOMAC	Pearson Correlation	.620**	-0.234	-0.261	.482**	0.136	-0.139	0.322	-0.110	0.178	-.727**	
	P value	0.000	0.189	0.142	0.004	0.452	0.441	0.068	0.543	0.323	0.000	
	N	33	33	33	33	33	33	33	33	33	33	
NPRS	Pearson Correlation	.646**	-0.310	-0.132	.398*	0.097	-0.140	0.234	-0.204	0.096	-.633**	.839**
	P value	0.000	0.079	0.463	0.022	0.591	0.436	0.190	0.255	0.594	0.000	0.000
	N	33	33	33	33	33	33	33	33	33	33	33

**. Correlation is significant at the 0.01 level (2- tailed).

*. Correlation is significant at the 0.05 level (2- tailed).

a. Group = Grade II Osteoarthritis Patients

Figure No 17:

Table No: 14 Overview of parameters in normal subjects

Descriptive Statistics	Mean	SD	N
STANCE TIME	932.00	303.784	10
% PRE-STANCE	29.62	13.719	10
% MID-STANCE	42.32	16.973	10
%TERMINAL STANCE	19.37	12.614	10
AVF	79.54	8.877	10
HEEL	0.04	0.084	10
MIDFOOT	0.51	0.498	10
FOREFOOT	0.65	0.540	10
TOE	-0.55	0.510	10
CLINICAL SCORES	30.00	<0.001	10
WOMAC	1.00	1.054	10
NPRS	0.00	<0.001	10
a. Group = Normal Subject			

Correlation Matrix		STANCE TIME	% PRE-STANCE	% MID-STANCE	NAL	AVF	HEEL	MIDFOOT	FOREFOOT	TOE	L	WOMAC	NPRS
STANCE TIME	Pearson Correlation												
	P value												
	N												
% PRE-STANCE	Pearson Correlation	0.159											
	P value	0.659											
	N	10											

	N											
% MID-STANCE	Pearson Correlation	-0.1767	-0.1187									
	P value	0.625	0.744									
	N	10	10									
%TERMINAL STANCE	Pearson Correlation	0.180	0.132	-0.068								
	P value	0.618	0.717	0.851								
	N	10	10	10								
AVF	Pearson Correlation	-0.088	0.051	0.054	0.147							
	P value	0.810	0.888	0.882	0.685							
	N	10	10	10	10							
HEEL	Pearson Correlation	-.715*	0.483	-0.129	-0.028	0.128						
	P value	0.020	0.157	0.721	0.939	0.724						
	N	10	10	10	10	10						
MIDFOOT	Pearson Correlation	-0.614	-0.112	0.020	-0.163	0.434	0.466					
	P value	0.059	0.758	0.957	0.654	0.210	0.175					
	N	10	10	10	10	10	10					
FOREFOOT	Pearson Correlation	-0.554	0.309	-0.125	-0.231	0.225	.732*	.858**				
	P value	0.097	0.384	0.730	0.521	0.532	0.016	0.002				
	N	10	10	10	10	10	10	10				
TOE	Pearson Correlation	-.807**	0.011	0.298	-0.082	-0.183	0.568	0.553	0.530			
	P value	0.005	0.975	0.403	0.822	0.612	0.087	0.097	0.115			
	N	10	10	10	10	10	10	10	10			
CLINICAL SCORES	Pearson Correlation	.d	.d	.d	.d	.d	.d	.d	.d	.d		
	P value	10	10	10	10	10	10	10	10	10		
	N											
WOMAC	Pearson Correlation	-0.014	-0.005	0.282	0.277	.933**	0.000	0.318	0.059	-0.145	.d	
	P value	0.970	0.990	0.430	0.439	0.000	1.000	0.371	0.872	0.690	10	
	N	10	10	10	10	10	10	10	10	10		
NPRS	Pearson Correlation	.d	.d	.d	.d	.d	.d	.d	.d	.d	.d	.d
	P value	10	10	10	10	10	10	10	10	10	10	10
	N											

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Group = Normal Subject

d. Cannot be computed because at least one of the variables is constant .

Figure No 18:

CONCLUSION

The present study concluded that there was statistically significant difference between stance time, clinical scores, WOMAC, NPRS and there was a significant correlation between the gait parameters obtained by our method and the clinical evaluation result. It also indicated that these gait parameters detected and quantified changes in the gait patterns in grade II osteoarthritis patients.

LIMITATIONS OF THE STUDY

- The sample size for the study was small.

- This study did not include walking velocity, BMI and postural sway.
- Sample included only one grade of knee osteoarthritis, and the result of this investigation should not be generalized to patients outside the sample population.
- The study did not include any therapeutic intervention and just merely compared the COP and gait parameters in osteoarthritis and normal individuals.

FUTURE SCOPE FOR THE STUDY

- The study can be performed with a large sample size.
- Duration of study can be extended to evaluate further grades of osteoarthritis.
- Other outcome measures such as balance changes can also be studied for different grades of knee OA.
- Pressure measuring system can also be used as a diagnostic tool to rule out the changes such as COP deviations in the lower extremity.

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AUTHORS CONTRIBUTION

All authors (S.J., R.P., J.S.,) participated in the framing of this study. S.J. and R.P. participated in methodology and analysis. J.S., R.P., and S.J. contributed to conceptualization and writing. S.J. took main contribution in manuscript writing. All authors (S.J., R.P., J.S.,) took part in manuscript revision and approved final version of the manuscript.

DECLARATION OF COMPETING INTEREST

The authors declare no competing interests to report.

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