Diagnosis of Knee Osteoarthritis Risk through Abnormal Musculo-postural Features

Apurba Ganguly

ABSTRACT

Background: In several parts of the globe, knee osteoarthritis (KOA) occurs as a painful chronic disease. The aim of the study was to determine the risk factors for musculo-postural abnormalities by detecting abnormal anatomical leg parameters caused by knee-osteoarthritis (KOA). Methods: Baseline data were collected and evaluated from 207 patients aged between 40-65 years (59.94% females) with KOA and an equal number of subjects without-KOA. Anatomical measurements included the gap at the knee between the short head of the biceps femoris and the level of the bed (KGB), diameter of muscles at the thigh (DTM), the calf (DCM) and 4cm above and below the patella (DAP and DBP) and flexion supine, prone and standing (KFS, KFP and KESt) and extension supine, prone and standing (KES, KEP and KEST) in different postural positions for both legs of both groups using appropriate instruments and Body Mass Index (BMI). The study was also correlated with radiological images. Results: Risk factors for KOA based on abnormal leg anatomical-features were observed with statistical significance (P<0.001) and R² (97-100%). The present results were evaluated after analyses of anatomical and flexion and extension range of motion measurements in different postural positions for both legs with KOA along with radiological features. The BMI of the experimental group was higher than that of the control group with high statistical significance (P<0.001). Conclusions: Abnormal muscle morphology and musculo-postural-features of the legs may be a suitable diagnostic protocol for the detection of early progression and risk of KOA.

Key words: Knee osteoarthritis, Diagnostic protocol, Musculo-postural feature, Risk of KOA, Progression of KOA.

INTRODUCTION

Knee osteoarthritis (KOA) is a painful chronic disease and is a matter of great concern worldwide.[1] KOA leads to morbidity and disability, ultimately resulting in medical and economic burdens on health resources. According to researchers, several factors such as obesity, joint injury, metabolic diseases, bone and joint deformations as well as genetic factors may be associated with the occurrence and extent of osteoarthritis (OA) progression.[4, 5] In general, OA develops in all joints, such as the knee and hip due to calcium crystal deposition.[6-8] Researchers have previously studied two forms of calcium crystals in articular cartilage, meniscus tissue and synovial fluid from patients with OA. These crystal forms include calcium pyrophosphate dehydrate (CPPD) and basic calcium phosphate (BCP), including partly carbonate-substituted hydroxyapatite, tricalcium phosphate and octacalcium phosphate.[6-9, 10] KOA is also considered a musculoskeletal disorder by several researchers.[11-16] KOA can easily be diagnosed based on anatomical parameters for abnormal muscular features during disease development. It is worth noting that several researchers have mainly studied ranges of motion in the supine position only for anatomical observations[17, 18] and other anatomical parameters.[14,15,19] Thus, to evaluate musculoskeletal deformities associated with KOA, a diagnostic tool using several anatomical parameters may be suitable and can be validated through statistical analyses. These parameters include the gap at the knee between the short head of the biceps femoris at the lateral part of the knee

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and the level of the bed (KGB), limb diameter at the thigh muscles (DTM), at the knee-joint 4 cm above the patella (DAP) and 4 cm below the patella (DBP) and at the calf muscles (DCM) as well as knee flexion in the supine (KFS), prone (KFP) and standing (KFS) positions while knee extension in the supine (KES), prone (KEP) and standing (KES) positions for both legs. This is a first endeavor to investigate anatomical parameters for musculo-postural abnormalities by analyzing statistically relevant R2 values and 95% confidence intervals (CIs) as well as P-values and respective 95% CIs of mean differences between subjects with KOA and those without KOA.

The present study was designed to diagnose the risk of musculo-postural abnormalities using abnormal leg anatomical parameters statistically correlated with KOA.

METHODS

Patient recruitment
A total of 684 participants (424 females and 260 males) between 40 and 65 years of age were evaluated. The participants were treated at OPTM Health Care (P) Ltd. centers in Kolkata, Delhi, Mumbai and Pune, India between January 2016 and March 2017. The study protocol was evaluated and approved by the OPTM Research Institute Ethics Committee. This institute is registered with the Indian government. An institutional review board-approved consent form for physical examinations, blood sample collections and knee joint images (X-rays, CT scan or MRI) was required for the study and was signed by all patients during the first phase of the screening procedure.

Exclusion criteria
Two hundred and seventy (180 females and 90 males) of the 684 participants were excluded for having other pathological conditions that could explain the existing symptoms. These conditions included rheumatic diseases, osteochondral diseases, intra-articular fractures, congenital dysplasia, radicular syndrome, joint symptoms caused by malignant tumors, ischemic bone necrosis and ligament or meniscus damage. The following additional exclusion criteria were considered: multiple drug dependence, a pacemaker, a history of cancer, severe neurological disease, chronic liver or heart diseases, or failure to consent to a physical evaluation.

Study design
After analyzing the exclusion criteria, 207 of the remaining 414 subjects (122 females and 85 males) without complaints of pain or visible inflammation and no signs of KOA as evidenced by X-ray, CT scan or MRI reports were enrolled as control subjects. The remaining 207 subjects (122 females and 85 males) with unilateral or bilateral KOA according to radiological analysis who complained of pain and had visible inflammation were enrolled into the experimental group. Separate evaluations were performed for subjects regarding various complaints and supplements taken to diminish pain or improve fitness. The baseline demographic characteristics of all patients who participated in the study are shown in Table 1.

Evaluation of anatomical parameters
All participants were examined at baseline for signs of musculoskeletal and nervous system damage typically associated with KOA in the following locations: patella, tarsal joint, abductor hallucis, abductor digitorium, gastrocnemius, vastus medialis, rectus femoris, vastus lateralis, gracilis, psoas/liliacus, tensor fascia lata, hamstring and popliteus muscles.

Additionally, the following parameters were checked and measured for both legs of all patients: the gap at the knee between the point of the short head of the biceps femoritis at the lateral knee and the surface of the bed while supine (KGB), diameter of the muscles 4 cm above the patella (DAP), diameter of the muscles 4 cm below the patella (DBP), diameter of the thigh muscles (DTM), diameter of the calf muscles (DCM), KFS, KFP, knee flexion while standing (KFS), KES, KEP and knee extension while standing (KES).

In the present study, a meter scale was used to measure KGB, and a goniometer was used for all flexion and extension measurements in accordance with the American Academy of Orthopedic Surgeons (AAOS).[20] DTM, DAP, DBP and DCM measurements were performed using a meter tape. The methods of anatomical measurements are shown in Fig 1 (A to K1). Measurements of difference between legs were also performed to identify muscular wasting and bone deformities in both study groups, as shown in Fig 2 (A to C).

Evaluation of knee joint images
Standing anterior-posterior (AP) X-rays of both knees of three of the 207 KOA patients revealed degenerative changes, particularly in the medial tibiofemoral compartment, with marked joint space narrowing and unilateral/bilateral genu varum. Some of the cases also exhibited near complete obliteration of the medial compartment joint space. AP X-rays of three participants without-KOA are depicted in Fig 3 (A-F).

Evaluation of Body mass index (BMI)
Body weight was measured without shoes or heavy clothing using an electronic scale. Height was measured without shoes using a wall-mounted stadiometer. Body mass index (BMI, kg/m²) was calculated for all subjects based on the measured weights and heights. BMI was categorized as >30.0 kg/m² (obese), 25.0 to 29.9 kg/m² (overweight), 18.5 to 24.9 kg/m² (normal weight) and <18.5 kg/m² (underweight). The overall and sex-specific means and standard deviations of BMI for KOA and non-KOA groups are shown in the histogram (Fig 3).

External study reviewers
All results and data were evaluated by an external reviewing panel consisting of a biostatistician, two radiologists, a biochemist, two physiotherapists and a general medical practitioner, none of whom were in contact with the participants.

Statistical analyses
Descriptive statistics were calculated. Continuous variables such as KGB, KFS, KFP, KFS, KES, KEP and KES were expressed as the means, standard deviations (SD) and 95% confidence intervals (CIs) of differences. These values were compared between the experimental and control groups to explore associations with risk factors during KOA. Statistical analyses were performed using Microsoft Excel 2016 statistical analysis add-on tool (version 10). Student’s t-test was used to determine significant values between two variables (control and experimental) at P<0.05. The respective 95% CIs were determined to measure different abnormal postures of the right and left legs of KOA patients.
both overall and separately by sex. Significant values such as $R^2$ (correlation coefficient) were also determined between independent and dependent variables with respective 95% lower and upper CI values to measure DTM, DAP, DBP and DCM abnormalities in each leg both overall and separately by sex.

RESULTS

The present results are indicative of muscle strength and postural abnormalities, which were evaluated after analyses of anatomical and flexion and extension range of motion measurements in different postural positions for both legs with KOA (Fig.1). Joint spaces narrowed in both knees. Joint space narrowing was particularly evident in the medial tibiofemoral compartment with unilateral/bilateral genu-varum apparent on radiological images compared to subjects without-KOA (Fig 4).

Risk factors and measurements of various anatomical features of 207 patients (122 females and 85 males) suffering from KOA were compared to subjects without-KOA (Tables 2-4).

In this study, the means and standard deviations (SD) of KFS, KFP and KFSt values for both legs of experimental group patients were significantly decreased, overall and separately by gender, compared to control subjects. The respective mean differences (MDs) and 95% CIs were highly significant (P<0.001) as shown in Table 2. Visual comparative measurements are shown in Fig.1 (A-C1). The mean± SD values of angular differences between legs during KFS, KFP and KFSt were also highly statistically significant (P<0.001) between KOA patients and control subjects, both overall and separately by gender, as depicted in Fig.2A.

The mean± SD values of KES, KEP, KEst and KGB for both legs of KOA patients were also significantly increased compared to control subjects, both overall and separately by gender. The respective MDs and 95% CIs were highly statistically significant (P<0.001), as shown in Table 3. The visual comparative measurements are shown in Fig.1 (D-G1).

The mean± SD of KGB differences and angles between legs during KES, KEP, and KEst were also highly significant (P<0.001) for KOA patients compared to subjects without-KOA, both overall and separately by gender, as depicted in Fig. 2B.

Furthermore, the respective means± SD values of DTM, DAP, DBP and DCM for both legs of the experimental group, both overall and separately by gender, were significantly decreased with correlation coefficients ($R^2$) between 94-100% compared to the control group as shown in Table 4. Visual comparative measurements are shown in Fig.1 (H-K1).

The mean± SD of diameter differences between legs during DTM, DAP, DBP and DCM were also highly statistically significant (P<0.001) between the experimental group and the control group, both overall and separately by gender, as depicted in Fig 2C.

The mean± SD BMI of the experimental group was higher than that of the control group with high statistical significance (P<0.001), both overall and separately by gender, as shown in Fig 3.

Finally, the X-ray reports of 207 subjects with KOA exhibited degenerative changes, particularly in the medial tibio-femoral compartment, with marked joint space narrowing and unilateral/bilateral genu-varum. Some cases exhibited near-complete medial compartment joint space obliteration. The AP knee X-rays of subjects without-KOA indicated no such degenerative changes. X-ray images of three KOA patients and three control subjects are presented in Fig.4 (A-F).

DISCUSSION

In this present population-based study, it was observed that KOA could be identified easily through anatomical parameters such as the postural positions of KGB, KFS, KFP, KFSt, KES, KEP and KEst and abnormal muscular characteristics of DCM, DTM, DAP and DBP.

Generally, KOA can be diagnosed using several techniques, such as biochemical parameters, range of motion while in the supine and radiological imaging modalities including X-ray, CT-scan or MRI. X-ray findings associated with KOA may include articular cartilage damage, joint space narrowing and bone spur formation.\cite{21} For optimal clarity, MRI is a suitable technique for detection of bone deformities in KOA.\cite{22}

According to Liikavainio et al.\cite{23} the quadriceps femoris muscle (QFM) is responsible for KOA in men based on comparison with age- and sex-matched control subjects. Studies of several mechanisms of muscle weakness in KOA have suggested that disuse atrophy of muscles due to joint pain\cite{23-28}, reflex inhibition of muscles moving the affected joint and inability to fully activate the QFM all may result in decreased force production.\cite{23, 27-29} In other words, KOA is characterized by muscular weakness, primarily in the QFM. Other studies have also reported reduced QFM strength as a risk factor for KOA.\cite{28, 30-33}

Research works on ranges of motion in KOA has mainly focused on knee flexion and extension in the supine position rather than the prone and standing positions.\cite{23, 34-35}

However, there are no studies on abnormal postural positions or muscular features in KOA. Meanwhile, other reports regarding flexion and extension findings during KOA progression confirm the presented results.\cite{23, 36-39}

The normal ranges of knee flexion and extension are between 140 to 145° and 5 to 0° respectively.\cite{40} The flexion angles of the experimental group in the supine, prone and standing positions were substantially and asymmetrically reduced during KOA compared with the control group. The two main actions of the knee joint are flexion and extension, along with slight rotation. Most of the muscles which move the joint are in the thigh, except for the gastrocnemius and popliteus. The muscles responsible for knee flexion are the biceps femoris, innervated by the tibial nerve (long head) and common peroneal nerve (short head) and the semimembranosus and semitendinosus, both innervated by the sciatic nerve (tibial, L5, S1, S2). These muscles and their nerve roots are significantly affected during KOA. Supine, prone and standing knee extension was also remarkably increased during KOA in the experimental group compared to the control group. The muscles responsible for knee extension (vastus medialis, vastus lateralis, vastus intermedius and vastus femoris) all insert into the patella via the quadriceps tendon and tibial tuberosity via the patellar ligament. These muscles are all innervated by the femoral nerve. All of the muscles and the nerve roots are severely damaged in KOA (Tables 2 & 3, Fig. 2).

The bilateral KGB measurements for the experimental group were widely and asymmetrically increased compared to the control group.
The reasons for the asymmetrical results and the inability of the posterior knee-joint (popliteal region) to touch the bed included the cumulative effects of muscle wasting and diminished strength of the vastus lateralis, vastus medialis and iliobibial tract, regional popliteal inflammation, rectus femoris stiffness, inflammation over muscles such as the sartorius, gracilis, semimembranosus and semitendinosus at the medial knee-joint as well as stiffness (due to calcification) of patella movement, etc. These may have occurred due to prolonged use of knee supports, hyaluronic acid or corticosteroid injections or arthrocentesis performed to reduced pain and inflammation quickly among other reasons (Table 3 & Fig. 6).

Concerning muscle deformities, of DTM, DAP, DBP, and DCM were mismatched and asymmetric between the experimental group and the control group during KOA. The reasons for differences in DTM included the cumulative effects of muscular wasting and bulging in the posterior thighs particularly including the rectus femoris, vastus lateralis, vastus medialis, sartorius (near the origin), semimembranosus, semitendinosus, long head of the biceps femoris, and adductor magnus. Moreover, the nerve roots for the semimembranosus and semitendinosus muscles the sciatic nerve (Tibial, LS, S1, S2) originating from the ischial tuberosity and inserting into the tibia (pes anserinus) were compressed. Patients suffering from KOA have complained about acute or mild pain sensations over the vastus lateralis (Table 4 & Fig.2)

### Table 1. Demographic data and baseline characteristics of the study subjects

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Combined</th>
<th>Experimental group</th>
<th>Male</th>
<th>Female</th>
<th>Combined</th>
<th>Control group</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of subjects (%)</td>
<td>207</td>
<td>122 (58.94)</td>
<td>85 (41.06)</td>
<td>207</td>
<td>122 (58.94)</td>
<td>85 (41.06)</td>
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</tr>
<tr>
<td>Mean age in years (SD)</td>
<td>58.31 (6.11)</td>
<td>57.46 (6.12)</td>
<td>59.55 (5.89)</td>
<td>56.29 (6.62)</td>
<td>55.72 (6.89)</td>
<td>57.12 (6.11)</td>
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</tr>
<tr>
<td>Mean BMI in kg/m² (SD)</td>
<td>33.10 (3.88)</td>
<td>33.75 (3.55)</td>
<td>32.18 (3.67)</td>
<td>26.57 (3.91)</td>
<td>26.91 (4.12)</td>
<td>26.07 (3.54)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean symptom duration in years (SD)</td>
<td>5.86 (1.93)</td>
<td>5.25 (1.73)</td>
<td>6.73 (1.87)</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</table>

### Indian ethnic group (%)

- Bengali: 71 (34.30)
- Gujarati: 21 (10.14)
- Marwari: 23 (11.11)
- Marathi: 25 (12.08)
- Tamil: 22 (10.63)
- Punjabi: 19 (9.18)
- Shindhi: 12 (5.80)
- North East India: 14 (6.76)
- Dietary habits (%)
  - Vegetarian: 109 (52.66)
  - Non-vegetarian: 98 (47.34)

### Analysis of radiological reports (%)

- Unilateral KOA with osteophytes: 55 (26.57)
- Bilateral KOA with osteophytes: 152 (73.43)

### Work status (%)

- Employed fulltime: 51 (24.84)
- Employed part time: 9 (4.35)
- Housewife / Home-maker: 65 (31.40)
- Retired: 35 (16.91)
- Self employed: 47 (22.70)

### Marital status (%)

- Single: 18 (8.70)
- Married: 128 (61.84)
- Separated: 21 (10.14)
- Divorced: 8 (3.86)
- Widowed: 32 (15.46)

### Multiple complaints or comorbidities (%)

- Constipation: 146 (70.53)
- Acidity and reflux: 98 (47.34)
- Insomnia: 171 (82.61)
- Varicose veins: 96 (46.38)
- Urinary incontinence: 98 (46.21)
- Crepitus during knee flexion: 121 (58.45)
- Morning stiffness (<30 min.): 133 (64.25)

### Measures taken to diminish pain and inflammation (%)

- Knee cap uses: 137 (68.18)
- Lumbar belt use: 42 (20.29)
- Collar belt use: 37 (17.87)
- Paracetamol and NSAID use: 128 (61.84)
- Arthrocentesis: 42 (20.29)
- Use of hyaluronic acid injection: 35 (16.91)
- Use of corticosteroid injection: 43 (20.77)
- Massage with herbal or other gels: 182 (87.92)
- Homeopathic treatment: 162 (78.26)
- Ayurvedic treatment: 153 (73.91)
- Stick/walker use: 45 (21.74)

### Supplements taken to reduce pain or improve fitness (%)

- Calcium: 198 (95.65)
- Vitamin D: 174 (84.06)
- Glucosamine: 87 (42.03)
- Glucosamine and chondroitin: 45 (21.74)
Table 2. Statistical interpretation of the risk of musculoskeletal postural abnormalities during KOA through KFS, KFP and KF St Values.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Control</th>
<th>Right leg</th>
<th>Right leg</th>
<th>Right leg</th>
<th>Right leg</th>
<th>Right leg</th>
<th>Left leg</th>
<th>Left leg</th>
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<tr>
<td></td>
<td>Right Leg Mean (SD)</td>
<td>Left Leg Mean (SD)</td>
<td>Right Leg Mean (SD)</td>
<td>Left Leg Mean (SD)</td>
<td>DBL Mean (SD)</td>
<td>ND</td>
<td>P-Value</td>
<td>Lower Value</td>
</tr>
<tr>
<td>Combined-sex</td>
<td>141.90 (0.30)</td>
<td>140.18 (0.915)</td>
<td>139.60 (0.51)</td>
<td>14.00 (0.05)</td>
<td>4.00 (0.05)</td>
<td>&gt;0.001</td>
<td>9.20</td>
<td>1.50</td>
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<tr>
<td></td>
<td>Female only</td>
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<td>9.00</td>
<td>1.50</td>
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Table 3. Statistical interpretation of the risk of postural and skeletal muscle abnormalities during KOA through KES, KEP, KES and KGB values.

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<td>3.80 (0.05)</td>
<td>&gt;0.001</td>
<td>9.00</td>
<td>1.50</td>
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Table 4. Statistical interpretation of the risk of muscle abnormalities during KOA through DTM, DAP, DBP and DCM values.

<table>
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<tr>
<th>Gender</th>
<th>Control</th>
<th>Right leg</th>
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KFS/KF/KFP/KES/KGB conversion factor.
The reasons for the muscle deformities associated with DAP included the cumulative effects of muscular wasting, inflammation, effusion and blood clotting due to saphenous vein engorgement in some cases. However, sartorius, gracilis, semitendinosus and semimembranosus all insert into the tibia (pes anserinus). Furthermore, 90% of patients suffering from KOA report acute pain in the area where the four muscles mentioned above connect to the medial part of the knee. The reasons for deformities associated with DBP included the cumulative effects of muscle wasting, inflammation, effusion or blood clotting involving the anterior, posterior, lateral and medial parts of the lower legs. These anatomic regions include structures such as the tibialis anterior, extensor hallucis longus and extensor digitorum longus, gastrocnemius, Achilles tendon, flexor digitorum longus, and flexor hallucis longus and brevis and soleus, all of which are severely affected as degenerative changes occur in both knee-joints (Table 4 & Fig. 2).
Furthermore, the reasons for differences in DCM included the cumulative effects of gastrocnemius muscles wasting due to prolonged use of knee supports, tenderness from the Achilles tendon, soleus (part of the triceps surae), the flexor digitorum, a calcaneus spur, ankle joint rigidity or other reasons. Of note, the calf muscles are very important for vertebral alignment. Slight differences in diameters between contralateral calf muscles may trigger lumbar vertebrae compression (Table 4 & Fig. 2).

CONCLUSION

The present results led to the conclusion that measurement of muscle deformities and abnormal postures using anatomical parameters in both legs of KOA subjects was suitable to detect the risk of abnormal musculo-skeletal morphology. Presently, KOA can be identified only through radiological diagnosis[1] and biochemical parameters for skeletal muscle damage.[10] Obesity is also a known marker of KOA due to impairments associated with BMI values.[41] However, in the present study, the measurement of several anatomical parameters such as KGB, DCM, DTM, DAP and DBP, flexion (KFP, KFS and KFSt) and extension (KEP, KES and KEST) was confirmed as a suitable diagnostic method. In comparison, other studies for KOA detection have only reported ranges of motion (only supine flexion and extension).[23, 34-35]

This study has confirmed a novel diagnostic protocol that can be used to detect early progression and risk of KOA, with or without any pain symptoms or external deformities, with the help of the statistically correlated anatomical parameters mentioned above. This method may also serve as a suitable predictive diagnostic tool to detect KOA with fewer cost and time requirements compared with relatively expensive methods such as estimation of biochemical parameters or methods such as X-ray, CT-scan or MRI examinations which may be especially hazardous for those with pacemakers or other artificial prostheses.

Acknowledgments

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Ethics approval and consent to participate

The study protocol was evaluated and approved by the OPTM Research Institute Ethics Committee. This institute is registered in the Indian government. All participants provided written informed consent.

Abbreviations

KOA: knee osteoarthritis, KGB: gap at the knee between the short head of the biceps femoris muscle in the lateral part of the knee-joint and at the level of the bed in the supine position, DTM: diameter of the group of thigh muscles, DAP: diameter of the group of muscles connected to the knee-joint 4cm above the patella, DBP: diameter of the group of muscles connected to the knee-joint 4cm below the patella, DCM: diameter of the group of calf muscles, KFS: knee flexion in the supine position, KFP: knee flexion in the prone position, KFS: knee flexion in the standing position, KEK: knee extension in the supine position, KEP: knee extension in the prone position, KES: knee extension in the standing position, R^2: correlation coefficient, OA: osteoarthritis, SD: standard deviation, AP: anterior-posterior, BMI: body mass index, Nc: number of control subjects, Ne: number of experimental subjects, DBL: difference between the right and left legs, CI: confidence interval, MD: mean difference.

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