Assessment of Functional End Ranges of Lower Limb Joints in Positions Commonly Used for ADLs in India

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Authors’ contributions
This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

ABSTRACT

Background: In many countries of Asian continent, floor sitting is preferred instead of chair supported sitting. Indian population differs noticeably in its cultural practice and daily tasks which involves squatting and cross-legged sitting on the ground.

Aim: The purpose of the study was to assess the functional end-ranges of the hip, knee and ankle joints in healthy Indian subjects in positions commonly used for ADLs in India which includes squatting and cross-legged sitting.

Methods: 66 healthy subjects were recruited from rural and urban populations with age range 30-50 years. Joint ROM of the lower extremities was measured using Universal Goniometer. All the subjects were asked to acquire squats and cross legged positions which were graded.

Results: Our results finding showed that the subjects in cross leg sitting grade 2 (independent CLS) had hip flexion ranges ≥115°, hip abduction ≥41°, hip external rotation ≥42°, ankle plantar flexion ≥46°, p<0.005. For squatting, grade 2 (independent squat) had hip flexion ranges ≥113°, p>0.005, Knee flexion ≥120°, p=0.005 and ankle dorsiflexion ≥15°, p<0.005.

Conclusion: From the results, it is suggested that squatting and cross-leg sitting multiple times a day can prevent the early closer of end ranges of the lower limbs.

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1. INTRODUCTION

ADLs are remarkably influenced by the culture. In many countries of Asian continent, sitting without external support is still preferred. They prefer floor sitting instead of chair supported sitting. Common floor-sitting static postures acquired by them are squatting, cross-leg sitting and kneeling [1]. They use these postures for eating, personal cleanliness and for religious purposes [2].

1.1 Squatting

It is floor sitting posture which requires full ankles dorsiflexion, knees and hips flexion [3]. Squatting is a multiple joint movements performed closed kinetically [4]. Squatting is said to be perfectly done when the hips, knees and ankles are in parallel alignment with heels firmly grounded [5].

In India, squatting is most importantly used for toileting activities. In villages, provisions for toilet and bathing activities are inadequate. So, they not only adopt squat position in farm for toileting and for bathing in rivers and lakes [6] but also squatting routine household works, meeting people at home and in religious discourse [6,7]. Whereas in wealthy and urban inhabitants, it is opposite to the above scenario. They squat rarely [8].

Deep squatting capacity is of great significance for the ADLs performed on the ground. It is a structured exercise to strengthen muscles of the lower limb. Deep squat is also a screening test to assess bilateral symmetrical strength and mobility of hip, knees and ankles [3]. If a person with decrease in muscle power and/or restricted joint range of motions, performs a deep squat, trick movements and compensations will be there to complete the movement. If hip flexion range of motion is decreased, individual will flex the trunk to gain desired deep squat. Such compensating movements are not suggested as it increases stress on the lumbar spine [3].

1.2 Cross-Legged Sitting

In Asia and Middle East, this is a common position at work, for eating, socializing, leisure or spiritual activities like yoga [7]. Cross-legged sitting is assumed by flexion, abduction and external rotation at hip, flexion at knee and plantar flexion at ankle joint [9].

An individual with restricted joint range of motion still can cross leg sit with compensation. For example, if an individual has reduced knee flexion range of motion, still cross-legged sitting position can be achieved by compensating at hip and ankle i.e. increasing range at hip and ankle joint [1].

In aged, joint ROM is reduced due to aging process resulting in various changes in the joint such as loss of elasticity due to changes in connective tissues, ultimately resulting in restricted squatting and cross-leg sitting [2,10]. In musculoskeletal health system, to evaluate joint motion, most common variable which is measured is Range of Motion (ROM) [10]. To measure the range of motion of lower limb, commonly used device is Universal Goniometer (U.G). It is a double-armed protractor. It is very functional and practical device to measure ROM [2,3,9,10].

Measuring joint ROM precisely is difficult. Even more difficult is measuring ROM during ADLs. So, the literatures so far present are culturally biased. On exploring the existing literature it showed rare studies which focused on squatting and cross-leg sitting positions. Perhaps this partially explains why so few studies have been done that quantitatively investigated ADLs [1].

So, the purpose of our study was to assess the functional end-ranges of the hip, knee and ankle joints in healthy Indian subjects in positions commonly used for ADLs in India which includes squatting and cross-legged sitting.

2. METHODS

2.1 Participants

Total 66 participants were recruited for the study (Fig. 1). The study population had age between 30-50 years including both genders from Dhiraj General Hospital. All the subjects who had any type of neurological, systemic or peripheral pathological disease, history of musculoskeletal injury, any lower limb surgery and pregnancy were excluded.
2.2 Procedure

The subject was taken to the procedure room to maintain the privacy. All the functional end ranges of the hips, knees and ankles were taken with the help of universal Goniometer and plastic Goniometer by a single examiner. After the measurements of the end ranges of lower limb, the subjects were asked to perform squatting and cross-leg sitting on the floor and the examiner graded it according to the grading system of squatting and cross-leg sitting.

A. Squatting Grades:
   - Grade- 0:- Unable to squat
   - Grade- 1:- Abnormal squatting (arm/wall support or heel raise)
   - Grade- 2:- Independent full squat

B. Cross-leg sitting Grades:
   - Grade- 0:- Unable to cross-leg sit
   - Grade- 1:- Deficits in ROM either at hip(flexion, abduction, external rotation) or knee(flexion)
   - Grade- 2:- Normal Cross-leg sitting

2.3 Statistical Analysis

All the statistical analysis was performed using SPSS version 22.0 software. Independent T test was used for comparing ROM with squatting grades (i.e. SQ1, SQ2) and cross leg sitting grades (i.e. CLS1, CLS2). ANOVA was used for comparing ROM with BMI of the subjects. In the study, all the statistical tests were performed with 95% confidence interval.

3. RESULTS AND DISCUSSION

3.1 Results

Total 66 subjects participated in the study, of which 21 were males and 45 were females. Their mean age was 41.24±6.5 years. Of the total 66 subjects, 09 were underweight, 28 had normal weight, 14 were overweight and 15 were obese with the mean BMI of these subjects was 22.35±4.38 kg/m².

4.2 Discussion

In India, commonly used positions in day to day living are squatting and cross-legged sitting. Functional end ranges of hip, knee and ankle joints play an important role in deriving these positions.

4.3 Squatting

Squatting is best defined as a posture in which one foot is in complete contact with ground and are extremely flexed, bringing the body down over the feet/foot. This posture demands maximum hip flexion, knee and the ankle joints [11].

Ankle joint: In our study when comparing ROM with squatting grades, all those subjects who were able to squat independently (GRADE 2) had ankle dorsiflexion ≥15° i.e. functional to full ROM. Our findings were in agreement with Bridger RS [12] who stated that if adequate ankle dorsiflexion is available, an individual can bring his/her COG on feet which in result prevents from falling backwards. Regularity of squatting has an additional effect on ankle dorsiflexion rather than squatting for a prolonged time.
Table 1. Comparison between ROM and squatting grades

| Variable | SQ 1 Mean | SQ 1 SD | SQ 2 Mean | SQ 2 SD | p value |
|----------|-----------|---------|-----------|---------|---------|
| HF-R     | 111.80    | 3.35    | 113.61    | 3.21    | 0.301   |
| HF-L     | 112.80    | 3.70    | 114.85    | 3.53    | 0.289   |
| HE-R     | 13.80     | 2.17    | 13.11     | 2.27    | 0.530   |
| HE-L     | 14.20     | 4.02    | 14.90     | 2.82    | 0.720   |
| HAB-R    | 39.80     | 2.59    | 39.26     | 2.97    | 0.678   |
| HAB-L    | 39.60     | 4.04    | 40.80     | 2.87    | 0.547   |
| HADD-R   | 26.00     | 1.58    | 26.54     | 1.92    | 0.502   |
| HADD-L   | 27.60     | 1.82    | 28.16     | 1.60    | 0.534   |
| HIR-R    | 41.80     | 1.10    | 41.52     | 1.71    | 0.627   |
| HIR-L    | 42.80     | 2.49    | 42.75     | 1.62    | 0.969   |
| HER-R    | 39.00     | 4.18    | 39.90     | 3.13    | 0.660   |
| HER-L    | 39.60     | 3.78    | 40.95     | 2.88    | 0.475   |
| KF-R     | 122.40    | 6.19    | 120.44    | 3.18    | 0.521   |
| KF-L     | 121.80    | 5.54    | 122.28    | 3.91    | 0.858   |
| ADF-R    | 13.60     | 1.14    | 15.82     | 1.83    | 0.008   |
| ADF-L    | 15.20     | 1.64    | 17.95     | 1.40    | 0.018   |
| APF-R    | 43.00     | 2.45    | 45.33     | 2.18    | 0.100   |
| APF-L    | 44.80     | 2.28    | 47.39     | 1.67    | 0.062   |
| AI-R     | 27.20     | 1.30    | 31.89     | 1.90    | 0.001   |
| AI-L     | 28.80     | 2.77    | 32.97     | 1.59    | 0.027   |
| AE-R     | 11.80     | 1.10    | 11.98     | 1.60    | 0.742   |
| AE-L     | 10.80     | 1.64    | 13.36     | 1.38    | 0.023   |

Fig. 2. Comparison of Ankle Dorsiflexion range with Squatting
Table 2. Comparison between ROM and Cross leg sitting grades

| Variable | CLS 1 Mean | CLS 1 SD | CLS 2 Mean | CLS 2 SD | p value |
|----------|------------|----------|------------|----------|---------|
| HF-R     | 111.22     | 2.063    | 115.03     | 2.969    | 0.001   |
| HF-L     | 111.81     | 2.602    | 116.69     | 2.637    | 0.001   |
| HE-R     | 12.63      | 1.904    | 13.54      | 2.426    | 0.094   |
| HE-L     | 13.41      | 2.531    | 15.85      | 2.729    | 0.001   |
| HAB-R    | 36.70      | 2.091    | 41.10      | 1.875    | 0.001   |
| HAB-L    | 38.00      | 1.922    | 42.59      | 1.874    | 0.001   |
| HADD-R   | 25.52      | 1.528    | 27.18      | 1.833    | 0.001   |
| HADD-L   | 27.56      | 1.739    | 28.51      | 1.412    | 0.022   |
| HIR-R    | 40.81      | 1.145    | 42.05      | 1.791    | 0.001   |
| HIR-L    | 42.33      | 1.593    | 43.05      | 1.685    | 0.084   |
| HER-R    | 36.81      | 2.095    | 41.92      | 1.869    | 0.001   |
| HER-L    | 38.00      | 1.981    | 42.82      | 1.554    | 0.001   |
| KF-R     | 119.74     | 3.737    | 121.18     | 3.170    | 0.108   |
| KF-L     | 121.26     | 4.184    | 122.92     | 3.779    | 0.105   |
| ADF-R    | 14.48      | .893     | 16.46      | 1.958    | 0.001   |
| ADF-L    | 17.11      | 1.086    | 18.18      | 1.730    | 0.003   |
| APF-R    | 44.30      | 1.613    | 45.74      | 2.479    | 0.006   |
| APF-L    | 47.26      | 1.655    | 47.15      | 1.967    | 0.815   |
| AI-R     | 31.00      | 1.664    | 31.90      | 2.511    | 0.086   |
| AI-L     | 33.07      | 1.730    | 32.36      | 2.158    | 0.141   |
| AE-R     | 11.74      | 1.095    | 12.13      | 1.809    | 0.284   |
| AE-L     | 13.48      | 1.282    | 12.95      | 1.685    | 0.150   |

Fig. 3. Comparison of hip external rotation range with cross-leg sitting
Similarly, Butler RJ et al. [13] also emphasized on ankle dorsiflexion range for squatting. He stated that ankle joint is one of the important part of closed kinetic chain during squatting. Restricted ankle joint ranges and inadequate stability of the ankle joint could hinder the performances of the hip and knee joints. We found that when comparing ROM with squatting grades, all those subjects who were able to squat independently (GRADE 2) had ankle dorsiflexion ≥15° i.e. functional to full ROM. Also, Kim SH et al., [3] in his study found that restricted ankle dorsiflexion range can limit squatting. Ankle dorsiflexion mobility can alter squatting position. In our study we noticed, that 01 subject had limited dorsiflexion range (12°) and maintained squat position with heel raise (Fig. 2).

**Knee joint:** In the literature, knee flexion angles showed consistency and higher ranges, implying that subjects performed deep flexion at knee to achieve squatting position [14]. We also observed consistency and high range in the knee flexion in both squatting grade 1 and grade 2 groups. We found mean knee flexion range 122° in our subjects.

Hip joint: In our study, we also found varying hip flexion ROM in both the squatting groups i.e. SQ 1 (grade 1) and SQ 2 (grade 2). The minimum hip flexion range in grade 1 squatting was 111.80°±3.5 and in grade 2 squatting were 113°.16±3.2. These findings were supported by the study of Hemmerich A et al., [14] who concluded that to gain maximum squat, mean hip flexion ROM should be 95.4 ±26.6° (Table 1).

### 4.4 Cross Leg Sitting

We analyzed that the subjects in cross leg sitting grade 2 (independent CLS) had hip flexion ranges ≥115°, hip abduction ≥ 41°, hip external rotation ≥ 42°, ankle plantar flexion ≥ 46°. This indicates that functional end ranges of hip flexion, hip abduction, hip external rotation, knee flexion, and ankle plantar flexion were maintained (Fig. 3). Our study results were in agreement with Mulholland SJ et al., [1] who reviewed the conclusions of 10 authors throughout the globe on cross-leg sitting and range of motion of lower extremities required for obtaining cross-leg sitting position. Also the values which we found in our study for cross-leg sitting falls within the ranges reported by Kapoor A et al. [9] in his studies (Table 2).

### 4.5 BMI

Another important analysis we found is of body weight (BMI) and lower limb ROM. In our study, we found statistically significant findings on increase in BMI and decrease in joint ranges. Most affected joint ranges are hip flexion, extension, abduction, hip internal rotation and knee flexion ranges with the increase in the body weight. Our findings were in agreement with Kathiresan G et al., [15], Macedo LG et al., [10] and Roach KE et al.,[16] stated that BMI affects ROM in different ways. So, we suggest that joint
ranges decreases as the body weight increases (Fig. 4).

5. CONCLUSION

Functional to near normal end ranges are very important to perform squatting and cross-leg sitting. The results of our study showed significant correlation of lower limb end ranges with squatting and cross-leg sitting positions. BMI influences the range of motion of lower limbs. From, our findings we suggest that squatting and cross-leg sitting multiple times a day can prevent the early closer of end ranges of the lower limbs.

6. LIMITATIONS OF THE STUDY

1. Equal number of both the genders was missed.
2. We also could not recruit equal number of subjects in urban and rural population.
3. We did not group the age to enclose hormonal changes of reproductive and skeletal maturity and perimenopause which are known to influence joint laxity and body mass.

7. RECOMMENDATIONS

1. It is important to acknowledge reasons for limitations in ranges, as this is significant for clinical application. By recognizing such reasons one can gain deep understanding to pilot future studies.
2. The reader must be very observant in generalizing the results as dissimilarities exists between people within countries and its cultures.

ETHICAL APPROVAL AND CONSENT

The study was ethically approved by Institutional Ethical Committee. All the subjects who fulfill the inclusion criteria were included in the study. There informed consent was taken from participants.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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