Knee laxity of Malaysian adults: Gender differentials, and association with age and anthropometric measures

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Background: Knee laxity measurements have been shown to be associated with some medical conditions such as chronic joint pain and collagen tissue diseases. The aim of this study was to determine the effects of demographic and anthropometric factors on knee laxity.

Materials and methods: Data were collected from 521 visitors, staffs and students from the University Malaya Medical Centre and University of Malaya between December 2009 and May 2010. Knee laxity was measured using a KT-1000 arthrometer. Multiple regression analysis was used to find the association of knee laxity with age and anthropometric measures.

Results: Using ANOVA, knee laxity did not show significant differences among ethnic groups for both genders. The average knee laxity in men was 3.47 mm (right) and 3.49 mm (left); while in women 3.90 mm (right) and 3.67 mm (left). Knee laxity in women was significantly higher (right knee p<0.01 and left knee p<0.05) than men. Right knee laxity of men was negatively associated with height (p<0.05) and BMI (p<0.05); also a negative association was observed between left knee laxity and BMI (p<0.05). Overweight and obese men had less knee laxity than normal weight and underweight individuals. Elderly men and women (age 55 and above) had lower knee laxity (p<0.01) than young adults (ages 21–39).

Conclusion: These results suggest that age and body size are important factors in predicting knee laxity.

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1. Introduction

Increased knee laxity is a known predisposing factor for knee injuries, which is a major cause of chronic joint pain and degeneration [1–7]. Incidences of subsequent knee injuries are quite common among patients with a history of Anterior Cruciate Ligament (ACL) injury which is possibly due to the laxer knee [8,9]. Increased knee laxity measures have also been associated with a number of known medical conditions which include collagen tissue diseases and several types of metabolic syndromes [10–13]. As such, due to its importance, studies related to this subject have been conducted extensively [5–7,14–16].

Although a wide variation in knee laxity measurements have been observed in normal individuals, studies determining factors associated with this variation are not well established [17–19]. Efforts to ascertain these factors are especially important when considering that normal baseline data is required to determine abnormal knee laxities in individuals with related medical conditions. It has been described that knee laxity varies between populations, ethnic groups, gender and individuals [17,18,20–23]. Although it is generally accepted that Asians have increased joint laxity as compared to the western population, the marginal differences between the more specific ethnic populations especially among the multi-ethnic Malaysian population is still not well established [17]. This information is important especially in countries with a multi-ethnic population. This may inherently influence the measurement of knee laxity in many studies thereby affecting the accuracy of the reported data. In addition, the differences in geographical distribution may be associated with variations in demographic and anthropometric measures, thus a data of selected population within a selected geographical region may be different from those published in previous literatures.

A study was therefore conducted to determine the effects of demographic (gender, age, and ethnic group) and anthropometric (height, weight and body mass index) measures on the variation in knee laxity among the adult population from the different Malaysian ethnic groups.

2. Materials and methods

2.1. Materials

A total of 521 (294 men and 227 women) healthy Malaysian adults were enrolled for the present study. The volunteers were...
selected using convenience sampling consisting of visitors, staffs and students of University Malaya Medical Centre (UMMC) and University of Malaya from December 2009 to May 2010. University of Malaya was an appropriate site for subject enrollment as the students and staffs of this centre are representative of the population from various parts of this country. Subjects consisted of three major ethnic groups; Malay 325 (62.4%), Chinese 107 (20.5%), and Indian 89 (17.1%). This distribution of the population sampling mirrors the actual racial distribution in Malaysia which consist of 60.3% Malays, 22.9% Chinese, 6.8% Indians, and 10% from other ethnic groups [24]. The age of the subjects recruited at the time measurements were taken ranged from 15–74 years old. Approval from the University Malaya Medical Centre ethical committee was obtained prior conducting this study.

2.2. Methods

2.2.1. Subjects recruitment system

Subjects were briefed about the project before being interviewed to ensure that all the criteria for subject study recruitment were fulfilled. The inclusion criteria of subject recruitment were: i) aged between 15 and 75 years old, ii) no history of serious knee injury, known collagen or joint diseases, iii) no metabolic, endocrine, autoimmune, or connective tissue diseases, iv) no walking difficulty and deformity of the lower limb, v) women with regular menses (between 28 and 35 days per cycle) and were less than 7 days from the first day of menses or less than 8 days from expecting their menses and, vi) not pregnant. Informed consent was obtained from each subject prior to subject enrollment. A single observer who underwent prior training interviewed the subjects recruited for this study. A standard questionnaire was administered to record the socio-demographic characteristics of these subjects.

2.2.2. Physical examination

Anterior knee laxity was measured using a KT-1000 arthrometer (MedMetric, San Diego, CA). The method used to examine was in accordance to the instructions provided by the manufacturers of KT-1000 as previously described [25,26]. Subjects’ legs were flexed at 90° and supported by the supplied thigh support apparatus. The arthrometer was then placed on the leg with the patella and tibia sensor pad positioned on the patella and tibial tubercle respectively. Subjects’ hamstring tendons were checked to ensure the subjects were completely relaxed. The calibrator gauge was adjusted to the zero position. Then, an anterior force was applied. An average of three readings was taken from each knee. Body height was measured from the vertex across the mid-sagittal plane to the floor weight with the subject in a standing position. Weight was measured using a clinical weighing scale in a standing position. In order to eliminate inter-examiner variability, all measurements were performed by a single clinically trained examiner. BMI, defined as the ratio of weight in kilograms to height squared in meters, was calculated based on the data obtained.

2.2.3. Statistical analysis

The sample was separately analyzed by gender. Descriptive statistics for right and left knee laxity were calculated. A T-test was used to compare the knee laxity values between two groups; (i) men and women (ii) right and left knee laxities. Analysis of variance (ANOVA) was utilized to determine the effects of ethnic groups on knee laxity. Multiple linear regression analysis was applied to find the effects of age, height and BMI on the knee laxity. In multiple regression analysis, explanatory variables are assumed to be independent of each other. However, in some cases the explanatory variables were related to each other, creating a multicollinearity problem. To detect the multicollinearity problem among the explanatory variables, variance inflation factor (VIF) was used in this study.

a) If 0 < VIF < 5, there is no evidence of multicollinearity problem
b) If 5 < VIF ≤ 10, there is a moderate multicollinearity problem; and

Statistical analysis was carried out using SPSS software (version 15.0). Statistical significance was accepted at 5% level of significance.

3. Results

In this study, 521 subjects consisted of 294 (56.4%) men and 227 (43.6%) women. The majority of the subjects were Malay (325; 62.4%), followed by Chinese (107; 20.3%), and Indian (89; 17.1%). The age range of the subjects was between 15 and 74 years old with mean age of 33.15±12.67 years. The mean knee laxity value of Malaysian men was 3.47±1.41 mm (right knee) and 3.49±1.38 mm (left knee), and for women was 3.90±1.49 mm (right knee) and 3.67±1.34 mm (left knee). Among the Malay, knee laxity of women was significantly higher than that of men (p < 0.01). However, knee laxity for women was significantly greater (right knee p < 0.01 and left knee p < 0.05) than men (Table 1). There were no significant differences between right and left knees, being both positively correlated (p < 0.01) to each other for both genders.

3.1. Effects of ethnicity on knee laxity

Before using ANOVA to find the effects, two important assumptions underlying the model; normality of the distribution about their mean and homogeneity of group variances were examined using Kolmogorov–Smirnov and Levene test, respectively. The Kolmogorov-Smirnov and Levene test showed that there was no problem concerning the normality of the data distribution and the data were homogenous. Thus the data satisfied the important assumptions of the ANOVA model. ANOVA results exhibited that there were no significant differences in right and left knee laxity among the ethnic groups for both genders. Also, right and left knee laxity did not show significantly variation among the age groups for both genders.

3.2. Effects of age, height and BMI on knee laxity

Multiple regression analysis was applied to find the effects of age, height and BMI on knee laxity. Variance inflation factor (VIF) showed that there was no evidence of a multicollinearity problem among the predictors; age, height and BMI (Table 2).

Table 1: Mean differences in knee laxity (KL) between men and women by ethnic groups.

<table>
<thead>
<tr>
<th>Ethnic group</th>
<th>Gender</th>
<th>N</th>
<th>Left KL Mean</th>
<th>SD</th>
<th>Right KL Mean</th>
<th>SD</th>
<th>p-Value for knee difference</th>
<th>p-Value for gender difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malay</td>
<td>Men</td>
<td>210</td>
<td>3.51</td>
<td>1.33</td>
<td>3.41</td>
<td>1.38</td>
<td>0.225</td>
<td>Left, 0.01**</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>115</td>
<td>3.87</td>
<td>1.38</td>
<td>4.07</td>
<td>1.50</td>
<td>0.147</td>
<td>Right, 0.001**</td>
</tr>
<tr>
<td>Chinese</td>
<td>Men</td>
<td>45</td>
<td>3.43</td>
<td>1.35</td>
<td>3.70</td>
<td>1.37</td>
<td>0.175</td>
<td>Left, 0.274</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>62</td>
<td>3.59</td>
<td>1.33</td>
<td>3.77</td>
<td>1.41</td>
<td>0.233</td>
<td>Right, 0.399</td>
</tr>
<tr>
<td>Indian</td>
<td>Men</td>
<td>39</td>
<td>3.47</td>
<td>1.72</td>
<td>3.51</td>
<td>1.61</td>
<td>0.458</td>
<td>Left, 0.327</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>50</td>
<td>3.33</td>
<td>1.21</td>
<td>3.63</td>
<td>1.52</td>
<td>0.132</td>
<td>Right,0.360</td>
</tr>
<tr>
<td>All</td>
<td>Men</td>
<td>294</td>
<td>3.49</td>
<td>1.38</td>
<td>3.47</td>
<td>1.41</td>
<td>0.431</td>
<td>Left, 0.04*</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>227</td>
<td>3.67</td>
<td>1.34</td>
<td>3.90</td>
<td>1.49</td>
<td>0.062</td>
<td>Right,0.001**</td>
</tr>
</tbody>
</table>

*: 1% level of significance and **: 5% level of significance.
The coefficient of the regression line showed that there was a negative association between right knee laxity and age, height and positive relationship with BMI, but these associations were not statistically significant. Similarly, no significant relationships were found between left knee laxity for women with age, height and BMI (Table 2).

The knee laxity for men showed significant association with BMI (Table 2). For the further analysis, men sample was divided into four classes according their body size; underweight (BMI ≤ 18.5 kg/m²), normal weight (18.5 < BMI ≤ 25 kg/m²), overweight (25 < BMI ≤ 30 kg/m²) and obese (BMI > 30 kg/m²) for determining the association between knee laxity and body size. Post-hoc comparison (LSD) test was used to find the pair wise differences between knee laxity and the body sizes. Trends in knee laxity with increasing body size is shown in Fig. 1. The LSD test demonstrated that the right knee laxity of overweight and obese individuals had significantly (p < 0.01) lower than that of under- and normal weight individuals. Besides, a decreasing tendency was observed for left knee laxity with increasing body size (Fig. 1), and the LSD test showed that the left knee laxity of obese participants had significantly (p < 0.05) lesser knee laxity than that of under- and normal weight participants. These results reported that body size for men was an important indicator to predict the measures of knee laxity.

The sample was then classified into five different age groups to determine the effects of age group on knee laxity for both genders. Comparison between knee laxities of the age groups for both genders is shown in Fig. 2. An increasing trend was observed from the age group of 15–20 to 25–39. The knee laxity values then decrease from the age group of 25–39 to 55 and above for both knees and both genders (Fig. 2). The Post-hoc comparison (LSD) test showed that elderly men and women at the age of 55 and above had significantly (p < 0.01) lesser knee laxity (right and left) than those at the age of 21 to 39 years old. Except for male right knee laxity, young men and women at the age of 15–20 had significantly (p < 0.01) less knee laxity than those at the age of 25–39.

4. Discussion

The present study demonstrates a complex association between age, gender, body size, the side of knee and, the degree of knee laxity among the different ethnic groups in the Malaysian population. However, there were no significant differences in knee laxity among the various ethnic groups. In a more detailed analysis, it is suggestive that the associations between knee laxity and anthropometric measurements are namely dependent on the side of the knee and gender. In some studies it has been reported that women had laxer knees than men [17,30]. Nevertheless, other studies have shown that knee laxity of women only differ from men depending on the age groups; Dayal et al. found no significant difference in knee laxity between elderly men and women while few studies have shown greater knee laxity in young women than in young men [31–33]. To ensure reliable indicators and robust investigation was conducted, gender as a factor was taken into account with other variables during data analyses, i.e. different knee sides, age, BMI and ethnicity. In the present study it was found that the knee laxity of Malaysian adult’s women was greater than that of men.

4.1. Parameters control

In this study, a lot of effort were made to eliminate as much as possible other factors that could potentially affect the measurement including sports participation, differences in hormonal level, gender, race, history of knee injury/disease. The position of the measured knee was standardized at 90°. Studies [28,29] demonstrated that when the normal knee is positioned in 90 degrees of flexion, the patellar ligament is oriented posteriorly, and therefore a quadriceps contraction would not result in a false positive anterior tibial shift. Besides, other researchers reported that in the normal knee, there is no shear component when the knee is flexed between 60 and 90 degrees, which can further influence the outcome of the study. The position of the tibia when the quadriceps is contracted at this angle is independent of integrity of the ligaments and serves as a reference point to distinguish anterior from posterior tibial displacement, which is important to ensure an accurate knee assessment is done for normal knees.

In correlation with previous studies, we found no significant differences between right and left knee, being both positively correlated (p < 0.01) to each other, in both sexes. Our previous published report...
observed that neither the ‘involved minus uninvolved’ (I-U) differences nor left-right differences nor the “leg dominance” (being referred to being equal to handedness or hand dominance) were of any consequence to the study of knee laxity or the discrepancy in measurement of normal adult knee laxities i.e. of the ACL.

4.2. Variations in knee laxity values of different age groups

Reports of previous studies were compared to the data obtained in the present study. The association between age and knee laxity appears to be conflicting [17,30,34,35]. Report from a study showed that age does not appear to influence knee laxity while there are studies showed negative and positive associations between joint mobility (laxity) and aging [17,30,34,35]. In the current study, further analysis was also conducted based on the different age groups. Knee laxity appears to be decreasing in age groups of ≥55 for both men and women. The distribution pattern for knee laxity in men and women in any age groups appears inconsistent and random. The reasons may have been the result of the different levels and types of activities conducted by the individuals within the different age groups. Based on Fig. 2, we can hypothesize that an increase in knee laxity may be associated with flexibility, which is a well-known measure of fitness [36]. The findings of the present study appear to support our assumption, as it is evident that knee laxity appears to be higher in the young adults (age 21–39). In men, this observation was seen in individuals from the age of 21 to 54 while in women, increased laxity were between the ages 21 and 39. The laxity value decreases after the age of 54 (for men) and 39 (for women), indicating that the knee ligaments are becoming increasingly stiff with aging. Although not analyzed here in the present report, coincidentally it was found that there was a marked reduction in levels of active sports participation in age groups above those described here. The associations between exercise and knee laxity have been well documented, which may explain the findings of the present study [37–39].

4.3. Comparison of knee laxity values between genders of different age groups

Comparisons between genders within these age groups were made. It was found that younger women aged between 21 and 24 years have higher left knee laxity than men; while between the age of 25 and 39, women had higher right knee laxity than men (Fig. 1) [32,33]. At ages below 21 and above 39, no significant differences were noted between genders. These findings are not always consistent to that previously reported; no significant difference in knee laxity between elderly men and women (64 ± 11 years) was observed in a study while another study reported that women have higher joint laxity than men at any age group [30,40]. The effects of aging on the joint mobility can be explained at the molecular level. Aging is believed to be associated with an increased number of intra-molecular and intermolecular cross-links that apparently restrict the ability of collagen molecules to slip past each other; thereby reducing joint mobility. Besides, increase in the diameter of collagen fibers with aging causes the structure to be more resistant to stretching [41]. Tensile strength reaches a plateau after collagen maturation and then declines with age [41]. Amount of glycosaminoglycan (GAG) and water volumes also reduced as the age increases, which leads to reduction of the critical fiber distance between collagen fibers [42]. Connective tissue fibers will come into contact with each other and eventually stick, thereby encouraging the formation of abnormal cross-linking which results loss of extensibility and increase in tissue stiffness [43,44]. Studies have demonstrated different observations when comparing knee laxity with aging. Beighton et al. (1973) showed joint mobility (laxity) diminished with aging. On the other hand, Noyes and Grood (1976) and Nachemson and Evans (1968) reported that knee laxity was directly proportional to age [34,35].

4.4. Associations of age, height, BMI and knee laxity

Previous studies have shown a relationship between anthropometric measures with knee injuries [3,6,14,45–48]. In men, right knee laxity appears to be reduced with the increase in age, height and BMI while in the left knee laxity, a reduced laxity is observed with the increase in BMI. There appears to be a strong association between knee laxity and BMI, influenced mainly by gender. In men, there appears to be a negative association while in women, a positive association was observed, though it was not statistically significant. Results from multiple regression analysis showed complex associations between knee laxity, age, height, and BMI for both genders. Despite the robust finding of this study, a direct association between knee laxity and anthropometric measurements could not be established which was, similar to that reported previously by other investigators. Kamarul et al. (2007) has shown that height, weight, and age are not predictors of knee laxity. The LSD test in the present study demonstrated that the knee laxity of overweight and obese individuals had lower than under and normal weight individuals. Increased BMI has been implicated by several studies as a risk factor for ACL injuries, especially among the females [3,46–49]. However, BMI alone may not be directly associated to increased risk of ACL injuries, [7,31,50].

4.5. Effects of ethnicity on knee laxity

When ethnicity was considered as a possible predictor for increased knee laxity, no association could be established suggesting that there are no differences in knee laxity in the different ethnic groups within the multi-ethnic Malaysia population. This finding is not consistent to that previously reported. A study conducted by Seow, Chow et al. (1999) on the multi-ethnic Singaporean population demonstrated that Malay had the highest joint mobility, followed by Chinese and Indians. In contrast, the report from Kamarul et al. (2007) on similar Malaysian population showed that Chinese has the highest knee laxity among other ethnic groups, although it can be argued that the study reported here had low number of recruits. However, when absolute data was compared to that published previously, our data appear to correspond well to that of the Malaysian and Singaporean populations. These findings did not however, exclude the differences in knee laxities amongst the population of different regions of the world, e.g. Asian versus Europeans. When comparisons were made between our data to that which have been obtained in Western societies, remarkable differences in knee laxities were observed; 3.66 mm (present study), 10.9 mm (Native Canadian) [18] and 5.2 mm (Swedes) [25]. This finding suggests that the demographic distribution of a population and the degree of differences in ethnicity may exist and is therefore worth investigating.

4.6. Study limitations

There were several limitations observed in this study. Unlike some other studies, we only focused on the assessment of the ACL. This is because ACL is the more frequently injured ligament of the knee presented in clinical practice [51–58]. A report indicated an incidence of 0.38 ACL injuries per 100,000 individuals [59,60]. In United States, approximately 80,000 to 100,000 anterior cruciate ligament (ACL) repairs are being done each year [61]. Anatomically, PCL is the strongest knee ligament and is approximately twice as strong as the ACL [62]. This explains why the ACL is 10 to 20 times more prone to injury than PCL. [52]. Besides, we felt that it is not necessary to analyze both the ACL and PCL, since all the factors contribute to ACL laxity should have had the same effect on PCL laxity.

Generalized laxity assessment such as the Beighton Hypermobility score system was not incorporated in this study. However, in our defence, we felt that the Beighton score was itself not a validated scoring system and that by doing so it would not have contributed
further to the findings of our study. In addition, this would also be beyond the scope of the reason for this study which is to determine, with the focus being, the degree of knee laxity among the general population.

Certain factors that contribute to ligamentous laxity was not considered or tested in the present study. These included factors such as genetic predispositions, level of fitness, effects of exercise and certain hormonal levels, in particular sex hormones e.g. oestrogen. Although studies have shown that hormonal level has a significant effect on knee laxity, measuring the level of sex hormones will not only significantly increase the cost of this study but also indirectly result in a decrease in the sample size [62–65]. Although hormonal level measurements were not included in this study, we did consider this in our inclusion criteria in order to minimize the wide degree of sex hormones level in our sample by excluding women who were pregnant and those who were in their mid-cycle of their menses. Several studies proposed that changes in the knee laxity are due to the changes of women sex hormones (e.g. estrogen) throughout the menstrual cycle, peaking during the ovulation phase which alters the collagen and elastin composition of the anterior cruciate ligament that may affect its overall structure and biomechanical properties that could predispose it to injury. Release of relaxin hormone during the menstrual cycle also may result in collagen remodeling which reduces soft tissue tension [62–66]. Other factors which include anatomical variations within individuals, level of activities and dynamic neuromuscular imbalances have been related to the difference in knee laxity value between genders and should be investigated concurrently [64].

5. Conclusions

The present study illustrates the complex relationship between several intrinsic factors i.e. height, weight, age and BMI, with knee laxity among the normal Malaysians population. It is generally found that women had laxer knees than men. Elderly men and women had lower knee laxity than young adults. In men, right knee laxity was shown to have negative associations with age, height, and BMI; while in the left knee laxity is negatively associated to BMI. Obese and overweight men had lower knee laxity than normal and underweight men. The knee laxity for women did not show any relationship with anthropometric measures. Ethnicity does not appear to be a predisposing factor for increased knee laxity.

6. Conflict of interest statement

All authors declared that there were no conflicts of interests in relation to this study.

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