Normal Anterior Cruciate Ligament Laxity in the Malaysian Population

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ABSTRACT

A study to determine average knee laxity in the Malaysian population and how it affects daily living was conducted at the University Malaya Medical Centre between January and April 2004. Fifty two male and 76 female subjects were recruited for this study, all of whom were healthy volunteers with no ambulatory problems. Side to side knee laxity testing was performed using a KT-1000 arthrometer. Significant differences in knee laxity were noted among different races and between sexes. For instance, overall, Chinese and female study participants had higher knee laxity: (left knee, 2.17 mm (SD=1.30) and right knee was 2.88 mm (SD= 1.51)). On average, the difference between knees was 0.70 ± 1.26 mm (less than 1 mm) which is a smaller variation than reported in previous studies which suggested 3 mm. Despite finding knee laxity ranging from 0 to 8mm, no correlations were found between Lysholm, IKDC and Tegner knee outcome scores and the degree of knee laxity. No other predictors such as height, weight and age correlated with levels of knee laxity. We therefore conclude that knee laxity is a common occurrence in the normal population and is therefore not suitable as a sole predictor of knee function and should not be used as the only criteria for surgical intervention.

Key Words:
ACL laxity, Arthrometer measurement, Normal knee laxity

INTRODUCTION

Ligamentous laxity is a genetically determined component of overall joint flexibility that is not readily altered by passive or active stretching[1]. Of the joints affected by this condition, the knee joint is most likely to be injured due to its laxity[1,2]. Whereas joint laxity may be advantageous in sports requiring good flexibility such as gymnastics, it can be potentially dangerous in contact-sports like football. The relation between ligamentous laxity and the overall occurrence of injury has not been examined in controlled trials, and studies published to date demonstrate conflicting results. For example, ligamentous laxity has been shown to result in a greater likelihood of knee ligament rupture in professional football players, but there is no documented relation to similar occurrence or type of injury in college and secondary school athletes[3,4,5]. Despite these contradictions, the predictive value and awareness of anatomical factors that increase this risk is extremely important. If this is achieved, clinicians will be increasingly able to develop individual rehabilitation programmes and pre-participation sports screening so as to decreasing the risk of injury; additionally, practitioners will then be better able to predict the sports at which athletes can best perform, and steer them away from potentially harmful activities[2].

Although there have been reports of higher incidences of joint laxity among Asians as compared to the western population, succinct differences between the more specific ethnic populations have not been established[6,7,8]. Without this information, it is impossible to determine the true incidence of joint laxity amongst the different Asian races. Although it is not known whether this physiological joint laxity present in the Asian population affects activity of daily living (ADL), it is a well established fact that in the presence of ligamentous injury, walking ability and ADL are significantly reduced[6].

The aim of any surgery to treat knee laxity that results from traumatic rupture of ligament(s) is to restore knee kinetics to its pre-injury state by trying to achieve the "tightest" possible repair with hopes that the reconstruction of the torn ligament(s) will be the perfect biological replacement[7-13]. In order to establish that such surgery is successful, objective assessments should be performed that compare the laxity of the operated knee over time or to the opposite knee (which is assumed to be normal)[8-10,19]. However, this technique may be flawed due to the fact that determination of any normality must use normal baseline values as a reference. It is

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therefore of paramount importance that normal knee laxity values be established. Thus, the aim of this study is to determine normal knee laxity among the Malaysian population so that norms are known and can facilitate objective assessment, to also determine whether knee laxity impacts activities of daily living in this population.

RESEARCH METHODS

One hundred and twenty eight (n=128) healthy volunteers were recruited for this study from University Malaya Medical Centre, Kuala Lumpur, Malaysia between January and April 2004. Subjects were randomly selected from the Orthopaedic follow up clinic and consisted of hospital staff, students and visitors. In order to ensure that only normal subjects were recruited, strict selection criteria were utilized; potential subjects were excluded if they reported history of knee injury, known collagen disease or joint disease, active sports participation, chronic illness or history of previous accident. Female subjects were included only if they reported regular (between 28 to 35 day cycles) and predictable menses and were less than 7 days from the first day of menses or less than 8 days from expecting their menses.

All subjects were interviewed and examined by a specifically trained technician who underwent more than 4 weeks of training by an Orthopaedic Surgeon. Subjects were clinically accessed for joint laxity using the Beighton scoring system, a 10 point system testing for laxity of the fingers, wrists, elbows, knees and spine[8,9]. A simple questionnaire inquiring about subjects' age, occupation, hand dominance, patients' perception of leg dominance and medical history including any history of trauma, was administered. Three knee outcome/activity specific scores (Tegner, Lysholm and the International knee documentation committee (IKDC) knee scores) were also calculated. These scoring systems introduced in the mid 1980s, are used to rate knee function and activity, and are focussed on determination of the degree of knee laxity[16,17]. More recently many other conditions are also assessed using these scores[17]. The IKDC however, was updated in 2000, and is the most comprehensive as it utilizes subjective and objective measurements to analyse knee function[22].

Traditionally, knee laxity has been assessed via clinical evaluation, but problems with inter-rater variability, poor repeatability and subjective assessment errors results in clinical examinations being overly subjective for the measurement of knee laxity[6-10]. The use of a standard measurement device is therefore appropriate and desirable for knee laxity calculations. It is well established that even among expert surgeons, there will be a significant scatter of data when testing manually as compared to using arthrometer data[18]. Although a number of arthrometers are available on the market, the two most established, portable and easy to use models are the KT-1000 arthrometer by MedMetric and Knee Laxity Tester by Stryker Orthopaedic Systems[19]. We chose the KT-1000 arthrometer was because it is widely used and has been extensively referenced in the literature. Even though this device can also be used to measure posterior knee laxity (posterior cruciate ligament) if used in a modified manner, we only determined anterior translation of the knee because anterior laxity is more easily determined using the KT-1000 and also because the most common presentation of knee laxity requiring surgery is mostly due to ACL laxity. Furthermore, as has been described in published studies, most laxities of the knee joint are found to be caused by ACL laxity[10,11].

Following the interview, knee laxity was measured using the KT 1000 arthrometer to detect anterior tibia translation. Knee laxity is defined as anterior translation of the tibia in relation to a fixed position of the unilateral femur. Knee laxity is not defined by comparing the differences between anterior translations of the tibia of one knee with that of the opposite knee and therefore should not be confused with the correct definition. All measurements using the arthrometer were performed by the designated operator (who also administered the questionnaires and examined the subject) who was trained as described earlier in this article. Side to side knee testing was performed on the examination table using the KT 1000 on all subjects. Subjects were asked to lie supine with the knees flexed at 90^{o}. A leg rest was placed underneath the feet to fix the position of the lower limbs. Subjects were asked to relax and consciously take deep breaths to prevent sudden contractions of the hamstring muscles. Test results were discarded if contraction of this muscle group was present during the test. While the technician applied anterior force by slowly pulling the handle of the KT-1000 using one hand, the other hand stabilized the equipment onto the patella as per instructions for use. The test was discontinued if subjects complained of pain during testing. The measurement is recorded when notification is given indicating that 20 lb of force has been applied. An average of three readings was taken from each knee. Testing was performed as per the description provided by Daniel *et al.*[20]. Data were analyzed using statistical software SPSS 11.0.

RESULTS

All 128 normal healthy subjects recruited in this study were screened and carefully selected. There were 52 male and 76 female subjects of whom 68 were Malay, 22 Chinese and 38 Indian. Subjects' ages ranged between 16 to 72 years with an average of 33.86 years for male and 39.23 years for female. The average height for male subjects was 168.67 cm and 154.43 cm for females. The average weight for male subjects was 65.28 kg and 58.99 kg for females. In our statistical analysis, we made no assumption of a normal distribution due to the limited number of subjects within each group, especially amongst the Chinese and Indian

Table 1: Mann Whitney U tests comparing the knee laxity of the different races.
*P values were significant at value less than 0.05.

Mann Whitney U test comparing different races	Average left (p value)	Average right (p value)
Malay-Chinese	0.020*	0.004*
Chinese-Indian	0.021*	0.011*
Malay-Indian	0.544	0.894

Table 2: Comparison of the mean knee laxity of both knees of different sexes.
Note that the difference between both knees is less than 1 mm.

	Sex M Mean (mm)	F Mean (mm)	Difference (mm)
Average Left	1.95	2.32	0.37
Average Right	2.54	3.10	0.56
Difference (mm)	0.59	0.78	

Table 3: Comparison of the mean knee laxity of both knees of different sexes.
Note that the difference between both knees is less than 1 mm.

Sex	Mean difference between right and left knee (mm)	Std. Deviation/SD (mm)	Range of knee laxity present in our study Upper limit	Upper limit
Male (*n*=52)	0.59	1.22	-0.63*	1.81
Female (*n*=76)	0.78	1.29	-0.22*	2.07
Total (*n*=128)	0.70	1.26	-0.56*	1.96

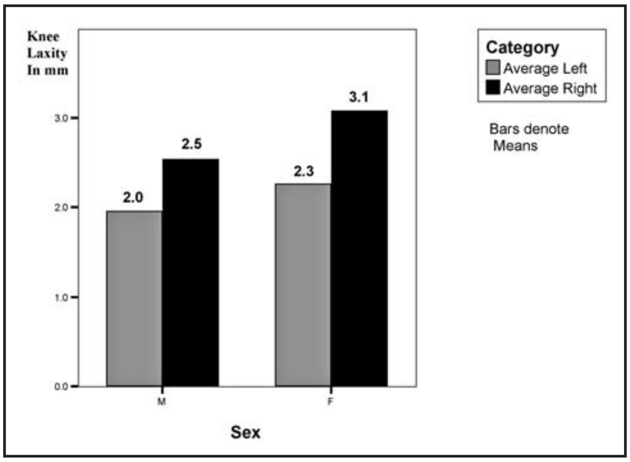

Fig. 1: The amount of knee laxity in mm comparing the each knee and gender.

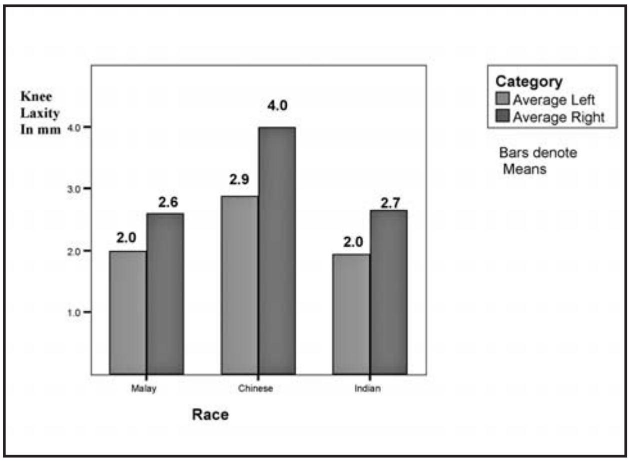

Fig. 2: The distribution of knee laxity (in mm) comparing the right and left knees of the different races.

participants. As a result, non-parametric tests were employed throughout. We also attempted evaluation of results using comparable parametric tests at the end of our analysis and found no significant differences in our result outcomes between these two sets of tests.

ACL laxity ranged between 0 to 8 mm for right knees and 0 to 6 mm for left knees. The average knee laxity for men was 1.95 mm (SD=1.19 mm) on the left side and 2.54 mm (SD=1.41 mm) on the right. Knee laxity was generally noted to be higher in females as compared to male subjects with the average left knee laxity of 2.32 mm and right knee laxity of 3.10 mm. Using both the T-test and Mann Whitney U test to compare knee laxities between males and females, significant differences were noted for both knees ($p \leq 0.05$).

There were also statistically significant differences noted in knee laxity of the different races (Fig. 2). Using Kruskal-Wallis H test, p value of < 0.05 was attained for both knees. In subsequent Mann Whitney U tests comparing the different races, significant differences were noted when we compared results for Chinese subjects to those of Malay and Indian subjects, but no significant difference was found when we compared mean knee laxity between Malay and Indian study participants (Table I). Compensation using Bonferonni correction methods did not alter the outcome of statistical analysis.

The mean differences of both knees in both sexes were 0.59 mm for males and 0.78 mm for females and the mean differences between the laxities of both knees between the different sexes are presented in Tables II and III. For calculation of the normal range of knee laxity, a standard deviation with a 95% confidence interval was added to the mean values. Note that a range of knee laxity difference is presented as the lower and upper limits in Table III. These values represent the normal range (with 95% confidence) for knee laxities in our study population. We found that 21.1% (n=27; 12 males and 15 females) of subjects presented with more laxity in the left knee than in the right knee, 71.1% (n=91; 57 males and 34 females) demonstrated greater laxity in the right knee and the remaining 7.8% (n=10; 6 males and 4 females) were found to have no laxity difference between both knees.

Spearman correlation test revealed p-value of > 0.05 in tests using the Tegner, IKDC and Lysholm scales in terms of laxity of both knees thereby indicating no correlation between the degree of knee laxity and knee function. There was also no significant correlation between knee laxity and age, height or weight (Spearman test; P >0.05). We were also not able to establish a correlation between Beighton laxity scores and the degree of knee laxity (Spearman test; P >0.05). Use of the Kruskal-Wallis test also revealed no significant differences between knee laxity and various occupations of study participants (P value > 0.05).

DISCUSSION

We found that knee laxity, as determined by measuring the millimetres of tibial translation using the KT 1000 arthrometer, was significantly greater in Chinese and in female subjects. Although previous published studies have not reported higher incidence of knee laxity in certain races, they have noted increased knee laxity in women[12]. It is postulated that this might be due to the inadequate protective ability of the quadriceps musculature in women to resist anterior tibial translation[12]. Furthermore, female hormone levels in women apparently have substantial influence on joint laxity[12-18]. As described in our methods, we were particularly cautious when recruiting female subjects as it is known that joints tend to be laxer during certain stages of the menstrual cycle. It has been reported that ACL laxity is influenced by hormonal changes during the menstrual cycle, peaking between Day 11 to 17 from the first day of menses. In order to prevent biased reporting of knee laxity when comparing the measurements attained between the different sexes, we were careful to exclude women that would be expected to have more knee laxity due to hormonal influences. Hence only women with history of regular menses and who were in the early days of their menses or close to the date of expecting their menses were included in this study. Women who were pregnant were also excluded form this study as they are known to have increased joint laxity. In excluding women according to these criteria, we thought perhaps that differences in the degree of knee laxity between women and men would not be significant. However this was not the case, as women in this study generally demonstrated higher levels of knee laxity than men (Fig. 1, Table II). Our findings of increased joint laxity among women are supported by previous reports[12-19].

Next, we compared our results to those described by Daniel et al in determining knee laxity in the normal population[20]. Contrary to our expectation that Asians have laxer joints than other populations, we found that our subjects had a mean laxity which was lower than the American population (current study, Asians, average: 2.6 mm; SD=1.4 mm. Americans, average: 5.3 mm; SD=1.6 mm, both at 20lb of applied force).

The differences in laxity levels between each subject's own knees, also known as "involved minus uninvolved difference" (I-U) were also different in our study population as compared to other studies. It has been recommended than an abnormal I-U is noted when the difference is more than 3 mm, applicable in either knee[19,20]. We found that identifying which knee is laxer was an important factor to be considered in determining normal knee laxity, as our results showed that for 70% of study participants, their right knee was laxer than the left. Furthermore, from the range we provided in Table III and taking into account that arthrometer readings are rounded to the nearest 0.5 mm, the I-U difference in individuals with laxer left knees was not more than 1mm but in individuals with laxer right knees, the difference was up to 2.5 mm. These values were lower than those found in Western study populations and are a consideration when analysing results of this local study[20-22]. Clinical practice guidelines suggest only an I-U difference of more than 3mm is abnormal (i.e., patients have a cruciate ligament tear). In comparison to our study, this value is above those attained in our experiment making this assumption questionable[6,8,10,12,15,18,20]. Based on our results, we therefore suggest that criteria used to define abnormal knee laxity (or ACL tear) should be reviewed and re-examined.

The striking difference of our findings that the right knee generally has a higher degree of laxity than the left, should be considered in discussion about whether the concept of leg dominance is valid and should also be taken into account when assessing knee laxity in general. However we were not able to confirm the existence of leg dominance, as we found no direct correlation between knee laxity levels and patients' perception of leg dominance. In addition, we were not able to prove that knee laxity is correlated with lower limb strength. The Beighton score did not correlate with the degree of knee laxity, a similar finding to previous studies[10].

Instrumented measurement of knee motion can assist the clinician in the diagnosis of an anterior cruciate ligament (ACL) or posterior cruciate ligament (PCL) disruption, and also provides documentation of the amount of pathologic laxity, which can aid determination of which patients may benefit from ACL reconstruction. Arthroscopy using autografts is the method of choice for most ACL reconstruction procedure and standard practise dictates that maximum tension is applied to the autograft as it undergoes final fixation[12,15]. It is believed that the tension created in the grafts will decrease anterior knee translation thus reducing knee laxity[7]. A 'good' ACL reconstruction is said to have lesser knee laxity denoting the need for a "tight" fixations[8,9,10,12,14]. It is therefore standard practice to assess for knee laxity at subsequent follow up so as to ensure that failure of grafts does not occur[7,8,10]. We share the opinions of other authors, such as Canon and Stone, that data published related to knee laxity and knee ligament surgery outcomes (namely ACL and PCL) must include arthrometer measurements, and we also note that the process of gathering and interpreting arthrometer data must be meticulously and carefully performed[8,9,19,20].

Regardless, using an arthrometer can indicate the success of an ACL reconstruction if the patient's normal joint kinetics are restored. It is also important to note that in most cases, hamstring and bone-patellar-bone grafts used in ACL reconstruction would stretch over time resulting in increasing laxity of the knee[7,8]. This phenomenon known as "stress-relaxation" is the reason why serial knee laxity measurement must be performed for at least 6 months following surgery to ensure that final graft stretching is attained as reflected by the knee laxity measurement[11,17,19,20].

There were limitations to the present study in that our sample was not a heterogeneous population sampling. Although, statistically significant, a larger population sampling would result in a more accurate average of knee laxity of the Malaysian population. Furthermore, larger subject recruitment and a stratified population sampling would ensure better data representation. Our arthrometer measurement also did not include 30 or 40 lb anterior force measurements (as recommended in the literature) because after applying a force of 40 lbs. to the first ten subjects, our subjects complained of anterior knee pain (mostly on the skin where force was applied)[19]. As result, we were not able to compare knees laxity at forces greater than 20 lb as described by Canon[19]. Canon's recommendation for the use of 40-lb force may not be applicable for our local population. Ideally, in order to ensure that knee laxity is not influence by hormonal changes, blood sampling to detect levels of oestrogen and progesterone should be conducted in all subjects (especially female), however, this would have increased the cost of our study beyond our current means. Future studies, should include such blood samples in their protocol to ensure that hormone levels do not skew knee laxity levels.

CONCLUSION:

Results of this study find that in the Malaysian population, the right knee is laxer than the left knee, with differences up to 2.5 mm in individuals in those subjects whose right knee was laxer, and 1mm if the individuals' left knee were laxer. Previous recommendation that more than 3 mm of laxity difference between both knees is a defined as abnormal knee laxity should therefore be reassessed in light of this new information. Chinese and female subjects had the highest levels of knee laxity denoting the importance of race and sex as a consideration when determining normal knee laxity in any population. We must remember however, that increased knee laxity is not necessarily an indication of poor knee function.

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