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THE STATUS OF STABILITY OF THE MEDIAL AND LATERAL COLLATERAL KNEE LIGAMENTS OF PRE-PUBESCENT, PUBESCENT, AND POST-PUBESCENT WOMEN

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THE STATUS OF STABILITY OF THE MEDIAL AND LATERAL COLLATERAL KNEE LIGAMENTS OF PRE-PUBESCENT, PUBESCENT, AND POST-PUBESCENT WOMEN

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CHAPTER 1

INTRODUCTION

The knee joint is formed by the articulation of the distal end of the femur and the proximal end of the tibia. The articular surface of the tibia is almost flat, but the two menisci which rest upon the tibia furnish the concavities within which the convex condyles of the femur move.[1]

The two bones articulating to form the knee joint are bound together predominately by two types of attachments, the ligaments and the muscles via their tendinous attachment. The ligaments serving to bind the articular surfaces of the tibia and femur are the medial and lateral collateral ligaments and the anterior and posterior cruciate ligaments. The other ligaments of the knee are functional in securing the patella and the menisci to various structures of the joint.[2]

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[1]M. Gladys Scott, Analysis of Human Motion (New York: Appleton-Century-Crofts, 1963), p. 39.

[2]Philip J. Rasch and Roger K. Burke, Kinesiology and Applied Anatomy (Philadelphia: Lea and Febiger, 1963), p. 269-275.

The muscular structures that reinforce this anatomically unstable joint are predominantly the quadriceps group and the hamstrings group. The quadricep muscles cover the entire anterior aspect of the thigh and converge to attach into the patella with some fibers of the aponeurosis extending medially and laterally to become continuous with the fascia of the leg. The hamstring muscles run from the posterior aspect of the femur and the pelvis to below the knee and insert via tendinous attachments on either side of the joint. The fact that the internal hamstrings pass around on the medial side of the upper tibia to attach on the anterior aspect gives a lateral stabilization component to the hamstrings. They also aid in preventing anterior displacement of the tibia on the femur.[1] Illustrations of the basic structures of the knee are presented in Appendix A.[2]

Allan J. Ryan, in Klein and Hall, referred to the knee as the "most vulnerable point of the athlete's anatomy."[3] The knee joint has been widely acclaimed by many authors as a vulnerable joint from the standpoint of lack of stability in performance and as an injury potential.

The knee joint is a uniaxial joint with anterior and posterior excursions being the normal pattern of movement. Most knee injuries are incurred when the knee is forced to move in a lateral plane. The medial

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[1]Don H. O'Donoghue, Treatment of Injuries to Athletes (Philadelphia: W. B. Saunders Company, 1962), p. 432.

[2]Rasch, op. cit., p. 271-273.

[3]Karl K. Klein and William L. Hall, The Knee in Athletics (Washington, D. C.: American Association for Health, Physical Education, and Recreation, 1963), p. iii.

and lateral collateral ligaments seem to be the major line of defense in preventing abnormal lateral excursions of the knee.

With an understanding of vulnerability and the prevalence of injury involving the knee joint, it is evident that more research is needed to provide a better understanding of the knee structure in general and the medial and lateral collateral ligaments in particular as they evolve through the sequences of growth and development of the human organism. Stability of the ligaments in any given joint area seems to be directly related to the integrity of that joint. The importance of ligamentous stability is widely accepted, yet substantiated factual information regarding the status of the collateral knee ligaments is very limited. Also, information concerning the change in ligamentous stability from one physical maturity group to another is lacking. Because of this void in professional literature regarding ligamentous stability of the knee joint at various levels of physical maturity among women, this study was undertaken.

Statement of the Problem

The problem of this study was to measure objectively the medial and lateral collateral excursions of the knee in an attempt to determine ligament tension in three maturity groups of women subjects. More specifically, the study was concerned with three questions:

1. What is the status of the stability of the medial and lateral collateral knee ligaments in a pre-pubescent group, a pubescent group, and a post-pubescent group of women subjects?

2. What are the relationships between the right and left medial and lateral collateral knee ligaments for the selected groups?
3. Do the relationships change from one physical maturity group to another?

The basic purpose of this study was to observe and describe the status of the medial and lateral collateral knee ligaments of three selected physical maturity groups of women subjects, and to assess the potential of the knee to withstand exercise and activity programs prescribed for the various age groups of female students. Another purpose of this study was to supplement the information concerning the knee which could be used as a basis for understanding the principles related to the injury potential of the knee joint.

Definition of Terms

Some of the more important terms used in this study have been defined to insure a more complete understanding of the material presented:

Medial Collateral Ligaments are those broad fibrous bands that cross the medial side of the knee joint from the femur to the tibia. They are fused with the medial meniscus.

Lateral Collateral Ligaments are those cord-like ligaments that pass from the lateral epicondyle of the femur to the head of the fibula.

Ligamentous Stability is a state in which the ligaments of the knee were sufficiently substantial to prevent abnormal movement of the knee joint particularly in a mediolateral plane.

Pre-pubescent Group was a group of women subjects who ranged in age from 6 years to 8 years.

Pubescent Group was a group of women subjects who ranged in age from 12 years to 14 years and 6 months and who started their menstrual cycle within the six months immediately prior to the onset of this study.

Post-pubescent Group was a group of women subjects who ranged in age from 17 to 20 years and who started their menstrual cycle between the ages of 12 and 14 years of age.

Related Research Studies

Most research directly related to the stability of the medial and lateral collateral ligaments of the knee were conducted and reported by Klein.[1] The majority of his data were presented from findings obtained from men; however, his data do include findings obtained from a group of women. Klein found that during the age levels of eight through thirteen there was a gradual significant increase in collateral ligament tension with brief periods of noted fluxation. By and large, the ligaments maintained their relative positions within the age group from eight to thirteen.[2] In the age group thirteen to fourteen, Klein

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[1]Karl K. Klein, "Strength Maintenance Following Specific Rehabilitation, Validation of a Specific Rehabilitation Apparatus and Exercise Potential Related to Injury Potential" (unpublished Research Paper presenting findings of an investigation supported, in part, by a research grant, Number RD 446 from the Vocational Rehabilitation Administration, University of Texas, 1963).

[2]Ibid., p. 74.

found a sharp increase in collateral ligament looseness which he felt might be associated with the onset of pubescence. At the age levels of fourteen to sixteen, he found no significant difference between the tension of the individual ligaments but he found that the right and left medial as well as the right and left lateral ligaments had changed their relative positions as compared to the original levels at eight years of age.[1]

In an attempt to find a partial explanation of the gradual significant increase in collateral ligament tension during the growth years, Klein studied age group knee X-rays of women with special emphasis on measuring and recording the femoral shaft and medial condyle growth increments. The illustrative presentation of the findings are presented in Figure 1.[2] It was noted that there was a gap of age group growth information for ages six, seven and eight years. This was due to the inability to locate age group X-rays for this level.[3] As judged by the patterns of growth demonstrated, this may offer a partial explanation for the increase in collateral ligament tension during the growth years.

For the college age group, Klein found a significant increase in ligament stability. For this age group there was no change in the relative stability of the various ligaments.[4]

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[1] Ibid., p. 76.

[2] Ibid., p. 61.

[3] Ibid., p. 76.

[4] Ibid., p. 77.

Organization of the Remainder of the Dissertation

The remainder of the dissertation will be presented in the following order: Chapter II explains the design and procedure of the study; Chapter III deals with the presentation, analysis and interpretation of data; and Chapter IV includes the summary, conclusions and recommendations for further study.

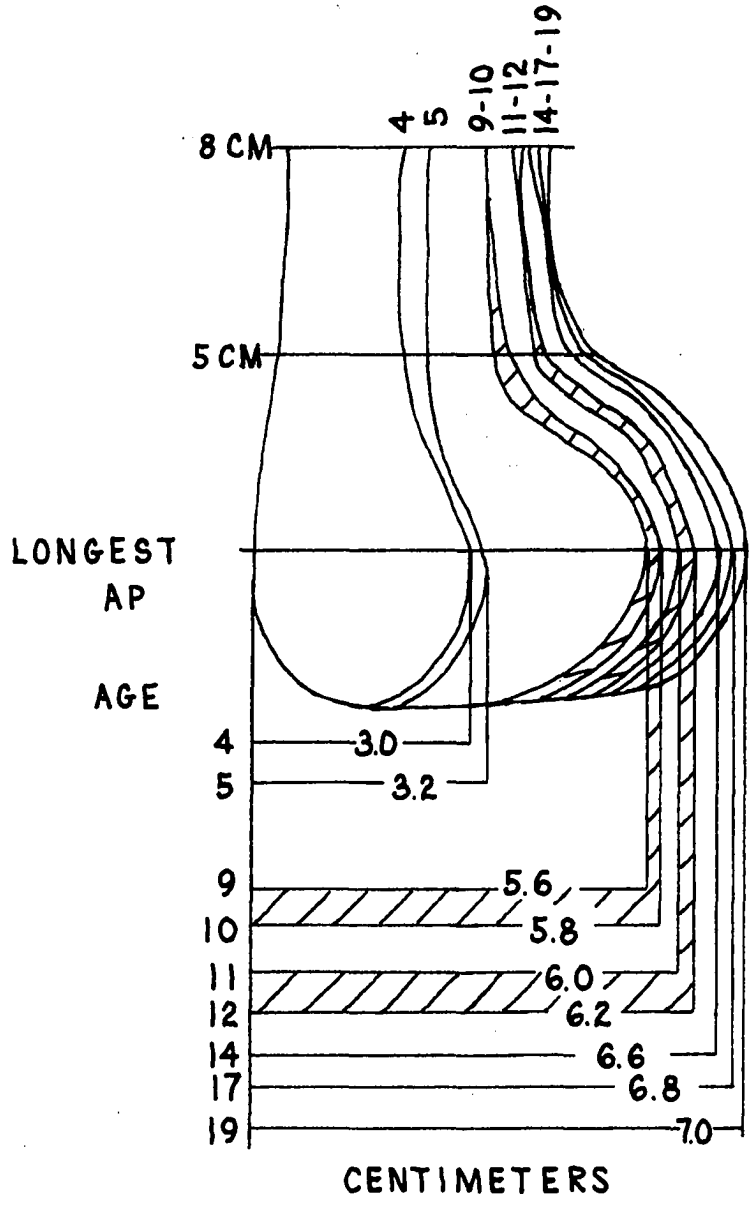

Figure 1.--Femoral condyle growth increments of women.

CHAPTER II

DESIGN AND PROCEDURE

Selection of Subjects

In order to establish three distinct maturity groups and to eliminate as many factors as possible that might influence or affect the data as not being representative of similar maturity groups, the following criteria were used for the selection of subjects:

1. The subjects were representative of one of the maturity groups used in this study. For the pre-pubescent group, they were from 6 years-0 months to 8 years-0 months. For the pubescent group, they were from 12 years-0 months to 14 years-6 months and must have started their menstrual cycle within the last six months. For the post-pubescent group, they were from 17 years-0 months to 20 years-0 months and must have started their menstrual period between the ages of 12 to 14 years.
2. The subjects were in reasonably good health and not recovering from any recent illnesses as determined by verbal consultation.
3. The subjects were free from structural or functional disorders of the knee as determined by verbal consultation.

4. The subjects were free from injuries to the knee that resulted in any significant damage to the knee structure as determined by verbal consultation.

The students at Clyde Howell Elementary School, Edmond Junior High School and Central State College were made available for the testing procedure. There were sufficient numbers available to fulfill the requirements for selection as set forth in number one of the criteria for selection of subjects.

The writer, with three assistants, met with all subjects and explained the purposes of the study and demonstrated the actual testing procedure. The potential subjects were then asked to report to a room that had been set up for the pre-test selection. See Appendix B for the physical layout for the subjective ratings and instructions to the subjects. The potential subjects were evaluated for fulfilling the remaining criteria for the selection of subjects. In addition to collecting the information directly related to the study, each subject's height and weight were recorded. This information was ascertained in order to be utilized in a cooperative study with another investigator.

A score card was used for recording the information of each subject. See Appendix C for a sample score card. After evaluating each prospective subject with regard to the criteria set for the selection of subjects, 102 subjects were selected because they met the criteria established. There were 37 in the pre-pubescent group, 35 in the pubescent group, and 30 in the post-pubescent group.

Description and Functional Operation of the Testing Technique

The relative stability of the medial and lateral collateral knee ligaments can be measured by a manual test or by the use of an instrument recently devised by Klein. Manual tests had the disadvantage of subjectivity of scoring as well as requiring a high degree of skill of the administrator. Klein reported that "the use of the manual method only permits gross estimate of differences that exist in unilateral inequality."[1] Voshell in his studies made an attempt to measure the lateral stability of the knee with a more objective type of procedure.[2] He reported the amount of lateral movement of the knee in degrees. It was assumed that the goniometer was used as the instrument for this evaluation. Since Voshell's study utilized cadavers, his procedure was not acceptable for this study. The goniometer, frequently utilized to measure range of motion in various joint areas, was not suitable for this type of testing because of the inability of this instrument to meet the criteria of accuracy and ease of administration.

The only other instrument available for this type of measurement was devised by Klein.[3] The Knee Ligament Testing Instrument for collateral ligament measurement was designed to measure movement in the

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[1]Karl K. Klein, "An Instrument for Testing the Medial and Lateral Collateral Ligament Stability of the Knee," American Journal of Surgery, 104 (November, 1962), p. 768-772.

[2]A. F. Voshell, Anatomy of the Knee. In: American Academy of Orthopedic Instructional Course Lectures, vol. 13. Ann Arbor, 1956. J. W. Edwards.

[3]Klein, "An Instrument for Testing," p. 768-772.

straight leg position. Klein recognized the fact that most manual orthopedic testing procedures involved the use of a bent knee position but, after his consultation with a number of orthopedic physicians, it was mutually agreed that the straight leg position would give significant evidence of stability or instability.[1]

The following description and functional operation for the instrument were presented by Klein.

> The instrument is designed to fit snugly over the thigh and lower part of the leg, with the bearing pivot placed above the mid-point of the knee joint. The main bar along the top of the thigh is constructed of rigid aluminum capable of withstanding the stress of the testing procedures. Spring clamps constructed of aluminum are designed to fit over the thigh and lower part of the leg and are attached on the underside of the main bar. The strap attachments enable the instrument to be fastened more securely to the leg.
>
> A machinist dial indicator (Ames 101) is attached just above the bearing pivot on one side of the apparatus and a pressure plate, which is adjustable by a thumb screw, on the opposite side so that it can be placed against the plunger of the dial indicator. The fact of the dial indicator is adjustable to a zero starting point for measurement and registers in 1/1,000 of an inch of movement. Full compression of the plunger of the instrument being described records 242/1,000 of an inch on the dial. Calibration of the instrument for mediolateral motion is computed at 17.2/1,000 of an inch equal to 1 degree. The instrument is constructed so that the standard procedure for collateral ligament testing can be administered without any pressure directly exerted against the instrument by the hands of the tester.[2]

After evaluation of the suitability, the instrument devised by Klein was selected as the instrument to be used in the study. See

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[1] Ibid.

[2] Ibid.

Appendix D for a picture of the instrument.

The functional application and operation of the instrument as described by Klein were used.

> The subject is lying in a complete reclining position. The instrument is placed over the thigh and lower part of the leg with the pivot placed above the knee joint. The straps are securely fastened to stabilize the instrument to the body part. The subject is encouraged to relax the thigh musculature. He is assured that the testing procedure will not be painful; thus anxiety that creates muscular tension is alleviated and a more accurate ligament assessment can be secured.
>
> The heel is lifted from the table and the knee is full extended. By pressure of the tester's thumb at the knee joint complete extension of the knee is insured. The tester, or preferably an assistant, takes up the slack between the dial indicator plunger and pressure plate, sets the dial face at zero, as determined by the position of the instrument dial needle, and also adjusts the hold indicator at the zero point. The tester then applies pressure at the ankle while holding the knee in a stable position. With the dial indicator attached to one side of the instrument, it is to be noted that in testing the medial ligament of the left knee, the reading is recorded by compresion of the plunger. In testing the lateral ligament of the same knee, the plunger has to start from a partially compressed position and the reading is made as the plunger is released. The reverse procedure takes place on the right leg. Consistent amount of pressure should be applied in the bilateral effort to assess accurately the collateral ligament stability or instability of the person. The basic test procedure is identical to that used in the manual orthopedic test.[1]

Figure 2 shows the technique for assessing the stability of the medial collateral ligament. Figure 3 shows the technique for assessing the stability of the lateral collateral ligament.

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[1] Ibid., p. 769.

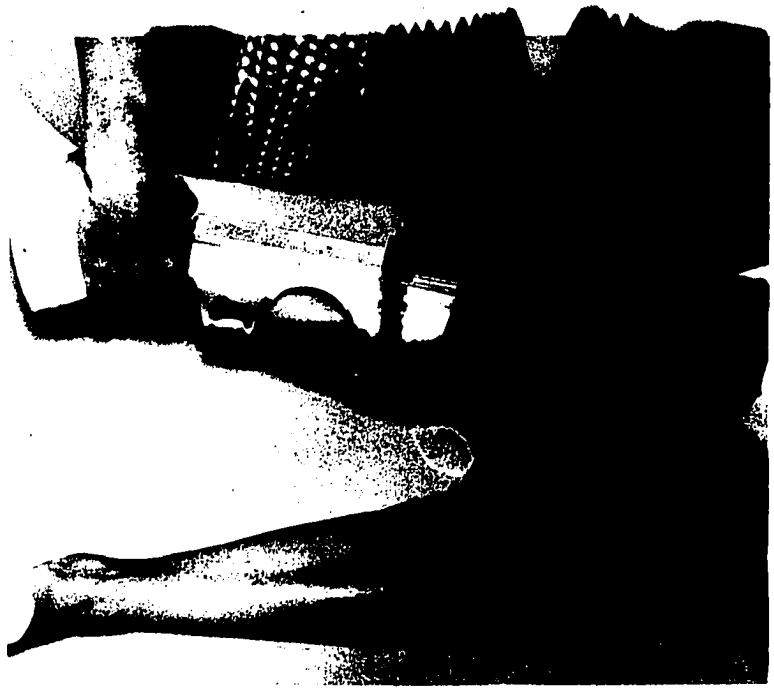

Figure 2.--Technique for assessing the stability of the medial collateral ligament.

Figure 3.--Technique for assessing the stability of the lateral collateral ligament.

In order to standardize the pressure application, a medical syphygmomanometer unit (aneroid type) was used. The pressure bag was removed from the cuff and placed in a small bag attached to a glove. By placing a given amount of pressure to the knee, the amount of pressure was recorded on the gauge. In pre-test application the writer utilized maximum pressure and an assistant watched the gauge. It was found that the pressure being applied did not differ significantly; therefore, the Sphygmomanometer modification was deleted as a part of the actual procedure. Klein utilized a similar method to standardize pressure on test-retest procedures.[1] On test and retest between the first and third test of thirty-five men and women between the ages of seven and fifteen years, coefficients of correlation were reported as .919 and .984. On thirty-five adult women between the ages of seventeen and fifty-four years, coefficients of correlation were reported at .895 and .951.[2]

Design

Each subject selected for this study was given the ligament stability evaluation. In order to facilitate ease of administration, the order for testing was as follows:

1. Medial Collateral Ligament - right leg
2. Lateral Collateral Ligament - right leg
3. Medial Collateral Ligament - left leg
4. Lateral Collateral Ligament - left leg

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[1] Ibid., p. 772.

[2] Klein, "Strength Maintenance Following Specific Rehabilitation," p. 46.

Each subject was tested twice in order to determine the reliability of the testing procedure. The second test results were utilized as the data for this study. The reliability of the testing procedure was determined by calculating the correlation coefficient (r) for each of the ligament measurements for each of the maturity groups.

The correlation coefficients were calculated and presented in Table 1. The lowest correlation coefficient obtained was .95 and the highest was .99. Therefore, all measurements were considered highly reliable.

TABLE 1

CORRELATION COEFFICIENTS FOR THE INDIVIDUAL LIGAMENT MEASUREMENTS ON THE FIRST TEST AS COMPARED TO THE SECOND TEST

	Pre-Pubescent Group	Pubescent Group	Post-Pubescent Group
Right Medial	.99	.97	.95
Right Lateral	.98	.97	.97
Left Medial	.98	.98	.98
Left Lateral	.99	97	.97

CHAPTER III

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

The measurements obtained for each individual are presented in tabular form in Appendix E. The calculations were completed separately for test results of the right knee and of the left knee. The comparisons were made of the test results of subjects representing one maturity group compared with the test results of subjects representing another maturity group. Correlations and comparisons were also made of the test results of one of the ligament measurements compared with the test results of another of the ligament measurements within the same maturity group.

Analysis of the Results of the Individual Ligament Measurements

The range, mean, median, and standard deviation of the original measurements of each ligament tested were calculated for each of the three maturity groups under investigation.

The raw data are the actual readings obtained from the dial indicator at the time of the testing procedure. In all of the previous studies utilizing the Klein testing instrument for the medial and lateral

collateral ligaments, the procedure has been to report the results by use of the raw data as determined by the actual reading obtained from the dial indicator. The meaning of the raw score, as explained in the description and functional operation of the testing technique section, is that one "mark" on the dial indicator is equal to 1/1000 of an inch of movement. Therefore, when referring to the analysis of data of this study, this interpretation should be noted.

The range, mean, median, and standard deviation of the dial readings are presented in Table 2. The mean for the right medial ligament was 118.6 for the pre-pubescent group, 68.5 for the pubescent group and 45.8 for the post-pubescent group. The mean for the right lateral ligament was 162.9 for the pre-pubescent group, 93.6 for the pubescent group, and 81.5 for the post-pubescent group. The mean for the left medial ligament was 157.7 for the pre-pubescent group, 90.6 for the pubescent group and 79.2 for the post-pubescent group. The mean for the left lateral ligament was 127.7 for the pre-pubescent group, 76.2 for the pubescent group and 58.2 for the post-pubescent group. By observation there was a significant tightening of all the ligaments tested from the pre-pubescent group to the pubescent group and to the post-pubescent group. Also it was noted that in all three maturity groups the right medial ligament was tighter than the left lateral; the left lateral was tighter than the left medial; and the left medial was tighter than the right lateral ligament. The measurements for the groups were skewed slightly to the right except for the right lateral measurement for the

TABLE 2

MEASURES OF CENTRAL TENDENCY AND VARIABILITY

OF INDIVIDUAL LIGAMENT MEASUREMENTS

(REPORTED IN 1/1000's OF AN INCH)

	Pre-Pubescent Group (N = 37)				Pubescent Group (N = 35)				Post-Pubescent Group (N = 30)			
	Range	Mean	Median	S.D.	Range	Mean	Median	S.D.	Range	Mean	Median	S.D.
Rm[a]	52-204	118.6	117.0	44.38	26-138	68.5	68.2	24.88	11-118	45.8	44.0	18.33
Rl[a]	98-250	162.9	164.5	41.67	45-150	93.6	94.5	27.91	47-155	81.5	77.0	23.51
Lm[a]	75-240	157.7	155.9	39.65	47-140	90.6	90.2	22.11	29-128	79.2	75.5	23.35
Ll[a]	72-250	127.7	118.9	42.62	33-127	76.2	74.5	22.36	18-116	58.2	54.5	23.41

[a]Legend

Rm = Right medial collateral ligament
Rl = Right lateral collateral ligament
Lm = Left medial collateral ligament
Ll = Left lateral collateral ligament

pre-pubescent and pubescent maturity groups which were skewed slightly to the left.

The standard deviation for the right medial ligament was 44.38 for the pre-pubescent group, 24.88 for the pubescent group and 18.33 for the post-pubescent group. The standard deviation for the right lateral ligament was 41.67 for the pre-pubescent group, 27.91 for the pubescent group and 23.51 for the post-pubescent group. The standard deviation for the left medial ligament was 39.65 for the pre-pubescent group, 22.11 for the pubescent group and 23.35 for the post-pubescent group. The standard deviation for the left lateral ligament was 42.62 for the pre-pubescent group, 22.36 for the pubescent group and 23.41 for the post-pubescent group. There was noted a significant decrease in the variability from the pre-pubescent group to the pubescent group for all the ligaments measured. There was also a decrease in the variability from the pubescent group to the post-pubescent group for the ligaments of the right knee; however, there was a slight increase in the amount of variability from the pubescent group to the post-pubescent group for the ligaments of the left knee.

By observation of the wide variabilities of the data it was decided that the distributions were much too platykurtic to receive statistical treatment reserved for normal distributions. Since rank correlations have the advantage that no assumptions are made about the distributions of the variables and can be used to test the hypothesis that two variables are independent, it was decided that this statistical

analysis should be used to describe these data.[1]

The hypothesis tested was that of independence between the different variables. Rho was calculated for each of the following pairs for each maturity group:

Right medial - Left medial

Right medial - Left lateral

Right medial - Right lateral

Left medial - Left lateral

Left medial - Right lateral

Left lateral - Right lateral

For each of the rank-correlation coefficients a two-sided test was made with level of significance of two per cent or ten per cent.[2] The rank-correlation coefficients and their level of significance are presented in Table 3.

The rank-correlation coefficients between the right medial ligaments and the right lateral ligaments were .304 (not significant) for the pre-pubescent group, .323 (significant at the 10% level) for the pubescent group and .491 (significant at the 2% level) for the post-pubescent group. This demonstrated a greater degree of relationship between the two variables at the post-pubescent level than at the pubescent level and also between the two variables at the pubescent level than at the pre-pubescent level as indicated by these data.

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[1]Wilfrid J. Dixon and Frank J. Massey, Jr., Introduction to Statistical Analysis (New York: McGraw-Hill Book Company, Inc.), p. 260.

[2]Ibid., pp. 260-262.

TABLE 3

RANK CORRELATION COEFFICIENTS

	Right Medial	Right Lateral	Left Medial	Left Lateral
Pre-Pubescent:				
Right Medial	----	.304	.361*	.128
Right Lateral		----	.530**	.414*
Left Medial			----	.572**
Left Lateral				----
Pubescent:				
Right Medial	----	.323*	.521**	.385*
Right Lateral		----	.144	.277
Left Medial			----	.109
Left Lateral				----
Post-Pubescent:				
Right Medial	----	.491**	.455**	.423*
Right Lateral		----	.311*	.390*
Left Medial			----	.478**
Left Lateral				----

*Reject hypothesis of independence significant at 10% level.

**Reject hypothesis of independence significant at 2% level.

The rank-correlation coefficients between the right medial ligaments and the left medial ligaments were .361 (significant at the 10% level) for the pre-pubescent group, .521 (significant at the 2% level) for the pubescent group and .445 (significant at the 2% level) for the post-pubescent group. This demonstrated a greater degree of relationship between the two variables at the post-pubescent and pubescent levels than at the pre-pubescent level as indicated by these data.

The rank correlation coefficients between the right medial ligaments and the left lateral ligaments were .128 (not sufficient) for the pre-pubescent group, .385 (significant at the 10% level) for the pubescent group and .423 (significant at the 10% level) for the post-pubescent group. This showed a greater degree of relationship between the two variables at the post-pubescent and pubescent levels than at the pre-pubescent level as indicated by these data.

The rank-correlation coefficients between the right lateral ligaments and the left medial ligaments were .530 (significant at the 2% level) for the pre-pubescent group, .144 (not significant) for the pubescent group and .311 (significant at the 10% level) for the post-pubescent group. The observation of loss of significant relationship at puberty and the regaining of the relationship by post-pubescent maturity levels as indicated by these data was an indication for further investigation.

The rank-correlation coefficients between the right lateral ligaments and the left lateral ligaments were .414 (significant at the 10% level) for the pre-pubescent group, .277 (not significant) for the pubescent group and .390 (significant at the 10% level) for the post-

pubescent group. These correlations showed a loss of significant relationship at puberty and the regaining of the relationship by post-pubescent maturity levels as indicated by these data.

The rank-correlation coefficients between the left medial ligaments and the left lateral ligaments were .572 (significant at the 2% level) for the pre-pubescent group, .109 (not significant) for the pubescent group and .478 (significant at the 2% level) for the post-pubescent group. These correlations showed a loss of significant relationship at puberty and the regaining of the relationship by post-pubescent maturity levels as indicated by these data.

From the analysis of the rank-correlation coefficients two basic patterns were evident.

1. The greater degree of relationship between the two variables at the pubescent and post-pubescent levels than at the pre-pubescent level.
   a. Right medial to Right lateral
   b. Right medial to Left medial
   c. Right medial to Left lateral
2. The significant relationship that existed at the pre-pubescent level was lost during puberty and was regained as a significant relationship at the post-pubescent level.
   a. Right lateral to Left medial
   b. Right lateral to Left lateral
   c. Left medial to Left lateral

Analysis of the Ligament Measurement Ratios

In order to find the relative stability of the ligaments under investigation ratios were calculated for the stability measurement of the right medial ligament to the stability measurement of the right lateral ligament; the stability measurement of the right medial ligament to the stability measurement of the left medial ligament; the stability measurement of the right medial ligament to the stability measurement of the left lateral ligament; the stability measurement of the right lateral ligament to the stability measurment of the left medial ligament; the stability measurement of the right lateral ligament to the stability measurement of the left lateral ligament; and the stability measurement of the left medial ligament to the stability measurement of the left lateral ligament.

The range and mean of these ratios were calculated for each of the maturity groups. See Appendix E for the individual ratios. The range and mean of these ratios are presented in Table 4.

The mean ratio of the right medial ligament to the right lateral ligament was .74 for the pre-pubescent group, .77 for the pubescent group and .60 for the post-pubescent group. In all three maturity groups the right medial ligament was tighter than the right lateral ligament. There was little difference from the pre-pubeacent group to the pubescent group; however, in the post-pubescent group there was even a greater inequality of the stability of these ligaments. On the average the right medial ligament possessed about four-fifths of the laxness possessed by the right lateral ligament for the pre-pubeacent group and the pubescent

group; whereas, in the post-pubescent group the right medial ligament possessed on the average about three-fifths of the laxness possessed by the right lateral ligament.

TABLE 4

RANGE AND MEAN VALUES FOR EACH OF THE RATIOS

	Pre-Pubescent Group		Pubescent Group		Post-Pubescent Group	
	Range	Mean	Range	Mean	Range	Mean
Rm:Rl[a]	.28-1.17	.74	.32-1.84	.77	.23-2.23	.60
Rm:Lm[a]	.29-1.46	.77	.40-1.42	.76	.31-1.00	.59
Rm:Ll[a]	.26-2.22	1.00	.41-2.14	.95	.37-1.83	.87
Rl:Lm[a]	.53-1.79	1.06	.43-2.16	1.08	.45-1.76	1.07
Rl:Ll[a]	.56-2.45	1.35	.45-2.36	1.31	.55-3.00	1.55
Lm:Ll[a]	.66-1.99	1.31	.50-3.50	1.30	.60-4.11	1.52

[a]Legend
Rm:Rl = Right Medial:Right Lateral Collateral Ligament
Rm:Lm = Right Medial:Left Medial Collateral Ligament
Rm:Ll = Right Medial:Left Lateral Collateral Ligament
Rl:Lm = Right Lateral:Left Medial Collateral Ligament
Rl:Ll = Right Lateral:Left Lateral Collateral Ligament
Lm:Ll = Left Medial:Left Lateral Collateral Ligament

The mean ratio of the right medial ligament to the left medial ligament was .77 for the pre-pubescent group, .76 for the pubescent group and .59 for the post-pubescent group. The relationship of the right medial ligament to the left medial ligament was approximately the same as the relationship of the right medial ligament to the right lateral ligament. On the average the right medial ligament possessed about four-fifths of the laxness possessed by the left medial ligament for the pre-pubescent group and the pubescent group; whereas, in the post-pubescent group the right medial ligament possessed on the average about three-fifths of the laxness possessed by the left medial ligament.

The mean ratio of the right medial ligament to the left lateral ligament was 1.00 for the pre-pubescent group, .95 for the pubescent group and .87 for the post-pubescent group. On the average the right medial ligament possessed the same degree of stability as the left lateral ligament in the pre-pubescent group; however, as the maturity level increased the proportional stability of the right medial ligament increased when compared to the left lateral ligament. There exists an equal relationship at the pre-pubescent level and this equal relationship decreased to the point of the right medial ligament possessing on the average a little less than nine-tenths of the laxness exhibited by the left lateral ligament.

The mean ratio of the right lateral ligament to the left medial ligament was 1.06 for the pre-pubescent group, 1.08 for the pubescent group and 1.07 for the post-pubescent group. On the average the right lateral ligament possessed a little less than one and one-tenth times the laxness exhibited by the left medial ligament in all of the maturity levels.

The mean ratio of the right lateral ligament to the left lateral ligament was 1.35 for the pre-pubescent group, 1.31 for the pubescent group and 1.55 for the post-pubescent group. On the average the right lateral ligament possessed about one and three-tenths of the laxness possessed by the left lateral ligament for the pre-pubescent group and the pubescent group. While for the post-pubescent group the right lateral ligament possessed a little more than one and one-half times the laxness possessed by the left lateral ligament.

The mean ratio of the left medial ligament to the left lateral ligament was 1.31 for the pre-pubescent group, 1.30 for the pubescent group and 1.52 for the post-pubescent group. The relationship of the left medial ligament to the left lateral ligament was approximately the same as the relationship of the right lateral ligament to the left lateral ligament. On the average the left medial ligament possessed about one and three-tenths times the laxness possessed by the left lateral ligament for the pre-pubescent group and the pubescent group; whereas, in the post-pubescent group the left medial ligament possessed about one and one-half times the laxness possessed by the left lateral ligament.

In summarizing the analysis of the ligament measurement ratios there seemed to be four basic patterns.

1. The average ratio of the right medial to the right lateral and to the left medial ligament was approximately the same for the pre-pubescent group and the pubescent group and the relationship decreased at the post-pubescent level. On the average the right medial ligament possessed about four-fifths of the laxness of the right lateral ligament and the left medial ligament for the pre-pubescent group and the pubescent group; whereas, the right medial ligament possessed about three-fifths of the laxness of the right lateral ligament and the left medial ligament for the post-pubescent group.

2. The average ratio of the left medial and the right lateral to the left lateral collateral ligament was approximately the same for the pre-pubescent group and the pubescent group and this relationship decreased at the post-pubescent level. On the average the left medial

ligament and the right lateral ligament possessed a little more than one and three-tenths times the laxness of the left lateral ligament for the pre-pubescent group and the pubescent group; whereas, the left medial ligament and the right lateral ligament possessed a little more than one and one-half times the laxness possessed by the left lateral ligament for the post-pubescent group.

3. The average ratio of the right lateral to the left medial collateral ligament was approximately the same for all maturity groups tested. On the average the right lateral ligament possessed slightly less than one and one-tenths of the laxness possessed by the left medial ligament in all maturity groups tested.

4. The average ratio of the right medial to the left medial collateral ligament decreased as the maturity level increased utilizing only the three maturity levels embraced in this study. On the average the relationship of the right medial ligament to the left lateral ligament was equal at the pre-pubescent level and this relationship decreased until at the post-pubescent level the right medial ligament possessed a little less than nine-tenths of the laxness possessed by the left lateral ligament.

Both the ratio analysis and the calculations of the individual dial readings, indicate the same relationships between the various collateral knee ligaments. On the average in all maturity groups tested: (1) the right medial ligament was tighter than the left lateral ligament; (2) the left lateral was tighter than the left medial; and, (3) the left medial was tighter than the right lateral ligament.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The knee has been widely acclaimed by many authors as a vulnerable joint from the standpoint of lack of stability in performance and as an injury potential. Stability of the ligaments in any given joint area is directly related to the integrity of that joint. The importance of ligamentous stability is widely accepted, yet substantiated factual information regarding the status of the collateral knee ligaments is very limited. Also, information concerning the change in ligamentous stability from one physical maturity group to another is lacking. Because of this void in professional literature regarding ligamentous stability of the knee joint at various levels of physical maturity among women, this study was undertaken.

The problem of this study was to measure objectively the medial and lateral collateral excursions of the knee in an attempt to determine the degree of ligament tension in three maturity groups of women subjects. More specifically, the study was concerned with three questions:

1. What is the status of the stability of the medial and lateral collateral knee ligaments in a pre-pubescent

group, a pubescent group, and a post-pubescent group of women subjects?

2. What are the relationships between the right and left medial and lateral collateral knee ligaments for the selected groups?
3. Do the relationships change from one physical maturity group to another?

The basic purpose of this study was to observe and describe the status of the medial and lateral collateral knee ligaments of three selected physical maturity groups of women subjects, and to assess the potential of the knee to withstand exercise and activity programs prescribed for the various age groups of female students. Another purpose of this study was to supplement the information concerning the knee which could be used as a basis for understanding the principles related to the injury potential of the knee joint.

Subjects were selected according to their ability to fulfill the requirements established by the criteria for the selection of subjects. Briefly, the criteria stated that subjects were representative of one of the maturity groups used in this study and that they were free from any disorder that might influence or affect the data as not being representative of similar maturity groups. After evaluating prospective subjects from Clyde Howell Elementary School, Edmond Junior High School and Central State College, 102 subjects were selected. There were 37 representative of the pre-pubescent group, 35 representative of the pubescent group, and 30 in the post-pubescent group.

Utilizing an instrument recently devised by Klein, each subject was evaluated for the stability of the medial and lateral collateral ligaments. The technique utilized for this evaluation was identical with prescribed procedures established for the instrument and this proved to provide a very reliable basis for ascertaining the integrity of the collateral ligaments.

The results of these tests were as follows:

1. For the pre-pubescent group the median for the right medial ligament was 117.0; right lateral 164.5; left medial 155.9; and the left lateral 118.9. The mean for the right medial ligament was 118.6; right lateral 162.9; left medial 157.7; and the left lateral 127.7. The standard deviation for the right medial ligament was 44.38; right lateral 41.67; left medial 39.65; and the left lateral 42.62.

2. For the pubescent group the median for the right medial ligament was 68.2; right lateral 94.5; left medial 90.2; and, the left lateral 74.5. The mean for the right medial ligament was 68.5; right lateral 93.6; left medial 90.6; and, the left lateral 76.2. The standard deviation for the right medial ligament was 24.88; right lateral 27.91; left medial 22.11; and, the left lateral 22.36.

3. For the post-pubescent group the median for the right medial ligament was 44.0; right lateral 77.0; left medial 75.5; and, the left lateral 54.5. The mean for the right medial ligament was 45.8; right lateral 81.5; left medial 79.2; and, the left lateral 58.2. The standard deviation for the right medial ligament was 18.33; right lateral 23.51; left medial 23.35; and, the left lateral 23.41.

4. By observation there was a significant tightening of all the ligaments tested from the pre-pubescent group to the pubescent group and to the post-pubescent group. Also it was noted that in all three maturity groups the right medial ligament was tighter than the left medial; and, the left medial was tighter than the right lateral ligament.

5. From the analysis of the rank-correlation coefficients there were basically two patterns that existed.

   1. The greater degree of relationship between the two variables at the pubescent and post-pubescent levels than at the pre-pubescent level.
      a. Right medial to Right lateral
      b. Right medial to Left medial
      c. Right medial to Left lateral
   2. The significant relationship that existed at the pre-pubescent level was lost during puberty and was regained as a significant relationship at the post-pubescent level.
      a. Right lateral to Left medial
      b. Right lateral to Left lateral
      c. Left medial to Left lateral

6. In summarizing the analysis of the ligament measurement ratios there seemed to be four basic patterns.

   1. The average ratio of the right medial to the left medial collateral ligament was approximately the same for the pre-pubescent group and the pubescent group and this

relationship decreased at the post-pubescent level. On the average the right medial ligament possessed about four-fifths of the laxness of the right lateral ligament and the left medial ligament for the pre-pubescent group and the pubescent group; whereas, the right medial ligament possessed about three-fifths of the laxness of the right lateral ligament and the left medial ligament for the post-pubescent group.

2. The average ratio of the left medial and the right lateral to the left lateral collateral ligament was approximately the same for the pre-pubescent group and the pubescent group and this relationship decreased at the post-pubescent level. On the average the left medial ligament and the right lateral ligament possessed a little more than one and three-tenths times the laxness of the left lateral ligament for the pre-pubescent group and the pubescent group; whereas, the left medial ligament and the right lateral ligament possessed a little more than one and one-half times the laxness possessed by the left lateral ligament for the post-pubescent group.
3. The average ratio of the right lateral to the left medial collateral ligament was approximately the same for all maturity groups tested. On the average the right lateral ligament possessed slightly less than one

and one-tenth of the laxness possessed by the left medial ligament in all maturity groups tested.

4. The average ratio of the right medial to the left lateral collateral ligament decreased as the maturity level increased utilizing only the three maturity levels embraced in this study. On the average the relationship of the right medial ligament to the left lateral ligament was equal at the pre-pubescent level and this relationship decreased until at the post-pubescent level the right medial ligament possessed a little less than nine-tenths of the laxness possessed by the left lateral ligament.

Conclusions

In terms of the findings of this study the following conclusions were drawn as answers to the three questions presented in the initial phases of this study.

1. What is the status of the stability of the medial and lateral collateral knee ligaments in a pre-pubescent, a pubescent group, and a post-pubescent group? It can be concluded that the medial and lateral collateral knee ligaments are extremely loose at the pre-pubescent level and become progressively tighter at the pubescent and at the post-pubescent level. It would seem that as maturity and stature are gained a greater degree of tension in the knee ligaments is necessary to stabilize the knee joint. It would be advisable to evaluate the exercise

and activity programs prescribed for the various maturity levels to make sure that activities are not imposed on the student that would tend to: (1) maintain a loosened condition of the collateral ligaments thus preventing what seems to be the normal process of tightening of these ligaments; and, (2) increase the injury potential of the knee particularly of the younger student. There can be expected a wider variability of ligamentous stability in the pre-pubescent aged student than at the pubescent or post-pubescent level. Because of this wider variability it will be more difficult to utilize the findings of this study in ascertaining normalacy or abnormality of the collateral knee ligament status in the younger age groups.

2. What are the relationships between the right and left medial and lateral collateral knee ligaments for the selected groups? There seems to be a basic relationship between each of the collateral knee ligaments based on the findings of this study. These relationships vary from group to group but basically the same relative degree of ligamentous tension exists in all three maturity groups. On the average the right medial collateral knee ligament was tighter than the left lateral and the left lateral ligament was tighter than the left medial and the left medial ligament was tighter than the right lateral collateral knee ligament. The significance of these relationships will have to be further explored.

3. Do these relationships change from one physical maturity group to another? Based on the findings of this study the basic relative position of ligament tension does not change, however, the correlations

and ratio findings indicate fluctuation of relationships between any two ligaments do occur from one maturity group to another. The relationship of the right medial ligament to each of the other collateral ligaments is not significant at the pre-pubescent level; whereas, its relationship is significant at both the pubescent and post-pubescent level. A significant relationship was found between all of the collateral ligaments except the right medial ligament at the pre-pubescent level and this significant relationship was lost by the pubescent level and was regained by the post-pubescent period. The significance of these alterations in relationships can perhaps be explained by growth changes and should be investigated further.

Concerning the comparable points that are available with Klein's studies the data corroborate his findings. His studies did not include women subjects comparable to the pre-pubescent age group included in this study. Also, his studies did not include information concerning the onset of the menstrual cycle in the pubescent aged group which probably accounts for the wider variability of his data for this age group.

If this study were repeated a number of alterations in design would yield a more conclusive study. Basically these alterations are: (1) increase the sample for each age group; (2) include two additional age groups between the maturity levels utilized; (3) include a limitation on body build; and, (4) continue the study over a longer period of time to obtain data on the same subjects at regular intervals throughout their growth cycles.

Implications and Recommendations for Further Study

As a result of the insights gained during the course of this study there seem to be two additional studies worthy of attention. The first of these actually would be a repetition of the present study with the additions recommended. This study should utilize the same testing procedure, as it proved to be very reliable, and should be conducted in accord with a longitudinal type of investigation. The design should be modified in order to establish not only maturity groupings but body build, height, and weight groupings as well.

The second study would involve an attempt to determine what relationships exist between the stability status of the knee, and: (1) various functional deviations of the knee and adjacent joint areas; (2) various conditioning exercises and movement patterns; and, (3) various therapeutic procedures. This type of investigation would necessarily be divided into many sub-divisions and then compiled and presented as a composite of the findings with close collaboration between the various investigators to insure unity of technique and procedure.

BIBLIOGRAPHY

BIBLIOGRAPHY

Bowen, W. P. and R. T. McKenzie. Applied Anatomy and Kinesiology. Philadelphia: Lea and Febiger, 1923.

Clarke, H. Harrison. Application of Measurement to Health and Physical Education. New York: Prentice-Hall Inc., 1950.

Dixon, Wilfred J. and Frank J. Massey, Jr. Introduction to Statistical Analysis. New York: McGraw-Hill Book Company, Inc., 1959.

Garrett, Henry E. Elementary Statistics. New York: Longmans, Green and Company, 1956.

Goldthwait, Joel E., and others. Essentials of Body Mechanics in Health and Disease. Philadelphia: J. B. Lippincott Company, 1945.

Gray, Henry. Gray's Anatomy. New York: Harper and Brothers, 1956.

Hollinshead, W. Henry. Functional Anatomy of the Limbs and Back. Philadelphia: W. B. Saunders Company, 1951.

Klein, Karl K. "An Instrument for Testing the Medial and Lateral Collateral Ligaments Stability of the Knee," American Journal of Surgery, 104 (November, 1962), pp. 768-772.

Klein, Karl K. "Strength Maintenance Following Specific Rehabilitation, Validation of a Specific Rehabilitation Apparatus and Exercise Potential Related to Injury Potential," (unpublished Research Paper presenting findings of an investigation supported, in part, by a research grant, Number RD446 from the Vocational Rehabilitation Administration, University of Texas, 1963).

Klein, Karl K. and William L. Hall. The Knee in Athletics. Washington, D. C.: American Association for Health, Physical Education and Recreation, 1963.

Lee, Mabel and Miriam Wagner. Fundamentals of Body Mechanics and Conditioning. Philadelphia: W. B. Saunders Company, 1949.

Lewin, Philip. The Knee and Related Structures. Philadelphia: Lea and Febiger, 1952.

Mathews, Donald K. Measurement in Physical Education. Philadelphia: W. B. Saunders Company, 1958.

Metheny, Eleanor. Body Mechanics. New York: McGraw-Hill Book Company, Inc., 1952.

Morrison, Whitelaw Reid and Laurence B. Chenoweth. Normal and Elementary Physical Diagnosis. Philadelphia: Lea and Febiger, 1928.

Morton, Dudley J. and Dudley Dean Fuller. Human Locomotion and Body Form. Baltimore: The Williams and Wilkins Company, 1952.

O'Donoghue, Don H. Treatment of Injuries to Athletes. Philadelphia: W. B. Saunders Company, 1962.

Phelps, W. M. and R. J. H. Kiphuth. The Diagnosis and Treatment of Postural Defects. Springfield: Charles C. Thomas, 1932.

Rasch, Philip J. and Roger K. Burke. Kinesiology and Applied Anatomy. Philadelphia: Lea and Febiger, 1963.

Rathbone, Josephine Langworthy. Corrective Physical Education. Philadelphia: W. B. Saunders Company, 1954.

Scott, M. Gladys. Analysis of Human Motion. New York: Appleton-Century-Crofts, 1963.

Steindler, Authur. Kinesiology. Springfield: Charles C. Thomas, 1955.

Voshell, A. F. Anatomy of the Knee. Ann Arbor: American Academy of Orthopedic Instructional Course Lectures, 1956.

Wells, Katharine F. Kinesiology. Philadelphia: W. B. Saunders Company, 1955.

Williams, Marian and Catherine Worthingham. Therapeutic Exercise. Philadelphia: W. B. Saunders Company, 1957.

APPENDIX A

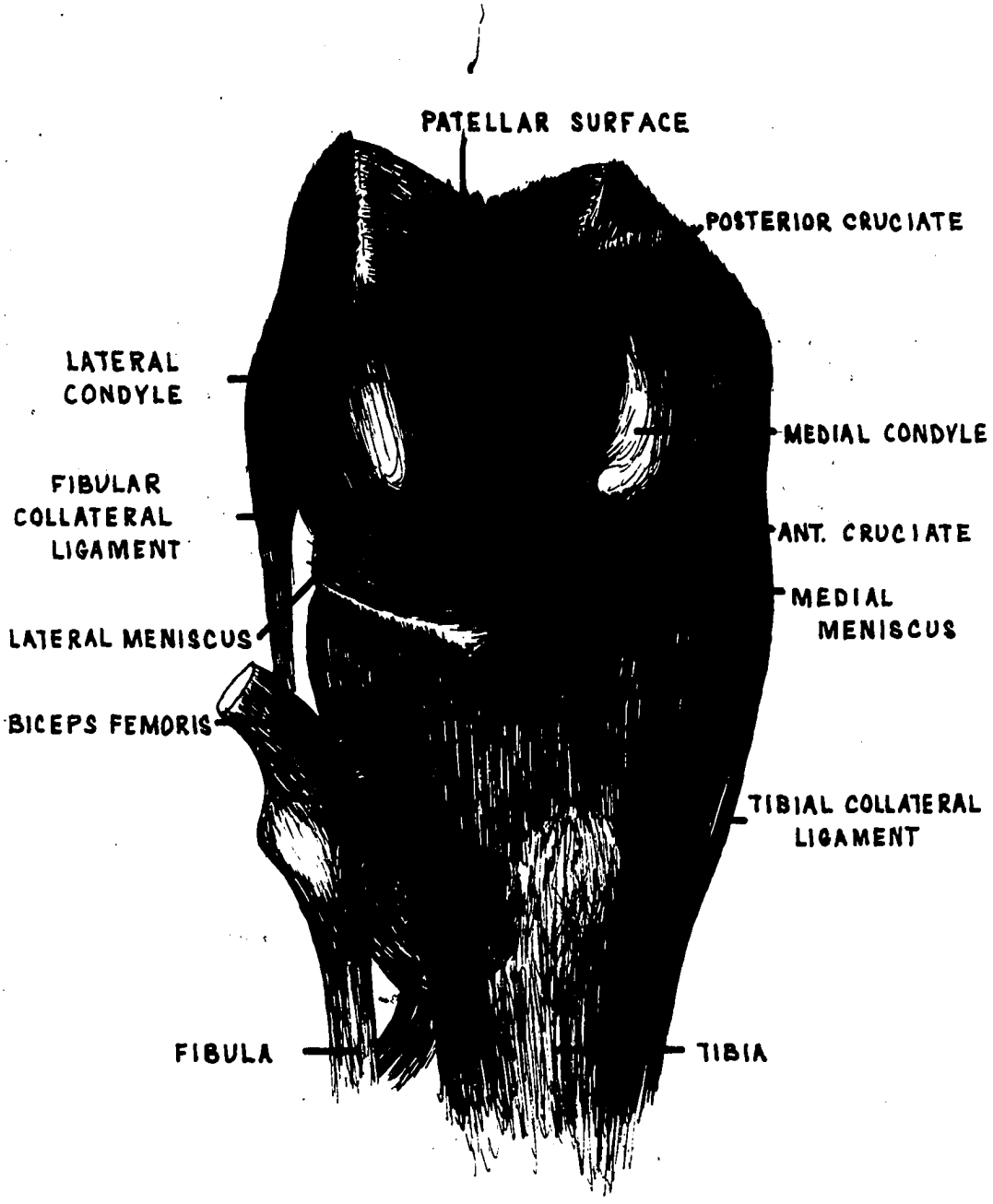


Figure 4.--Anatomical Description of the Knee -- Anterior View

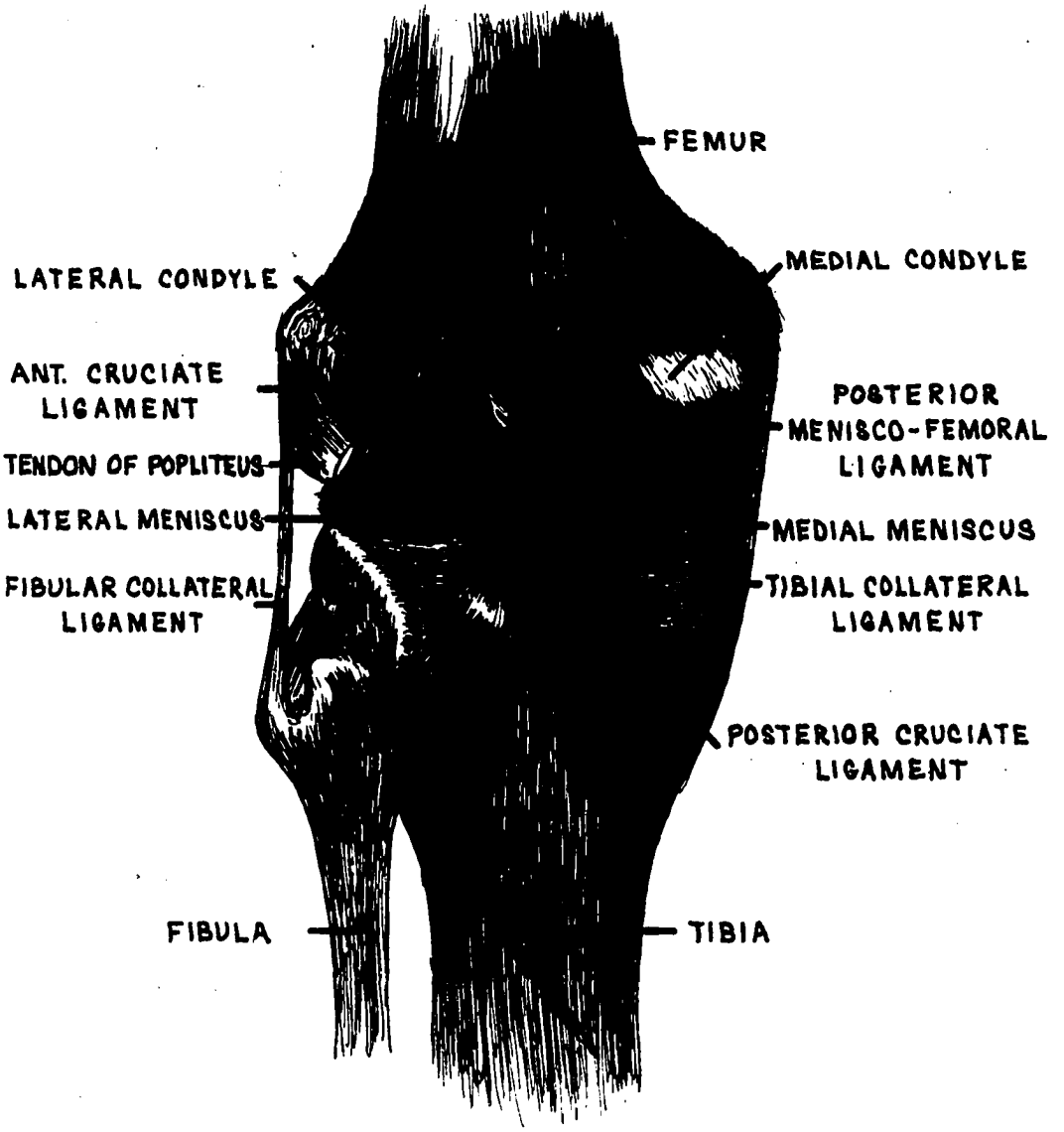


Figure 5.--Anatomical Description of the Knee -- Posterior View

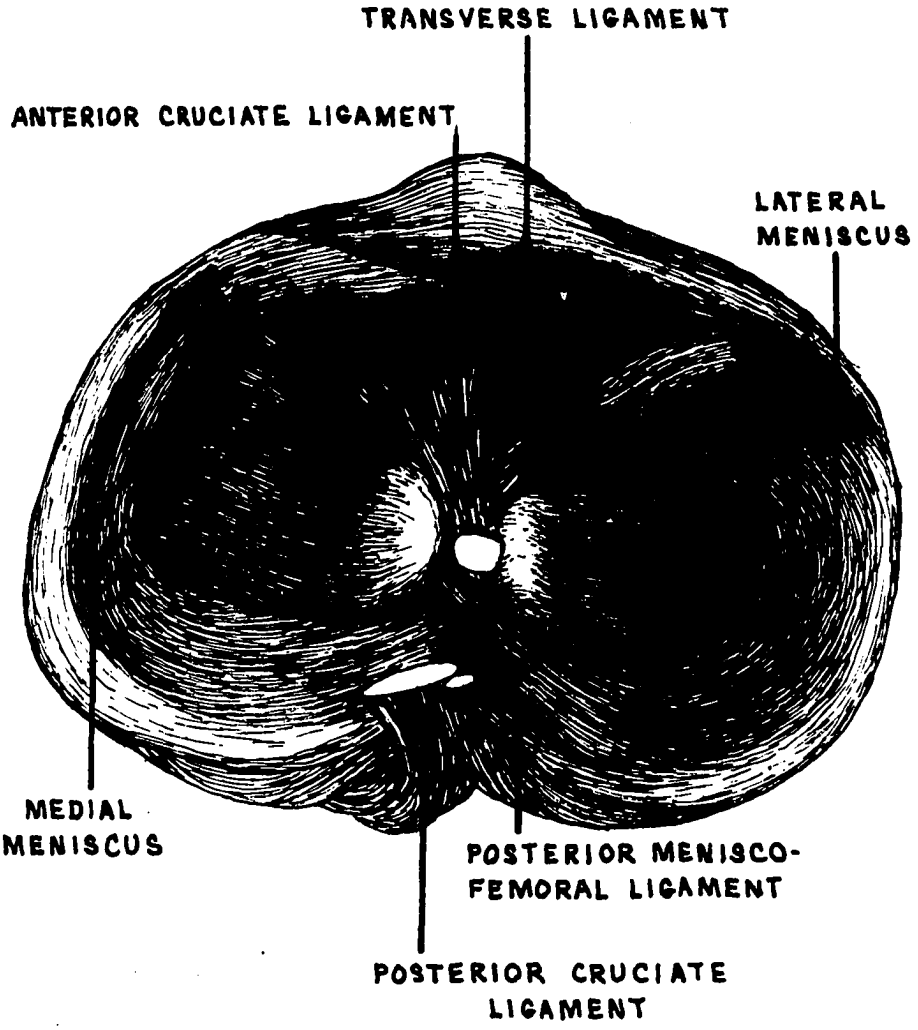
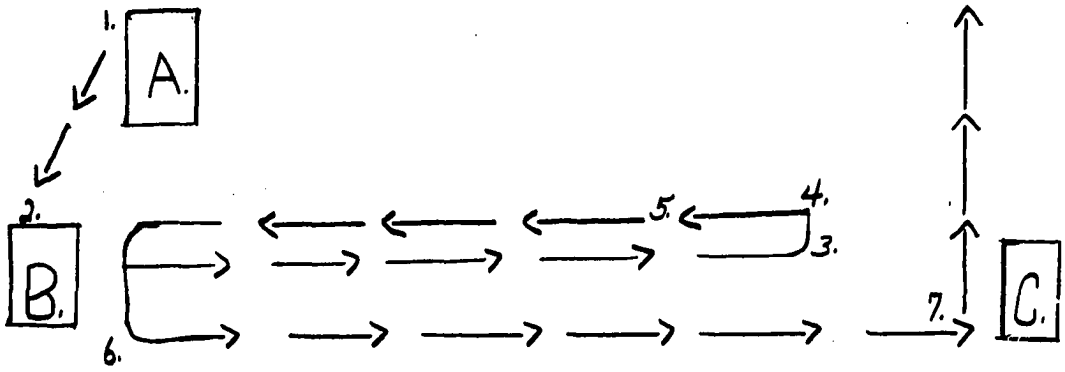


Figure 6.--Anatomical Description of the Knee -- Superior View

APPENDIX B

THE PHYSICAL LAYOUT FOR THE SUBJECTIVE RATINGS



A. Table with score cards (student assistant)

B. Rating Judge

C. Rating Judge

1. Student assistant numbered cards and obtained the information from the subject to fill out the top part of the score card.

2. Subject gave her card to rating judge B and was asked about recent injuries, illnesses, and structural disorders. This information was obtained from health records for the pre-pubescent group. Subject was then asked to walk toward rating judge C and to stop at point 3 facing judge C.

3. Subject was asked to turn a one-quarter turn to her left.

4. Subject was asked to turn a one-quarter turn to her left again and stand facing judge B.

5. Subject was asked to return to judge B and get her card.

6. Subject was asked to take her card and leave it with judge C.

7. Subject was asked to return to classroom.

APPENDIX C

SAMPLE SCORE CARD

Name_____ Code No._____

School_____ School year_____

Age_____Height_____ Weight_____

Sex_____Race_____ Age of onset of menstruation_____

Rm_____	Lm_____
Rl_____	Ll_____
R_{ac}_____	L_{ac}_____
R_{pc}_____	L_{pc}_____

APPENDIX D

Figure 7.--Picture of the Instrument

DIAL READINGS, RATIOS, HEIGHT, WEIGHT, AND AGE OF EACH SUBJECT BY PHYSICAL MATURITY GROUPING[a]

APPENDIX E

TABLE 5

RAW DATA -- PRE-PUBESCENT GROUP

	DIAL READINGS				RATIOS						HT.	WT.	AGE	
No.	Rm	Rl	Lm	Ll	Rm:Rl	Lm:Ll	Rm:Lm	Rl:Ll	Rm:Ll	Rl:Lm	In.	Lbs.	Yrs.	Mo.
1	192	197	192	127	.97	1.51	1.00	1.55	1.55	1.51	51	65	8	0
2	59	188	124	111	.31	1.12	.47	1.69	.53	1.52	49	60	8	0
3	187	250	233	250	.75	.93	.80	1.00	.75	1.07	52	68	7	1
4	120	119	161	116	1.01	1.39	.75	1.03	1.03	.74	47	48	6	0
5	137	165	182	135	.83	1.35	.75	1.22	1.01	.91	50	59	7	11
6	150	175	154	110	.86	1.40	.97	1.59	1.36	1.14	53	67	8	0
7	156	169	184	120	.93	1.53	.85	1.41	1.30	.92	53	59	8	0
8	120	160	155	78	.75	1.99	.77	2.05	1.54	1.03	47	47	7	11
9	137	159	159	116	.86	1.37	.86	1.37	1.18	1.00	49	62	7	7
10	99	111	147	76	.89	1.93	.67	1.46	1.30	.76	48	67	7	2
11	151	211	150	86	.72	1.74	1.01	2.45	1.76	1.41	47	50	7	4
12	98	111	93	140	.88	.66	1.05	.79	.70	1.19	48	55	7	10
13	100	172	182	132	.58	1.38	.55	1.30	.76	.98	48	60	6	3
14	110	194	122	139	.57	.88	.90	1.40	.79	1.59	49	48	6	7
15	74	112	122	110	.66	1.11	1.26	1.02	.67	.92	54	82	8	0
16	196	167	155	172	1.17	.90	.62	.97	1.14	1.08	49	65	8	0
17	109	140	176	120	.78	1.47	.92	1.17	.91	.80	51	66	7	9
18	69	98	75	77	.70	.97	.90	1.27	.90	1.31	52	78	7	0
19	131	124	146	86	1.06	1.70	.61	1.44	1.52	.85	53	57	7	10

[a]Legend: Rm = Right Medial Collateral Ligament
Rl = Right Lateral Collateral Ligament
Lm = Left Medial Collateral Ligament
Ll = Left Lateral Collateral Ligament

Ht. = Height
Wt. = Weight
Age = Years and Months

APPENDIX E (continued)

RAW DATA -- PRE-PUBESCENT GROUP

	DIAL READINGS				RATIOS						HT.	WT.	AGE	
No.	Rm	R1	Lm	L1	Rm:R1	Lm:L1	Rm:Lm	R1:L1	Rm:L1	R1:Lm	In.	Lbs.	Yrs.	Mo.
20	76	126	118	102	.60	1.15	.64	1.24	.75	1.07	53	70	7	9
21	204	174	140	92	1.17	1.52	1.46	1.89	2.22	1.24	53	60	7	9
22	183	190	196	149	.96	1.32	.93	1.28	1.23	.97	52	59	8	0
23	115	198	158	156	.58	1.01	.73	1.27	.74	1.25	49	50	8	0
24	155	145	159	126	1.07	1.26	.97	1.15	1.23	.91	47	43	7	10
25	52	122	100	72	.43	1.39	.52	1.69	.72	1.22	49	58	7	6
26	98	105	94	72	.93	1.31	1.04	1.46	1.36	1.12	50	65	7	11
27	85	120	148	96	.71	1.54	.57	1.25	.89	.81	48	51	7	1
28	132	170	198	111	.78	1.78	.67	1.53	1.19	.86	49	62	7	6
29	52	160	178	110	.33	1.62	.29	1.45	.47	.90	59	60	7	7
30	82	184	103	118	.45	.87	.80	1.55	.69	1.79	49	59	7	6
31	121	114	169	205	1.06	.82	.72	.56	.59	.67	46	51	6	5
32	90	230	215	174	.39	1.23	.42	1.31	.51	1.07	50	55	6	10
33	195	244	162	104	.80	1.56	1.20	2.35	1.88	1.51	48	61	6	6
34	63	153	129	176	.41	.73	.49	.87	.36	1.19	50	49	6	1
35	60	217	209	235	.28	.89	.29	.92	.26	1.04	46	48	6	7
36	82	213	240	157	.38	1.53	.34	1.36	.52	.89	48	51	6	10
37	125	114	214	150	1.10	1.43	.58	.76	.83	.53	46	45	6	9

APPENDIX E (continued)

RAW DATA -- PUBESCENT GROUP

	DIAL READINGS				RATIOS						HT.	WT.	AGE	
No.	Rm	Rl	Lm	Ll	Rm:Rl	Lm:Ll	Rm:Lm	Rl:Ll	Rm:Ll	Rl:Lm	In.	Lbs.	Yrs.	Mo.
1	114	129	140	105	.88	1.33	.81	1.23	1.09	.92	61	81	14	3
2	50	80	107	66	.63	1.62	.47	1.21	.76	.75	63	110	13	4
3	86	117	119	114	.74	1.04	.72	1.03	.75	.98	61	93	13	0
4	51	66	94	68	.77	1.38	.54	.97	.75	.70	62	104	12	11
5	49	102	101	71	.48	1.42	.49	1.44	.69	1.01	64	95	13	0
6	36	57	61	52	.63	1.17	.59	1.10	.69	.93	64	103	13	10
7	56	92	81	57	.61	1.42	.69	1.61	.98	1.14	62	109	13	8
8	79	45	87	99	1.76	.88	.91	.45	.80	.52	61	102	13	2
9	80	78	77	104	1.03	.74	1.04	.75	.79	1.01	61	98	12	9
10	80	86	95	127	.93	.74	.85	.68	.63	.91	63	104	12	7
11	47	77	51	102	.61	.50	.92	.75	.46	1.51	62	106	12	3
12	80	112	64	92	.71	.70	1.25	1.22	.87	1.75	62	103	14	6
13	42	132	61	103	.32	.59	.69	1.28	.41	2.16	60	92	12	9
14	80	132	70	76	.61	.92	1.14	1.74	1.05	1.89	60	80	13	0
15	94	65	97	75	1.45	1.29	.97	.87	1.25	.67	59	87	12	4
16	61	55	81	43	1.11	2.14	.66	1.28	1.42	.60	61	86	12	8
17	79	114	92	97	.69	.84	.98	1.18	.81	1.41	64	95	13	7
18	108	101	120	60	1.07	2.00	.90	1.68	1.80	.84	70	140	13	10
19	75	113	103	85	.66	1.21	.73	1.33	.88	1.10	61	95	12	11
20	47	87	64	74	.54	.86	.73	1.18	.64	1.36	62	109	12	6
21	138	75	97	89	1.84	1.09	1.42	.84	1.55	.77	64	103	12	6
22	58	150	85	79	.39	1.08	.68	1.90	.73	1.76	63	110	12	4
23	26	51	47	33	.51	1.42	.55	1.55	.79	1.09	61	104	12	1
24	61	107	123	65	.57	1.89	.50	1.65	.94	.87	64	105	13	3
25	76	103	90	52	.74	1.73	.84	1.98	1.46	1.14	63	107	13	4

APPENDIX E (continued)

RAW DATA -- PUBESCENT GROUP

	DIAL READINGS				RATIOS						HT.	WT.	AGE	
No.	Rm	Rl	Lm	Ll	Rm:Rl	Lm:Ll	Rm:Lm	Rl:Ll	Rm:Ll	Rl:Lm	In.	Lbs.	Yrs.	Mo.
26	77	85	126	36	.91	3.50	.61	2.36	2.14	.67	60	107	13	5
27	64	111	93	55	.58	1.69	.69	2.02	1.16	1.19	61	104	13	0
28	42	123	77	68	.34	1.13	.55	1.81	.62	1.60	61	110	13	0
29	103	110	110	80	.94	1.38	.95	1.38	1.29	1.00	60	95	12	0
30	72	100	85	61	.72	1.39	.85	1.64	1.18	1.18	62	115	13	0
31	34	53	86	80	.64	1.08	.40	.66	.43	.43	59	94	12	9
32	40	81	76	52	.49	1.46	.53	1.56	.77	1.07	60	97	13	0
33	42	59	104	91	.71	1.14	.40	.65	.46	.57	62	108	12	2
34	63	82	74	57	.77	1.30	.85	1.44	1.11	1.11	63	112	14	3
35	94	124	114	90	.76	1.27	.82	1.38	1.04	1.09	65	117	12	9

RAW DATA -- POST-PUBESCENT GROUP

	DIAL READINGS				RATIOS						HT.	WT.	AGE	
No.	Rm	Rl	Lm	Ll	Rm:Rl	Lm:Ll	Rm:Lm	Rl:Ll	Rm:Ll	Rl:Lm	In.	Lbs.	Yrs.	Mo.
1	38	66	67	39	.58	1.72	.57	1.69	.97	.99	69	133	20	0
2	11	47	35	30	.23	1.17	.31	1.57	.37	1.34	69	160	18	10
3	47	88	107	48	.53	2.23	.44	1.84	.98	.82	66	150	18	0
4	42	91	69	103	.46	.67	.62	.88	.41	1.32	65	112	19	5
5	39	68	88	64	.57	1.38	.44	1.06	.61	.77	66	190	17	10

APPENDIX E (continued)

RAW DATA -- POST-PUBESCENT GROUP

	DIAL READINGS				RATIOS						HT.	WT.	AGE	
No.	Rm	Rl	Lm	Ll	Rm:Rl	Lm:Ll	Rm:Lm	Rl:Ll	Rm:Ll	Rl:Lm	In.	Lbs.	Yrs.	Mo.
6	18	51	29	48	.35	.60	.61	1.06	.38	1.76	68	131	20	0
7	56	95	101	52	.59	1.94	.55	1.83	1.08	.94	61	117	19	1
8	60	124	128	70	.48	1.83	.47	1.77	.86	.97	66	124	19	8
9	49	155	123	116	.32	1.06	.40	1.34	.42	1.26	59	98	19	4
10	33	51	74	18	.65	4.11	.45	2.83	1.83	.69	66	135	19	8
11	52	74	120	77	.70	1.56	.43	.96	.68	.62	72	146	19	4
12	46	76	52	60	.61	.87	.88	1.37	.77	1.46	67	139	18	2
13	42	67	74	47	.63	1.57	.57	1.43	.89	.91	61	113	19	8
14	47	68	88	58	.69	1.52	.53	1.17	.81	.77	63	121	18	10
15	38	52	76	34	.73	2.24	.50	1.53	1.12	.68	65	140	19	0
16	36	83	75	89	.43	.84	.48	.93	.40	1.11	69	140	18	10
17	42	105	77	65	.40	1.18	.55	1.62	.65	1.36	66	110	20	0
18	61	90	68	37	.68	1.84	.90	2.43	1.65	1.32	67	126	18	0
19	37	71	80	45	.52	1.78	.46	1.58	.82	.89	67	126	18	6
20	63	89	75	79	.71	.95	.84	1.13	.80	1.19	64	110	19	11
21	45	70	79	78	.64	1.01	.57	.90	.58	.89	63	128	18	4
22	40	78	71	67	.51	1.06	.56	1.16	.60	1.10	69	141	20	0
23	58	97	67	36	.60	1.86	.87	2.69	1.61	1.45	65	120	18	0
24	47	97	65	62	.48	1.05	.72	1.56	.75	1.49	62	115	18	10
25	36	102	75	34	.35	2.21	.48	3.00	1.06	1.36	67	140	18	1
26	65	117	102	81	.56	1.26	.64	1.44	.80	1.15	62	117	19	8
27	23	71	70	41	.32	1.71	.33	1.73	.56	1.01	69	155	20	0
28	118	53	118	97	2.23	1.22	1.00	.55	1.22	.45	60	106	18	1
29	56	70	58	40	.80	1.45	.97	1.75	1.40	1.21	65	135	18	9
30	46	77	84	46	.60	1.83	.55	1.67	1.00	.92	64	131	19	7