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The Comparison of Innovative Image Processing and Goniometer Methods in Q Angle Measurement

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Abstract: Q angle is defined as an acute angle between two imaginary lines drawn from the ASIS to the center of patella and from the center of the patella to the tibial tuberosity. Measuring of Q angle usually was conducted in the supine position by two main methods, invasive methods such as radiography and CT scan and non-invasive methods, including goniometer and photogrammetry. The purpose of this study was to examine the validity of a new method for measuring of the Q angle. The Q angle of 9 subjects (18 knees), with mean and standard deviation of age 23.55±2.24 (years), mean weight of 73.00±10.47 (kg), thigh length of 43.11±3.17 cm, pelvis width of 39.66±3.00, using CT scan method, innovative method of image processing and goniometer in the supine position were calculated and the correlation between the innovative method of image processing, goniometer and CT scan was measured via Pearson Correlation Coefficient. The findings of this study revealed a significant relationship between Q angles obtained through the innovative method of image processing and CT scan method in the supine (r=0.92), It also showed significant relation between Q angle obtained with the goniometer and CT scan in the supine position(r=0.81)(p=0.001). According to the result of this research, tools and instruments applied for Q angle calculation can be rated according to the correlation rate that they have with the CT scan method. Therefore, the innovative method of image processing can be an appropriate substitute for goniometer method in measuring Q angle in the supine position.

Keyword: Supine position · CT scan · Goniometer · Innovative method · Q angle · Validity

INTRODUCTION

Q angle is defined as an acute angle between two imaginary lines drawn from the ASIS to the center of patella and from the center of the patella to the tibial tuberosity [1-6]. A normal Q angle value in men is ranged between 10 to14 degrees and in women it ranges between 14.5 to 17 [2]. Although the Q angle is widely used in clinical research and treatments, few studies have been conducted to examine the validity of Q angle measuring methods [4,7]. Therefore, a method with a high validity is of a great significance to measure this angle [7]. Validity of a test or tool is considered to be the ability or capability of the test or the tool to measure what it claims to measure [8]. Validity as the most critical characteristics of a measurement tool is equal to pertinence, significance and usefulness of deductions and interpretations that are inferred based on the test values and also it expresses the generalizability of the test [9]. The measurement of the Q angle is conducted by two main methods; invasive methods including radiography and CT scan [2,10] and non-invasive methods such as goniometer [2,10] and photogrammetry [7,11] in supine and stand position.

Invasive methods include ordinary radiography (X-Ray) and local scan using computer (CT scan). These methods are considered to be the most accurate and valid ones and are applied to every new measurement method as the validity criteria [12,13]. Although these methods have high advantages such as accuracy and precision, because of being invasive, expensive, time consuming, not always available and subject dissatisfaction, they are less used in research and clinics [14].

Goniometer method is however widely used in clinical therapies for range of motion assessment [15,7]. Among the advantages that can be attributed to goniometer are its low-cost and availability [7]; however it also makes researchers face some problems. Various studies have reported various levels of validity and

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reliability for this tool [4,16,11,7,17], when it used in a research with repeated measures design, the Rezontal effect may occur (expectations test), hence this factor can affect the generalizability degree or the external validity [18], Another limitation is mostly referred to as boring and time consuming (especially if it is needed to calculate the angle more than once).

With the advent of technology, digital measurement is more concerned with measuring angles and linear quantities. Photogrammetry makes the exact record of physical changes and relations among various parts of the body possible, that the measurement of which is not easy by other tools [7,19]. This method has the following benefits: the restore process is easily conducted in photogrammetry [7], reduction of measurement errors caused by goniometers alternations and also reduction of investigator errors compared to that of goniometers method [11], recorded files are always much more accessible, digital photogrammetry is always possible to be conjugated with computerized measuring processes. Therefore computerized photogrammetry is the combination of digital photography and software such as Corel Draw [20,7].

In order to decrease universal goniometer measurement errors, a method is intended to invent to measure the Q angle with the most possible minimum measurement error. With the advent of technology, digital measurement is more concerned with measuring angles and linear quantities. The purpose of this study was to examine the validity of a new non-invasive method in measuring Q angle. For this purpose, the researcher will compare each one of the prevailing methods with the criterion (CT scan method).

MATERIALS AND METHODS

This is a correlation and comparative study that trying to design and build a software in order to measure Q angle using photography method, different methods of measurement like CT scan [21], goniometer and the innovative image processing method and finally calculating the coefficient of correlation between the gathered data from the goniometer method and the innovative image processing method with that of the CT scan method. The study was conducted by 9 male volunteers (18 knees, right and left) between 18 to 26 years, the subjects who all signed the consent form.

In order to measure the Q angle, four steps were taken. In the first step the participants filled out the personal questionnaire together with the consent form. In the second step, with palpation the Anterior Superior Iliac Spine (ASIS), the Patella Center (PC) and the Tibial Tubercle Center (TTC) were recognized and marked. Also participant's the pelvis width and thigh length were measured [1-6]. Pelvis width was measured by use of meter according to the distance between the right and left ASIS in frontal plane while the participants were in standing position [22]. The thigh length was measured from the frontal plane of the joints center (thigh great throchanter and thigh lateral condyle) of the participants in standing position [22]. In the third step, the participants were transported to a radiology center and CT scan images were taken. In this method, first some markers were tagged on the marked areas. Because of iliac bone density overlapping with the density of ASIS bone and innovative method was used to place marked needles on the three intended points to insure a better recognition of the points on the CT scan image. Then the participants in a supine position with relaxed quadriceps muscle, knee full extension [11], bare foot, their legs straight up with a 12 cm trapezoid shape sponge placed between the medial malleolus [23] were asked to lie down on the bed and, the picture was taken. Next, a radiology specialist measured the Q angle with the help of DICOM Eye software.

In the fourth step, the participants were transported to the testing location and lied down on the ground in a supine position with knee full extension [11], bare foot and their legs straight up with a 12 cm trapezoid shape sponge placed between the medial malleolus [23]. Their background was meant to be non-reflexive [11]. Then marker were labeled white and digital camera (cannon 5mega pixel) was placed on a tripod in superior view from the lower body parts. The lens was fixed in line with the longitudinal center of thigh. Then in the same position the Q angle of the right and left feet was measured with the universal goniometer. Finally the investigator pictured the participants in the above mentioned position again.

Measuring the Q Angle in the Supine Position Using Goniometer Method : In order to measure the Q angle, the universal goniometer with one degree accuracy was used. The Q angle was measured in a supine position. Goniometers center was placed on the patella center and its stationary arm in the ASIS direction and mobile arm in the tibial tubercle center direction. The number on the goniometer was then written down [4,11,7,23]. This process was repeated for three times and the average of the three measurements was registered as the Q angle.

Fig 1: Photography by CT scan

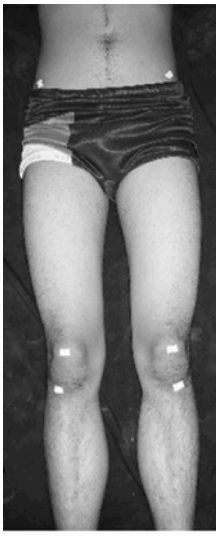

Fig 2: An example of image used for measurement of Q angle

Fig 3: Selected area that its dimension being magnified

Measuring the Q Angle in the Supine Position with the Innovative Image Processing Method: In order to extract the Q angle from the digital picture, the markers positions

Fig 4: Compatible threshold application on image and markers related point extraction

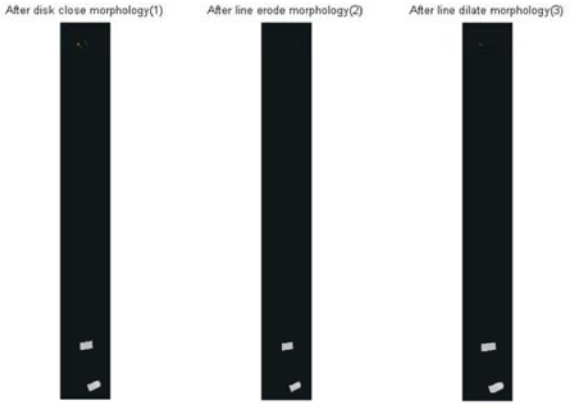

Fig 5: Three continuous morphological operator's application (Disk close, Line Erode and Line dilate) respectively from left to right

Fig 6: The values that are approximate to one is indicator of the rate of roundness in markers

was extracted first from the image. This was normally done with applying compatible threshold. Next, using morphological operators, the markers positions were indicated and subsequently the Q angle was determined according to the position of markers centers.

In the innovative image processing method, Q angle measurement is based on the three intended markers location in relation to each other. In order to avoid compounding the image processing algorithm, it is required that the pictures be taken in a closely observed and the background color be carefully chosen. Figure 2 is an example of the images used in this study and Figure 3 is an example of a chosen part of these images, that was taken in a black background. In order to increase the methods accuracy, the chosen part is magnified. In the next step performing some processes, the markers positions and finally the Q angle was determined from the picture. Different processing stages utilized for locating markers positions and also for the measurement of the Q angle are fully explained below.

Q Angle Calculation: In the first step of the Q angle measurement, the colored picture should be changed into a black and white image. In a controlled situation, the marker related areas may be easily indicated from the black and white image. According to the following formula, it was done by applying the compatible threshold.

$$I_{th}(x,y) = \begin{cases} 1, I(x,y) > +.95 \times \max(I(x,y)) \\ +, I(x,y) \le +.95 \times \max(I(x,y)) \end{cases}$$

This application of compatible threshold, as shown in Figure 3, extracts the marker related areas in figure 4. As shown in Figure 4, with threshold application, all of markers that are related to one markers situation doesn't make a continuous area.

The incoming image dimensions are not the same; on the other hand all the morphological operators applied on the image are directly related to the number of image pixels. At first all of the images dimensions are changed to a certain value. In this study the ratio of horizontal dimension to vertical dimension considered as stable and the images vertical dimension was decided to be 450 pixels.

After applying three morphological operators (DISK CLOSE OPERATION, LINE ERODE OPERATION and finally LINE DILATE) the remaining image points will clearly show the markers places. By calculating the factor (metric which indicates white areas roundness) and indicating the center of each area, the real location of each marker was determined.

Finally the software draw lines between the markers and calculate the angle between these lines. For example, the image shown in figure 6 indicates a calculated 160.4589degree which bears a Q angle of 19.5411 degrees.

To ensure data distribution normality the Colmogrov-Smirnov (k-s) analysis was used and to investigate a relationship between data provided from the goniometer method and the data from innovative image processing method with CT scan, scatterplot and Pearson correlation coefficient were used (significance level 0.05 and ICC 0.95).

RESULTS

The participants characteristics (age, weight, thigh length and pelvis width) are shown in Table 1.

Standard deviation and average of the Q angle calculated through CT scan method, goniometer, innovative image processing method is shown in Table 2.

To prove the variables linear relationship, which is one of the requirements of Pearson correlation formula, the scatterplot was used (Figure 1 and 2).

Figure 1 and 2 show a linear relationship between the data obtained from the innovative image processing method and the CT scan method. It also indicates linear relationship between the data obtained from goniometer method and the CT scan method in a supine position.

The findings indicates a significant relationship between the Q angle calculated through the innovative image processing method and the CT scan in a supine position method (r=0.92). A similar relationship was also found between the goniometer method and CT scan method in a supine position (r=0.81) (Table 3).

DISCUSSION

Regarding the accuracy of the Q angle obtained from the CT scan method [21], the Q angle obtained in this study is compared with the Q angle obtained from innovative image processing and goniometer in a supine position method.

The findings indicates a significant relationship between the Q angle calculated through the innovative image processing method and the CT scan method in a supine position method (r=0.92). A similar relationship is also found between the goniometer method and CT scan method in a supine position (r=0.81)

Table 1: Average and standard deviation of age, weight, thigh length and pelvis width

Variable	Measure Average	Standard deviation
Age (year)	23.55	2.24
Weight (kg)	73.00	10.47
Thigh length (cm)	43.11	3.17
Pelvis width (cm)	39.66	3.00

Table 2: Averages and standard deviation Q angle in supine position

Method	Indicator Number	Average	Standard deviation
CT scan method	18	15.78	2.71
Innovative image processing method	18	15.31	2.63
Goniometer method	18	19.55	3.20

Table 3: The results of Pearson's correlation coefficient

Method	Results: Pearson's correlation coefficient	Results: Standard deviation
CT scan and innovative image processing method in supine position	0.92	0.001
CT scan and goniometer method in supine position	0.81	0.001

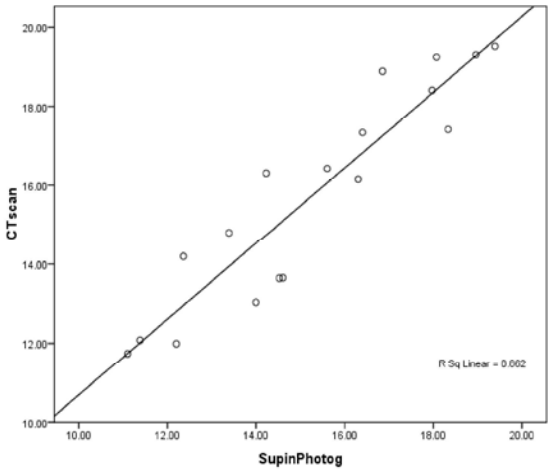

Diagram 1: The regression line resultant from the liner relationship between two variable of CT scan method and innovative image processing methods in Q angle measurement in supine position

The findings imply a significant relationship between the Q angle obtained from the CT scan and the goniometer method in a supine position (r=0.81) which is quite acceptable. Green *et al.* (2001) calculated the Q angle

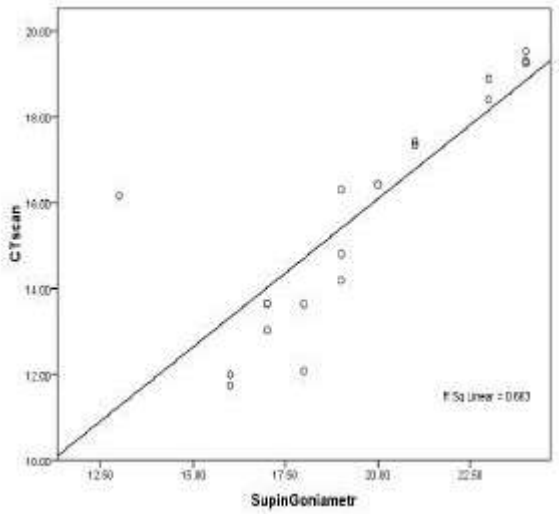

Diagram 2: The regression line resultant from the liner relationship between two variable of CT scan method and goniometer methods in Q angle measurement in supine position

in two different positions: first in supine position with relaxed quadriceps muscle, full extension knee and foot in natural position and second in supine position with relaxed quadriceps muscle and 20 degree knee flexion. Both goniometer and radiography methods were used. Based on their results, reported the goniometer method validity in comparison with radiography in supine position with relaxed quadriceps and full extension knee was 0.32 for both right and left knee and in supine position with relaxed quadriceps and 20 degree knee flexion was 0.19 and 0.13 for left and right knee respectively [4]. Shultz *et al.* (2006) has also conducted a validity analysis between clinical and radiography method to calculate the Q angle in 20 female participants and the findings had report showed 0.42 validity [23].

Comparing the findings of the present study with the above mentioned ones regarding the correlation between the CT scan and goniometer in a supine position method, this study is quite in line with Green *et al.* (2001) and Shultz *et al.* (2006) and totally corroborates their findings. However this study in comparison with Green *et al.* (2001) and Shultz *et al.* (2006), reports greater values. This may be the result of a standard testing situation; the accuracy of the measures taken or well may be due to the investigator's experience. Also in this study the error caused by bone landmark identification were reduced, because in this study in the first step the intended points were identified, but Green *et al.* and Shultz *et al.* hadn't done that.

In relation to Q angle obtained from innovative image processing method and CT scan method in supine position, the results showed a significant correlation (r=0.92). This meant that this method has a suitable and high validity for Q angle measurement. Few studied have focused in this method to calculate the Q angle, some of them have made a comparison between the innovative image processing method and the goniometer method [11,7]. However, none of them has studied this method with regard to the aggressive ones (like MRI, CT scan, X-Ray). It seems that the innovative image processing method lacks the investigator's error and consequently is entitled with more validity in calculating the knees Q angle, which is also corroborated here through the reported correlation between Q angle values in the supine position obtained from the innovative image processing method and the CT scan method. Among the advantages of this method are the convenience in saving process [7], the reduction of the measurement errors caused by goniometers alterations and also reduction of investigator's errors while using the goniometer method [11], accessibility of the recorded files in every time and possibility of conjugation with computerized measuring processes [7]. However the most noticeable disadvantage of this method is the impossibility of utilization for female subjects in Iran.

Therefore, innovative image processing method can be used for Q angle measurement in supine position. Among the most important reasons for this methods validity is the fact that the process goes on quite fast and automatic and also needless to any human interference. Also, being totally dependent to digital and logical processes increases its accuracy. The error existing in the universal goniometer method may be a result of human body reaction. However in this method, after fixing the indicators, no kind of physical touch is done to the body which can itself prevent many measurement errors. Obviously this method of measurement improves different studies quality and provides more accessibility to the instruments used for research.

CONCLUSION

As was declared in the investigation of other studies, different methods and instruments with different validities are used to study the Q angle of the knee. According to the findings of this study these instruments can be classified based on their correlation with CT scan method. Based on results, the innovative image processing method were correlated with CT scan method in a supine position (r=0.92) and likewise the correlation between the goniometer and the CT scan method in a supine position was (r=0.81). Therefore, concluded that the innovative image processing method can be an appropriate substitute for the goniometer method for calculating the Q angle in a supine position.

REFERENCES

1. Bayraktar, B., I. Yucesir, A. Ozturk, A.K. Cakmak, N. Taskara, A. Kale, D. Demiryurek, A. Bayramoglu and H. Camlica, 2004. Change of quadriceps angle values with age and activity. Saudi Medical J., 25(6): 756-760.
2. Belchior, A.C.G., J.C. Arakaki, D. Bevilaqua-Grossi, F.A. Reis and P.T.C. Carvalho, 2006. Effects in the Q angle measurement with maximal voluntary isometric contraction of the quadriceps muscle. Rev. Bras. Med. Esporte. 12: 1.
3. France, L. and C. Neste, 2001. Effect of errors in the indentification of anatomical landmark on the accuracy of Q angle values. Clinical Biomechanics, J16: 710-713.
4. Greene, C.C., T.B. Edwards, M.R. Wade and E.W. Carson, 2001. Reliability of the quadriceps angle measurement. Am. J. Knee. Surg., 14(2): 97-103.
5. Hungerford, D.S. and M. Barry, 1979. Biomechanics of the patellofemoral joint. Clin. Orthop. Relat. Res., 144: 9-15.
6. Tsujimoto, K., M. Kurosaka, S. Yoshiya and K. Mizuno, 2000. Radiographic and computed tomographic analysis of the position of the tibial tubercle in recurrent dislocation and subluxation of the patella. Am J. Knee. Surg., 13: 83-88.
7. Sacco, I.C.N., S. AlIbert, B.W.C. QueIroz, D. Pripas, I. KlelIng, A.A. Kimura, A.E. Sellmer, R.A. MalveStIo and M.T. Sera, 2007. Reliability of Photogrammetry in Relation to goniometry for postural lower limb assessment. Rev. Bras. Fisioter. pp: 411-17.
8. Evans, R. and G. Elwyn, 2004. Edwards. A Review of instruments for peer assessment of physicians. BMJ. 328: 1240.
9. Janda, L., 2001. The psychologists book of personality test. New York : Wiley.
10. Holmes, S.W. and W.G. Clancy, 1998. Clinical classification of patellofemoral pain and dysfunction. J. Orthop Sports Phys. Therapy. 28: 299-306.

11. Roush, J.R., K. Bustillo and E. Low, 2008. Measurement Error Between a Goniometer and the NIH Image J program for measuring Quadriceps angle. J. Allied Health Sciences and Practice. pp: 1540-580.
12. Bryan, J.M., E.A. Mosner, R. Shippee and Stull, M.A. 1990. Investigation of the validity of postural evaluation skills in assessing lumbar lordosis in black and white adult female sample populations.Journal of Orthopedic and Sports Physical Therapy. 12: 24-28.
13. Tillotson, K.M. and A.K. Burton, 1991. Noninvasive measurement of lumbar sagittal mobility. An assessment of the flexicurve technique. Spine. 16: 29-33.
14. Nagamine, R., H. Miura, K. Urabe, S. Matsuda, W.J. Chen, T. Matsunobu and Y. Iwamoto, 1999. Radiological assessment of the position of the tibial tuberosity by means of a marking wire in knees with patellofemoral arthritis. Skeletal Radiol., 28: 27-32.
15. Sabari, J.S., I. Maltzev, D. Lubarsky, E. Liszkay and R. Homel, 1998. Goniometric assessment of shoulder range of motion: comparison testing in supine and sitting positions. Arch. Phys. Med. Rehabil. 79: 647-51.
16. Livingston, L.A. and J.L. Mandigo, 1999. Bilateral Q-angle asymmetry and anterior knee pain syndrome. Clinical Biomechanics, 14: 7-13.
17. Shultz, S.J., A.D. Nguyen, T.C. Windley, A.S. Kulas, T.L. Botic and B.D. Beynnon, 2006. Intratester and intertester reliability of clinical measures of lower extremity anatomic characteristics: implications for multicenter studies. Clin J. Sport Med., 16: 155-161.
18. Sarmad, Z., A. Bazargan and A. Hejazi, 1387. Research methods in behavioral science, Tehran. [Persian].
19. Watson, A.W., 1998. Procedure for the production of high quality photographs suitable for the recording and evaluation of posture. Rev Fisioter univ São Paulo., 5(1): 20-6.
20. Mattos, F., Rodriguese *et al.* 2003. Corel Draw 11. Rio de Janeiro: Brasport.
21. Ando, T., H. Hirose, M. Inoue, K. Shino and T. Doi, 1993. A new method using computed tomographic scan to measure the rectus femoris-patellar tendon Q-angle comparison with conventional method. Clin Orthop Relat Res., 289: 213-219.
22. Pantano, K.J., S.C. White, L.A. Gilchrist and J. Leddy, 2005. Differences in peak knee valgus angles between individuals with high and low Q-angles during a single limb squat. Clinical Biomechanics. 20: 966-972.
23. Stensdotter, A.K. P.I. Andersson, A. Rydh, Hager and C.H. Ross, 2009. Q-angle variations in standing and supine positions and for different measurement methods in women with and without patellofemoral pain. Advances in Physiotherapy. 11: 88-96.