FUNCTIONAL INSTABILITY OF THE ANKLE AND ITS RELATIONSHIP TO THE Q ANGLE.

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ABSTRACT

Ankle ligament injuries are common, and the majority of ankle sprains can be treated successfully. However ankles that demonstrate recurrent sprains or have the tendency to give way are known to be functionally unstable. Functional Instability (FI) can present with three pathophysiological factors; mechanical instability, proprioceptive deficits and peroneal muscle weakness. Clinical examination reveals that with increased inwards rotation and forward displacement of the calcaneus, the subtalar joint will be held in a supinated position resulting in compensatory tibial, femoral and pelvic external rotation.

To evaluate functional instability a number of tests were carried out bilaterally on all participants (N=27), in order to compare their control and symptomatic ankles. The participant stated on the information sheet which of their ankles was symptomatic. Two mechanical tests were conducted, the anterior draw test and the talar tilt. Postural sway was mapped using the Force Vector Visualisation System and peroneal muscle strength was measured using a kinetic dynamometer. Following these tests the Q angles of each participant were measured and calculated.

Peak peroneal concentric torque demonstrated a significant negative relationship with Q angle in subjects experiencing FI of the ankle (p=.000). FI of the ankle may result in hyper supination of the foot, with compensatory external rotation of the tibia and femur, accounting for a decrease in Q angle as found in this study, altering patellofemoral kinematics. From the results obtained, it can be said that with a maximum effort of the

Q angle. Further investigation is needed into the relationship between the components of FI and the kinematics of the entire lower limb.

Key words; Quadriceps angle, Functional instability, Ankle

INTRODUCTION

Ankle ligament injuries are the most common injuries in sports and recreational activities[1]. Therefore, ankle sprains are not scarce in the general population nor amongst athletes. Eighty five percent of ankle sprains are caused by an inversion trauma[2], which damages the lateral stabilising ligaments of the ankle. The capsule of the ankle joint is thin and especially weak anteriorly and posteriorly, so the stability of the ankle is dependant on an intact ligamentous structure[3]. The majority of ankle sprains can be treated successfully, however ankles that suffer recurrent sprains or have the tendency to give way, are known to be functionally unstable [2-5].

Functional Instability (FI) can present with three pathophysiological factors; mechanical instability, proprioceptive deficit and peroneal muscle weakness[2,4,5]. Mechanical instability of the talocrural joint, that is, adduction or posterior - anterior instability of the talus in the ankle mortice is the most widely accepted aetiological factor contributing to FI[5]. The Anterior Draw sign, an anterior glide of the talocrural joint, is the most significant test for ankle instability[6]. Some magnitude of excessive talar tilt, may also be present[7], contributing to subtalar instability. Adduction stresses the calcaneofibular ligament and to some degree the anterior talofibular ligament while abduction stresses the deltoid ligament. Reliability studies conducted by Ryan[5] showed there was agreement in 19 of the 20 grades of movement, performed on five subjects on two separate occasions, and 17 of the 20 grades of instability demonstrated interexaminer reliability of the two instability tests; anterior draw and talar tilt. Paired t-test analysis in Ryan's[5] study revealed no significant difference between the values recorded at each examination ($t = 1.04$, $p = 0.325$), and the Pearson product moment correlation coefficient indicated a high degree of consistency ($r = 0.94$).

Upon spraining of the lateral ligaments an interruption of afferent nerve impulses occurs, resulting in impaired proprioception, potentiating the recurrent "giving way" of the ankle[5]. A normal individual will demonstrate a rhythmic anterior posterior sway envelope, whereas, a subject exhibiting a deficit in ankle proprioception will demonstrate a relatively uncontrolled sway envelope. Stabilometry to measure postural sway variables was used by Friden et al[8] who assessed 14 patients who had sustained acute ankle sprains, there was a significant difference when comparing injured and uninjured legs, representing poorer performance on the injured side.

The peroneal muscle group plays a major role in preventing ligamentous injury. The strength of peroneus longus and brevis is believed to be highly important in absorption of stress and in providing support to the lateral ligaments [9]. Therefore weakness of the peroneal muscle group would render the ankle joint to be more susceptible to "giving way". Peak torque: body weight ratios help to put in perspective the amount of muscle torque generated by the everter muscle group for each participant taking into account their height and weight.

In vitro studies conducted by Cass et al[10] and Sommer et al [11] have demonstrated that the lateral ankle ligaments play a vital role in not only maintaining lateral ankle stability but also play a significant part in maintaining rotational ankle stability and in transferring movement between the leg and the foot. In being the link between the shank and the ground, the foot and its many components control the amount of tibial rotation [11]. Because the lower extremity functions as a closed kinetic chain during the stance phase of gait, the movement of one joint effects the movement of another. Thus, rearfoot motion variables may be useful in the prediction of lower extremity injury. Clinical examination reveals that with increased inwards rotation and forward displacement of the calcaneous, the subtalar joint will be held in a supinated position, resulting in compensatory tibial, femoral and pelvic external rotation.

As early as 1986 Tropp[9], the theory that pronator muscle weakness and impaired postural control occurred in the ankle in patients who presented with FI was tested. Tropp's[9] study confirmed that peroneal muscle weakness is a component of FI of the ankle, and postulates that the muscular impairment is probably due to secondary muscle atrophy caused by inadequate rehabilitation.

Residual symptoms resulting from recurrent episodes of inversion-type ankle sprains may be attributed to a decreased neuromuscular response of the peroneal or tibialis anterior muscles. Ebig et al[4] also conducted a study based on participants who reported a history of unilateral inversion-type ankle sprain and compared reaction time in milliseconds of the peroneal and tibialis anterior muscles to a sudden plantar flexion/inversion sprain to the contralateral normal ankle, in 13 subjects. The results indicated no significant differences between the stable and unstable ankles for the peroneal and tibialis anterior muscles reaction time.

The Q angle is created by a line connecting the Anterior Superior Iliac Spine (ASIS) to the midpoint of the patella and the extension of the line connecting the tibial tubercle and the midpoint of the patella[12]. The Q angle represents the frontal plane angle of the quadriceps resultant force on the patella and tibial tuberosity[12]. The Q angle can be measured reliably and may be implicated with altered patellofemoral contact pressures and foot mechanics [12]. The mean values for the Q angle are 13.5° $\pm$ 4.5° in healthy subjects between 18 - 35 years of age [13]. A normal Q angle in women may range from 2.5° – 10 and in men 0° – 8°[14], and according to Kernozek and Greer[15] the most effective angle of pull of the quadriceps muscle is 10° of valgus and women typically have a Q angle greater than men 17° and 14° respectively.

The mechanism for a decrease of the Q angle as the foot shifts from pronation to supination indicates rotational movement of the entire limb, Inman [16] suggests that the ankle joint in combination with the subtalar joint acts as a torsion transmitter, and consequently a supinated foot position, will cause an external rotation of the tibia and thus a decrease in the Q angle. If there is alteration of the Q angle, there is altered patellofemoral biomechanics. Patellofemoral joint biomechanics demonstrate a strong correlation with the aetiology of patellofemoral disorders such as chondromalacia, and are significantly influenced by tibial rotation[17]. As knee flexion increases, the patella sits in the trochlear groove more securely and therefore is less affected by external and internal rotation of the tibia.

According to Lee et al[18] who investigated the change of patellofemoral contact pressures with various degrees of tibial rotation found that there is a greater change of patellofemoral contact pressures at 15° of external rotation of the tibia at 0°, 30° and 60° of knee flexion, than in internal tibial rotation. As FI can result in a compensatory hypersupination of the foot, causing external tibial rotation, this can result in an increase in patellofemoral contact pressures. Q angle variation can shift the patella across the width of the trochlear with coupled variations in the patella tilt and rotation. A Q angle decrease alters patella kinematics by tilting the patella laterally.

In normal patellofemoral joints, the contact pressures are remarkably even [17]. However, Lee et al[18] found that a varus orientation of the lower limb produced by a decrease in Q angle, increases the medial tibiofemoral contact pressure. A decrease in Q angle significantly influenced patella kinematics by tilting the patella laterally. The increase in the patellofemoral contact pressures due to tibial rotation showed higher patellofemoral contact pressures with external tibial rotation than internal [17]. It has also been reported that both an increase and decrease in Q angle lead to more non uniform pressure distributions, with higher peak stresses and unloading of other areas [17].

The most striking finding reported by Sanfridsson et al[19] was that dislocating knees showed a smaller Q angle than healthy knees. Further, the habitual dislocation group demonstrated greater relative rotation between the tibia and the femur and an increased patella translation compared to the traumatic group and healthy volunteers. An abnormal Q angle can lead to many pathological conditions involving the knee. Alignment of lower extremity segments has often been implicated as a potential cause of running injury[20].

If the literature accurately links an decrease in the Q angle with altered patellofemoral contact pressures, this may be a predisposition for knee injury, and early wear and tear of the cartilaginous components of the joint, then the role of adequate rehabilitation of both mechanical ligamentous support, proprioceptive deficits and peroneal muscle weakness is vital to maintain a normal Q angle.

The purpose of this study was to evaluate the change in the Q angle measurement in patients with unilateral FI of the ankle.

MATERIALS AND METHODS

Participants

A total of 27 students (10 males, 17 females, range 18 - 32yrs, mean age 22.60years ± 7.56years) from the student body of Victoria University and associated sporting clubs were recruited from a volunteer list. Participants were required to have a history of recurrent ankle sprains and/or a sensation of "giving way" in one ankle. Participants were excluded if they had a history of previous reconstructive or orthopaedic surgery to the lower ankle or knee, or congenital abnormalities of the foot; such as tarsal coalition, rearfoot varus deformity, forefoot valgus deformity, plantar flexed first ray, or valgus/varus deformities of the knee or any pain during Dynamometer testing. The study was approved by the Faculty of Human Research Ethics Committee of Victoria University. All participants signed consent forms and were free to withdraw from the study at any time.

Procedure

Data collection was conducted over five days at the City Campus of Victoria University, Melbourne, Australia. The time taken to test each subject was approximately 25 minutes.

Participants who met the inclusion criteria were notified and informed of the day and time of testing. An information sheet was handed out to participants to prior to testing, where participants volunteered information regarding exclusion criteria and ankle injury history information. The participant stated on the information sheet which of their ankles was symptomatic and hence the other ankle was regarded as the control.

1. The Anterior Draw: the participant was placed supine on a treatment table with the knee flexed and supported at 60°, measured by a goniometer, to help eliminate gastrocnemius muscle tension [3]. The practitioner stabilised the tibia and fibula and a shear force was applied pulling the calcaneus and foot anteriorly. The movement was graded on a scale adapted from Ryan[5].

1 = very hypomobile

2 = slightly to moderately hypomobile

3 = normal

4 = slightly to moderate hypermobile

5 = Very hypermobile

2. Talar Tilt test; the subject layed supine, on a treatment table, the practitioners hands were placed around the calcaneus and the talus was then tilted from side to side into adduction and abduction. The examiners thumb was used to detect the gapping between the talus. The movement was graded on the same scale at the Anterior Draw Test[5].

Peroneal muscle strength was assessed by a kinetic dynamometer (Biodex Multijoint Dynamometer, Biodex Inc. Shirley, NY, USA). The subject was placed in a seated and aligned position according to the Biodex Multijoint Dynamometer Manual[21].A practise run of five maximal repetitions at a speed setting of 120 degrees/second was conducted to familiarise the subject with the machine, then three maximal repetitions at a setting of 30 degrees/second was completed. Peak concentric torque data was recorded.

Assessment of proprioceptive muscle deficit of the ankle consisted of measuring the participant's postural sway, in unilateral stance with the eyes open. The subject stood on one foot, on a force platform, an AUTI (Massachusetts, USA) force platform was used, running Beta-2 Stability Action software for data collection. The subject's hands were placed on their hips, the non weight bearing leg flexed so the big toe was resting next to the medial malleolus of the weight bearing leg, and the subject was asked to focus on a marked spot on the wall in front of them and hold the position for ten seconds. The total sway of each subject was recorded.

The measurement of the Q angle was performed with the subject asked to undress so that the appropriate landmarks could be clearly visualised. The ASIS, the midpoint of the patella, and the centre of the tibial tuberosity were palpated and marked with reflective markers. The Q angle was assessed by taking one photograph using a digital camera (Canon Video Camcorder, MV 430i, Japan), placed three metres away from the subject. The subject stood with their feet at a comfortable distance apart, with the large toes level with a line marked on the floor. The memory card images were downloaded onto a desk top computer and the Image maker program displayed the photographs of each participant. From each digital photograph the Q angle was measured five times bilaterally, with the angle measuring tool from the program. Each subject's average Q angle was calculated and recorded.

Statistical methods

To evaluate the presence of a correlation between multiple variables, means and standard deviations were used to report the data and a factor analysis was performed, with significance levels set at $p \leq 0.05$, using SPSS version 11.0. Factor analysis is a data reduction technique, used to reduce a large number of variables to a smaller set of underlying factors that summarise the essential information contained in the variables. A factor is a group of items that may be said to belong together, and thus a subject who scores high on one item of a particular factor, is likely to score high on other items within that factor but not those items within another factor.

RESULTS

Q angles ranged from 9.47° ± 5.73° in males on their symptomatic leg to 17.32° ± 7.29° in females on their symptomatic leg. These are displayed in the following table (Table 1). Interestingly, the symptomatic males produced the only mean value below ten°. Large standard deviations values were also reported in most categories.

Table 1; Means, Standard Deviations of Q angle Measurements

Q angle	M	SD
Males **Symptomatic**	9.47°	5.73°
Males **Control**	13.2°	7.42°
Females **Symptomatic**	17.32°	7.29°
Female **Control**	17.05°	7.07°
Combined **Symptomatic**	14.41°	7.68°
Combined **Control**	15.63°	7.31°

As highlighted below in Table 2, a moderate negative relationship was calculated between peak torque generated by the everter muscle group (r = -0.308, p = .000) and peak torque control (r = - 0.439, p = .000) with the symptomatic Q angle measurement. A significant relationship was also found between the symptomatic Q angle and the control anterior draw mechanical stability measurement, (r = 0.385, p = .000), and the control Q angle and the symptomatic talar tilt mechanical stability measurement (r =

0.304, p =.000). There is also evidence of a moderate positive relationship between the symptomatic eversion-inversion percentage and the control Q angle (r=0.546, p =.000).

Table 2; Means, Standard Deviations and Correlations with Q angle

Component of FI	M	SD	Q angle **Symptomatic** Correlation	Q angle **Control** Correlation
Anterior Draw **Symptomatic**	3.4	0.70	.229	.147
Anterior Draw **Control**	3.26	0.53	.385*	.264
Talar Tilt **Symptomatic**	3.52	1.02	.193	.304*
Talar Tilt **Control**	3.40	0.75	-.014	.025
Postural Sway (l value) **Symptomatic**	59.49	12.99	.069	.054
Postural Sway (l value) **Control**	59.37	14.23	-.081	-.207
Peak Torque (Nm) **Symptomatic**	16.62	5.33	-.308*	.102
Peak Torque (Nm) **Control**	15.99	4.44	-.439*	-.089
Peak Torque: Body weight % **Symptomatic**	25.96	7.55	-.136	.231
Peak Torque: Body weight % **Control**	24.88	5.69	-.248	.042
Eversion:Inversion % **Symptomatic**	100.15	42.02	.100	.546*
Eversion:Inversion % **Control**	92.16	30.4	-.229	.038

*p = .000

The factor matrix demonstrates that there are seven complex factors, making interpretation of the output more complex. The rotated factor matrix enhances interpretation; however in this instance it still contains seven complex variables. These complex items must be interpreted with caution because simple structure is not apparent.

Table 3: Representation of Variables that Make up Factor 1 - 7- Rotated factor Matrix

	FACTOR						
VARIABLE	1	2	3	4	5	6	7
MALE FEMALE		0.345				0.613	
AGE	0.722						
RIGHT/LEFT				0.61			
MOST RECENT INJURY				-0.694			
ANKLE PAIN				-0.38	0.413		
ANTERIOR DRAW SYMPTOMATIC		0.861					
ANTERIOR DRAW CONTROL		0.614					
TALAR TILT SYMPTOMATIC		0.729					
TALAER TILT CONTROL	-0.305	0.624					
POSTURAL SWAY SYMPTOMATIC	0.341			0.501			0.359
POSTURAL SWAY CONTROL							0.802
PEAK TORQUE SYMPTOMATIC	0.918						
PEAK TORQUE CONTROL	0.44		0.758				
PEAK TORQUE:BODY WEIGHT SYMPTOMATIC	0.843						
PEAK TORQUE:BODY WEIGHT CONTROL	0.324		0.758				
EVERSION:INVERSION SYMPTOMATIC					0.898		
EVERSION INVERSION CONTROL			0.422	0.418			
PEAK TORQUE DEFICIT						0.692	
Q ANGLE SYMPTOMATIC			-0.594				
Q ANGLE CONTROL					0.602		

Factor 1 demonstrates a strong correlation with peak torque, because the peak torque variable makes up a large percentage of factor 1.The Eigenvalue represents the total amount of variance explained by a factor, and the most important factors extracted from this analysis initially represented 79.182% of the cumulative total variance. There are seven factors with Eigenvalues greater than 1.

Table 4 Total Variance Explained - Rotated Sums of Squared Loadings

Factor	Eigenvalue	Percentage of Variance	Cumulative Percentage
1	2.947	14.735	14.735
2	2.486	12.428	27.163
3	2.170	10.849	38.012
4	1.845	9.226	47.238
5	1.701	8.507	55.744
6	1.442	7.210	62.955
7	1.159	5.796	68.751

Factor 1, representing the largest amount of variance was composed of the following variables; age, talar tilt control, postural sway symptomatic, peak torque symptomatic, peak torque control, peak torque: body weight symptomatic and peak torque body weight control.

DISCUSSION

It is commonly thought that Q angles in excess of 15° – 20° contribute to knee extensor dysfunction and patellofemoral pain[14], therefore it is important to place this study's population data within the bounds of the already established research. This study reported mean Q angles (control 15.63° ± 7.31°, symptomatic 14.41° ± 7.68°). The mean values obtained are greater than normal range. The high mean Q angle range may be attributed to the participants in this study reporting a history of recurrent sprains and ankle injuries, hence questioning their ability to fall within a "normal" range.

Khun et al[13] conducted a study evaluating the changes in the Q angle after the insertion of full length flexible orthotics. Forty subjects had a mean Q angle of 12.1° ± 2.6°. This population of subjects all demonstrated bilateral hyper pronation of the feet. In the present study, the mean Q angle within the symptomatic group was 14.41° ± 7.68°, the populations of Khun et al[13] study and the present study are considered to be comparable as they both assess an abnormal population.

The current study's population consisted of ten males and seventeen females, all within the age range of eighteen to thirty-two years of age. Interestingly age was found to be grouped with other components of FI to make up Factor 1of the Rotated Factor matrix.

Continued FI of the ankle, can be partly explained by mechanical instability and proprioceptive deficits. The means for both the mechanical and proprioceptive symptomatic measurements of FI were greater than those of the control. A mild significant relationship was found between the control anterior draw measurement and the symptomatic Q angle ($r = 0.385$, $p = .000$). Although the symptomatic ankle showed a greater mean measurement of anterior draw, the control ankle illustrates a stronger positive correlation with the symptomatic Q angle, raising some doubt as to the reliability of the mechanical stability tests performed in this study. Also highlighted was a mild significant relationship between the symptomatic talar tilt and the control Q angle ($r = 0.304$, $p = .000$), even though the mean symptomatic talar tilt measurement was greater than that of the control measurement. The mean statistical measurements of both elements of mechanical stability demonstrated some differences; anterior draw: symptomatic 3.4 +0.70, control 3.26 + 0.53, talar tilt: symptomatic 3.52 +1.02, control 3.40 + 0.75. These tests performed manually by the same practitioner showed some consistency with studies conducted by Ryan[5]. Values obtained in this present study were on a mobility scale between normal and hypermobile. As all the participants in this study were recruited on the criteria that they reported a history of recurrent sprains, this does then not appear to be an extreme result.

The postural sway envelope measurements were not found to be significantly different between the two groups, (symptomatic 59.491 + 12.991, control 59.371 +14.231),these results are consistent with Ryan[5] who also failed to demonstrate a significant variance in postural sway between the affected and contralateral normal ankle, using a similar force platform system. There was also no correlation between postural sway and the Q angle. This may have been affected by the method of this study, although both ankles were being assessed the participant may have been aware of their subjective ankle and accommodated by trying harder to maintain their balance, and hence more control of their sway envelopes. Also the participant was allowed to have 3 - 5 seconds to balance, prior to the sway envelope being measured, it may have been more accurate to record this initial stabilising mechanism, recruiting muscular and ligamentous control as part of the sway envelope, rather than allowing the participant time to control any severe sway when at the beginning of the unilateral weight bearing stance.

The strength of the peroneus longus and brevis musculature is believed to be highly important in absorption of stress and in providing support to the lateral ligaments. Tropp[9] confirmed earlier research that peroneal muscle weakness is a component of FI and the symptomatic ankle in this present study has demonstrated to have a significant relationship with a decrease in the Q angle. However this study failed to confirm the theory of everter muscle weakness with control peak torque 15.99° $\pm$ 5.69° and symptomatic peak torque 16.62° $\pm$ 5.33°. Ryan[5] also failed to demonstrate this relationship, in which there was no significant difference in the mean strength score of everters of the affected and unaffected ankles, with values of 18.8Nm $\pm$ 6.6Nm and 19.2Nm $\pm$ 5.8Nm respectively. Ryan[5] considered the order of the testing, in his study's failure to achieve the same results as Tropp[9] and explained that the order may have influenced a learning effect that was biased in favour of the symptomatic ankle. In the current study the order of testing was based on the layout of the facilities. Peroneal muscle strength testing was also the final component assessment in order to eliminate fatigue having an effect on the other tests. From the results obtained in this present study it can be said that with a maximum effort of the everter muscles the peak torque generated had a significant relationship with a decreased Q angle.

A significant negative relationship exists between peak torque and Q angle measurement (r = -.308, p=.000). As each participant was asked to produce a maximum effort during which everter muscle torque was evaluated, increased muscle torque is a result of increased muscle strength. As peroneal muscle strength is a factor in FI, it is important to investigate this relationship further.

The results of this study do not agree with Tropp[9], who did much of the preliminary work with FI of the ankle. Tropp[9] demonstrated significant peroneal muscle weakness in fifteen patients suffering from unilateral FI presenting to a Hospital Orthopaedic Department. The severity of FI experienced by Tropps[9] participants may be assumed to be greater than that experienced by the university and sporting population in this study. All of the patients Tropp[9] used in his study had consulted the Orthopaedic Department of the Hospital and their FI interfered with their sporting activities, this was not the case in the population used in the current study, the impact of this studies participants FI on their sport involvement was not ascertained but believed to be minimal.

FI of the ankle may result in hyper supination of the foot, with compensatory external rotation of the tibia and femur, accounting for the decrease in the Q angle as found in this study. The lower extremity functions as a closed kinetic chain during the stance phase of gait and the movement of one joint effects the movement of another[14] .The ankle joint in combination with the subtalar joint acts as a torsion transmitter, and consequently a supinated foot position will cause an external rotation of the tibia and thus a decrease in the Q angle[16]. This excessive tibial rotation transmits abnormal forces upward to the knee, altering the force vectors of the quadriceps muscle resulting in medial translatory forces on the patella[18]. As the patella tracks medially the Q angle is subsequently decreased[18].

The factor matrix tells us that there are many components of FI and their interrelationship with Q angle variation is complex. However, Factor matrix has enabled us to group like factors that represent the greatest amount of variance and hence influence the Q angle.

The findings of this study have important implications for the treatment and management of FI of the ankle. With altered patellofemoral joint function originating from ongoing FI of the ankle, altered patellofemoral biomechanics may ensue. Patellofemoral joint biomechanics demonstrate a strong correlation with the aetiology of patellofemoral disorders such as chondromalacia and are significantly influenced by tibial rotation[15]. Thus with thorough post injury rehabilitation and management of FI subsequent progression to further lower limb biomechanic stresses may be avoided.

CONCLUSION

Lower limb everter muscle peak torque was demonstrated to have a significant negative relationship with a decrease in the Q angle, in a group of 27 subjects, experiencing FI of the ankle. However this study failed to confirm the theory of everter muscle weakness with control peak torque 15.99° $\pm$ 5.69° and symptomatic peak torque 16.62° $\pm$ 5.33°. From the results obtained in this study it can be said that with a maximum effort of the everter muscles the peak torque generated had a significant relationship with a decreased Q angle. Further investigation is needed into the relationship between the components of FI and the kinematics of the entire lower limb

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