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Original Research Article

Correlation between Body Mass Index, Waist Hip Ratio & Quadriceps Angle in Subjects with Primary Osteoarthritic Knee

Ved Prakash[1], Pallavi Sahay[2], Ananya Satapathy[3]

[1]Student M.P.T. (Orthopedics), [2]Physiotherapist, [3]Senior Professional Trainee,
[*]Department of Physiotherapy, National Institute for Locomotor Disabilities (Divyangjan) (NILD), B.T. ROAD, Bonhoogly, Kolkata-700090, West Bengal, India.

Corresponding Author: Ved Prakash

ABSTRACT

Background: American rheumatism association has defined OA as a heterogeneous group of condition that leads to joint symptoms & sign which are associated with defective integrity of articular cartilage, in addition to related changes in underlying bones & at the joint margins. It is mainly found in weight bearing joints. A high Q-angle interferes with the smooth gliding movement between the patella & the knee & over time eventually knee become degenerative & develop OA. Increased knee joint loads are present in patients with knee OA & interaction between axial alignment & dynamic knee joint loading is especially pronounced in patients with high BMI. The WHR suggests that truncal obesity is the greatest contributor to the relation between body habitus & chronic disease. So aim of this study was to find the correlation between BMI, WHR & Q-ANGLE in subjects with primary OA knee.

Methods: Total 185 subjects with age more than 38 years (male & female) were assessed of which out them 150 subjects were included in this study as per inclusion & exclusion criteria after detail assessment. Informed consent was taken in their preferred language.

Results: Mean & standard deviation of BMI , WHR & Q-ANGLE were 27.28 ± 4.05 kg/m^2 , 0.91 ± 0.07 , 19.7° ± 2.06° respectively. Among these three variables, there was significant positive correlation between BMI & Q-ANGLE ($p \leq 0.05$) only where as insignificant positive correlation between BMI & WHR, insignificant negative correlation between WHR & Q-ANGLE was ($p \geq 0.05$) found.

Conclusion: These 3 independent parameters as risk factors for primary OA were also a risk factors for the same interdependently.

Key Words: Primary OA, BMI, WHR, Q-ANGLE

INTRODUCTION

Osteoarthritis (OA) is defined by the American College of Rheumatology as a "heterogeneous group of conditions that lead to joint symptoms and signs which are associated with defective integrity of articular cartilage, in addition to related changes in the underlying bone at the joint margins." [1] The term osteoarthritis derived from the Greek word "osteo" meaning bone, "arthro" meaning joint and "itis" meaning inflammation. [2] Osteoarthritis is the most commonly encountered disorder of the musculoskeletal system and it is the major cause of disability and socioeconomic burden. Osteoarthritis is the second most common rheumatological disorder and is a non-specific term denoting an

inflammatory, degenerative joint process without auto-immune component which may affect the articular cartilage and the other soft tissues associated with the joint.[1]

Osteoarthritis is a widespread, slowly developing disorder, with a high prevalence increasing with age. Osteoarthritis is the most frequent joint disease with prevalence of 22% to 39% in India. [3] It is the 4th leading cause of years lived with disability (YLDs), accounting for 3.0% of total global YLDs (Years Lived with Disability), as per WHO 2000 estimation. [4] The World Health Organization has reported knee osteoarthritis is the 4th most common cause of disability in women and the 8th in men. [5] Osteoarthritis is becoming increasingly recognized in both developed and developing countries as a major cause of pain and disability, with 44%-70% of people over the age of 55 years having radiological evidence. [6] The peak onset for development of osteoarthritis is between 50 years to 60 years of age. [7] OA occurs commonly in females above 45 years of age while before 45 years it is common in males. [8] Females, particularly those ≥55 years, tend to have more severe OA in the knee but not in other sites. [7]

Studies done by Srikanth V K et al (2005) demonstrated sex differences incidence of knee OA particularly after menopausal age. [8] Studies done in Jammu using the ACR criteria demonstrated the prevalence to be 4.24% and the associated risk factors of knee OA to be age, female gender, and repeated bending of the knee. [9] The COPCORD (Community oriented program from control of rheumatic diseases) studies conducted in India, Bangladesh and Pakistan each collected data from several communities revealed a significantly higher prevalence of knee pain in the rural (13.7%) compared with the urban (6.0%) community. [10]

Body mass index is a measure of weight adjusted for height, calculated as weight in kilograms divided by the square of the height in meter (Kg/m^2). Although body mass index is often considered an indicator of body fitness, it is a surrogate measure of body fat because it measures excess weight rather than excess fat. [11] Body mass index is a simple, inexpensive & non-invasive surrogate measure of body fat. In contrast to other methods, body mass index relies solely on height & weight. [11] Increased knee joint loads present in patients with OA knee & the interaction between axial alignment & dynamic loading, is especially pronounced in patients with high body mass index. The biomechanical theory concludes that obesity leads to repetitive application of increased axial loading on the knee joint with consequent degeneration of articular cartilage & sclerosis of subchondral bone. [12] Study showed that body mass index & Quadriceps angle have significant contribution in overall clinical deficits in the osteoarthritis knee. [12]

Waist hip ratio looks at the proportion of fat stored on body in the waist & hip areas. Most people have body fat distribution in two ways in which one is around the middle of the body known as apple shaped while another one is around the hip known as pear shaped. people who tend to gain the body weight mostly in the hips & buttocks have roughly a pear body shape ,while a people who tends to gain the body weight in their abdomen have a apple shaped body. Having the apple body shape put people at higher risk for health problems than having a pear body shaped. [13] It has been used as an indicator or measure of health & the risk of developing serious health conditions. Research shows that people with apple shaped bodies face more health risk than those with pear shaped body who carry more weight around the hips. It is used as a measurement of obesity, which in turn is a possible indicator of other more serious health conditions. [11] The world health organization states that abdominal obesity is defined as a waist hip ratio above 0.90 for males & above 0.85 for females, or a body mass index above 30.0.The National institute of diabetes, digestive & kidney

diseases states that women with waist hip ratio more than 0.8, & men with more than 1.0, are at increased health risk because of their fat distribution. [14] The waist hip ratio suggests that truncal obesity is the greatest contributor to the relation between body habitus & chronic disease. It is believed that truncal adipocytes are metabolically active exocrine glands that secrete inflammatory mediators into the systemic circulation. [11] The impact of obesity on knee osteoarthritis has been shown in many studies; however, recent studies suggest that this effect may be mediated through systemic metabolic effects rather than just mechanical effects. In addition to the inflammatory mediators released, truncal & visceral adipocytes release the hormone leptin, which has direct damaging effects on joint chondrocytes. This argument is supported by the relation between obesity & non-weight bearing joints. Men were obese more than women by waist hip ratio criteria. [11]

The pull of the quadriceps & patellar ligaments can be assessed clinically using a measurement called the Quadriceps angle (quadriceps angle).The Quadriceps angle is formed between a line connecting the anterior superior iliac spine (ASIS) to the midpoint of the patella & a line connecting the tibial tuberosity & the midpoint of the patella. [12] Normal value of Quadriceps angle is 12°-15° & 15°-18° in male & female respectively. Quadriceps angle is more in female because of wider pelvic, increased femoral anti-version & relative knee valgus.

A high Quadriceps angle increases the chance of developing the various knee problems. One of the most common problems associated with increased Quadriceps angle is patellofemoral tracking syndrome. A high Quadriceps angle interferes with the smooth gliding movement between the patella & the knee. Overtime, especially with repetitive activities, this type of microtrauma causes non specific pain to the front of the knee. As this abnormal tracking continues, various knee muscles like hamstrings, quadriceps & calf muscle become imbalanced, [15] & the cartilage on the underside of the patella begins to wear & thin, Eventually knee becomes degenerative & develops osteoarthritis. [16] Any alteration in alignment that increases Quadriceps angle cause increase in lateral force on the patella such that a higher Quadriceps angle increases the lateral pull of the quadriceps femoris muscle on the patella & potentiates patellofemoral disorders. [12]

MATERIALS & METHODS

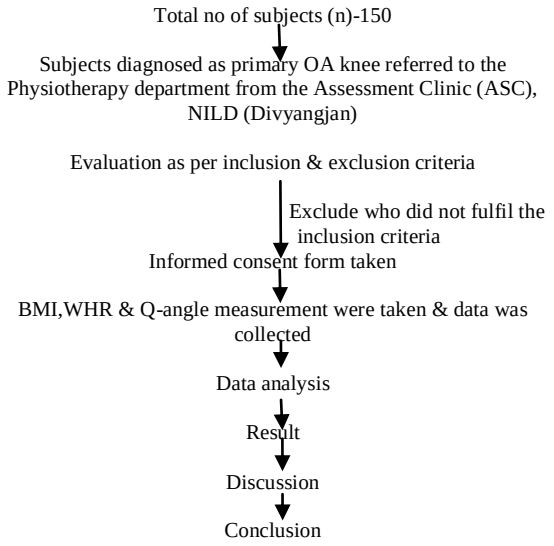
Subjects: This correlation study establish the relation between BMI, WHR & Q-ANGLE in primary OA knee patients came to the NILD, (Divyangjan), Kolkata, India between April, 2016 to December, 2017. Scientific and Ethical approval was taken from Institute Ethical Committee (IEC) on 13th April, 2016. A stratified purposive sample design was used to select the patients. Inclusion criteria were patients who fulfilling the American College of Rheumatology clinical criteria for knee osteoarthritis' male and female with unilateral/bilateral osteoarthritis. Patients who had secondary osteoarthritis, any congenital deformities, contracture, surgery around the knee & in lower limb, patients with neurological disorders, unco-operative subjects ,patients under physical conditioning program in three months prior to study, under exercise therapy treatment in previous 3 months, pregnancy were excluded.

Procedures: subjects were approached with the proposal of the study. The patients were screened according to the inclusion and exclusion criteria. Those fulfilling the criteria were explained in detail about the study and a written informed consent, in their preferred language, was obtained from the subjects willing to participate. The measurement includes body mass index, Waist-hip ratio & Quadriceps angle. The body weight of the subjects were measured with a portable weighing scale calibrated in kilogram.Height was measured with fixed height measuring tape where subject stood with bare foot. Then body mass index was

calculated based on given formula [weight(kg)/height(m^2)]. To measure the waist circumference: Measurement was taken midway between the bottom of the last palpable ribs and the top of the iliac crest. To measure the hip circumference: Measurement was taken at the widest point of the buttocks [17] Three readings were taken & then average of these three readings was done. Then the waist-hip ratio was calculated by given formula (Waist measurement÷ Hip measurement = WHR). The posture of the subject was in standing with arms at the sides, feet positioned close together, and weight evenly distributed across the feet. The waist circumference was measured at the end of a normal expiration, when the lungs are at their functional residual capacity. All the subjects were advised to relax and take a few deep, natural breaths before the actual measurement is made, to minimize the inward pull of the abdominal contents during the waist measurement. [17]

For measuring the Quadriceps angle; Subject´s position was in supine lying. [18] Three landmarks were identified on the involved limb namely; anterior superior iliac spine (ASIS), centre of the patella and tibial tuberosity. For marking center of patella, borders of patella were palpated and outline of patella was drawn using a body marker and making sure that the skin is not stretched while doing it. Intersecting point of maximum vertical and transverse diameters of patella has to be taken as centre of patella. The point of maximum prominence at anterior upper end of tibia is marked as the tibial tuberosity. Then the squaring of pelvis was done. Subjects were instructed to relax the quadriceps muscle with lower limbs in neutral rotation and the foot pointing upwards as well as perpendicular to the resting surface. The axis of goniometer was placed on centre of the patella, fixed arm aligned with the ASIS and the movable arm with the tibial tuberosity. The first line was drawn from the ASIS to the center of the patella using the straight edge of measuring tape. The second line was drawn from the tibial tuberosity to the centre of patella & then extending the second line upwards, the angle formed between these two upper lines was Quadriceps angle.

Statistical analysis: Statistical package for the social sciences (SPSS) version 21 software was used for analysis of the collected data. BMI, WHR & Q-ANGLE are independent variables & continuous data. To determine the normality in the distribution of data, "pearson test" was used which revealed that the data was normally distributed ($p > 0.05$); thus non- parametric test was used for analysis of this continuous data. The tests were applied at 95% confidence interval with p-value set at 0.05. The results were taken to be significant if $p \leq 0.05$.



RESULTS

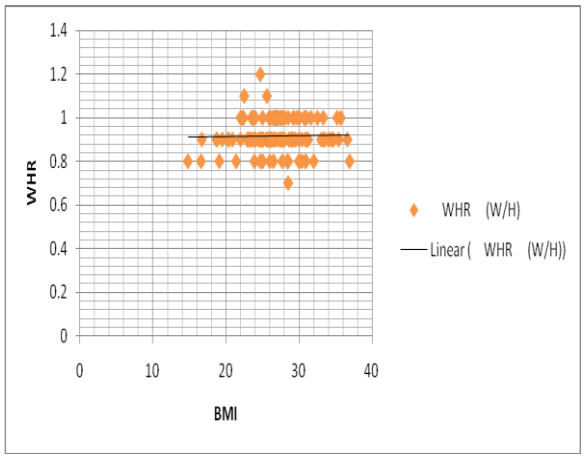
A total of 185 subjects were taken out of which 150 fulfilled the inclusion criteria &were evaluated where 90 subjects were females & 60 subjects were male who were analyzed for the study. There demographic data & variables were measured. Mean & standard deviation of BMI , WHR & Q-ANGLE were 27.28 ± 4.05 kg/m^2 , 0.91 ± 0.07 , 19.7° ± 2.06° respectively. Among these three variables, there was significant positive correlation between BMI & Q-ANGLE ($p \leq 0.05$) only where as insignificant positive correlation

between BMI & WHR, insignificant negative correlation between WHR & Q-ANGLE were ($p \geq 0.05$) found.

BMI & WHR:

TABLE:1 Showing correlation coefficient between BMI & WHR

Pearson correlation coefficient	BMI
BMI	1
WHR	0.021



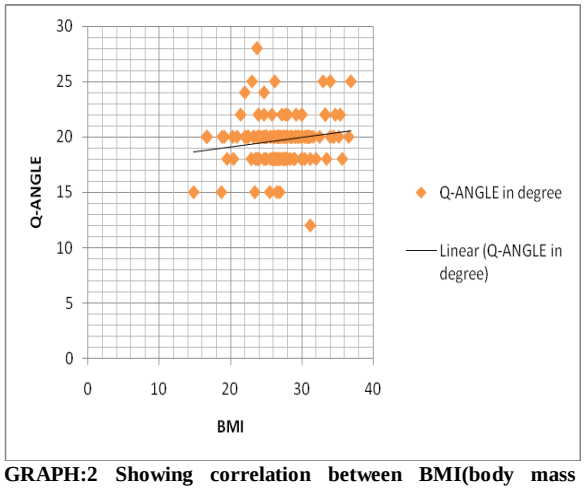
GRAPH:1 Showing correlation BMI(body mass index) & WHR(waist hip ratio)

The above graph represents positive insignificant correlation between BMI & WHR means that there is overlapping of BMI & WHR in primary OA knee i.e. both have equal contribution for as risk factor for OA knee where BMI represents body mass index whereas WHR represents waist hip ratio.

BMI & Q-ANGLE:

TABLE :2 showing correlation coefficient between BMI & Q-ANGLE

Pearson correlation coefficient	BMI
BMI	1
Q-ANGLE	0.168



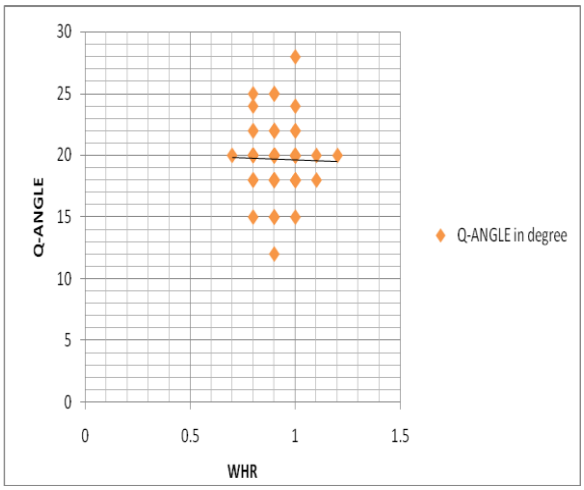
GRAPH:2 Showing correlation between BMI(body mass index) & Q-ANGLE(Quadriceps angle)

The above graph represents positive significant correlation between BMI & Q-ANGLE means that as BMI increases, Q-angle will also increases where BMI represents body mass index where as Q-ANGLE represents quadriceps angle.

WHR & Q-ANGLE:

TABLE :3 Showing correlation coefficient between WHR & Q-ANGLE

Pearson correlation coefficient	WHR
WHR	1
Q-ANGLE	- 0.023



GRAPH:3 Showing correlation between WHR(waist hip ratio) & Q-ANGLE(Quadriceps angle)

The above graph represents negative insignificant correlation between WHR & Q-ANGLE means that as WHR increases, Q-angle will decrease where WHR represents waist hip ratio where as Q-ANGLE represents quadriceps angle.

DISCUSSION

This study attempted to focus our attention to find out the correlation between BMI, WHR & Q-ANGLE in subjects with primary osteoarthritic knee as how these three modifiable independent risk factors are predisposing factors for OA knee.

In this study, subject's weight (kg), height (m), waist & hip circumference (cm) & Q-angle (in degree) were measured. The data showed that there is significant positive correlation between BMI & Q-ANGLE where as insignificant positive & negative correlation between BMI & WHR, WHR & Q-ANGLE respectively.

Body mass index is a measure of weight adjusted for height, calculated as weight in kilograms divided by the square of the height in meter (Kg/m^2). Body mass index is a simple, inexpensive & non-invasive surrogate measure of body fat. In contrast to other methods, body mass index relies solely on height & weight. [13] Increased knee joint loads present in patients with OA knee & the interaction between axial alignment & dynamic loading, is especially pronounced in patients with high body mass index. The biomechanical theory concludes that obesity leads to repetitive application of increased axial loading on the knee joint with consequent degeneration of articular cartilage & sclerosis of subchondral bone & result showed that body mass index has significant positive correlation with Q-ANGLE in overall clinical deficits in the osteoarthritis knee. [12]

Similarly, Felson et al (1991) reported that participants with symptomatic knee OA had higher BMI levels compared to their asymptomatic counterparts. Majority (86.5%) of the participants in this study were either overweight or obese. [18] The pull of the quadriceps & patellar ligaments can be assessed clinically using a measurement called the Quadriceps angle (quadriceps angle). The Quadriceps angle is formed between a line connecting the anterior superior iliac spine (ASIS) to the midpoint of the patella & a line connecting the tibial tuberosity & the midpoint of the patella. Normal value of Quadriceps angle is 12° - 15° & 15° - 18° in male & female respectively.

A high Quadriceps angle interferes with the smooth gliding movement between the patella & the knee. Overtime, especially with repetitive activities, this type of micro trauma causes non specific pain to the front of the knee & the cartilage on the underside of the patella begins to wear & thin, eventually knee becomes degenerative & develops osteoarthritis. Any alteration in alignment that increases Quadriceps angle cause increase in lateral force on the patella such that a higher Quadriceps angle increases the lateral pull of the quadriceps femoris muscle on the patella & potentiates patellofemoral disorders. In this study, result showed that Q-angle has significant positive correlation with BMI in OA knee i.e. increase in BMI substantially cause increase in Q-ANGLE predisposing the deficits in OA knee. [12]

In a study done by B Emmanuel et al (2015), [12] that Q-ANGLE and BMI were the significant predictors of the overall clinical deficits in the sampled participants. A greater proportion of participants (82.7%) were women compared to men (17.3%) which fall in line with the previous findings in which about 13% of women and 10% of men have symptomatic knee OA. Finally they concluded that body mass index and Q-angle substantially contribute to the clinical deficits of the knee Osteoarthritis among the knee OA. Possible mechanism described by them was that any alteration in alignment that increases Q-angle is thought to increase the lateral force on the patella such that a higher Q-angle increases the lateral pull of the quadriceps femoris muscle on the patella and potentiates patellofemoral disorders.

Jehoon Lee et al (2014) reported that abnormally high Q-angles (more than 15° for males and 20° for females) are regarded as an anatomical risk factor in the etiology of PFPS of the knee.

Above study shows that there is equal contribution of BMI & Q-ANGLE as a risk factor for primary OA knee means that these two independent risk factors for primary OA knee as increase in weight (BMI) leads to increased axial loading on the knee joint which causes degeneration of articular cartilage & also increases lateral force on the patella predisposing it to degeneration leading to tri-compartmental OA knee; are also a strong interdependent risk factors for the same & might be a po0ssible explanation of result of my study.

Zhen-Yu Zhou et al (2014) reported in their meta analysis that BMI had significant increased association with risk of knee OA. The point estimate of BMI at 25

kg/m^2 and 30 kg/m^2 had increased risk of knee OA 1.59 (95% CI: 1.34-1.81) and 3.55 (95% CI: 2.51-5.11) compared with reference (22.5 kg/m2). They also found that the knee OA risk increased almost exponentially when BMI increased. Some studies have investigated the mechanism between BMI increase and knee OA risk. One important factor is that excessive body weight contributes to a major mechanical load on the knee. One clinical study also confirmed that abnormal loads can lead to changes in the composition, structure, and mechanical properties of articular cartilage (Meundermann A et al 2005).

K.L. Holliday et al (2010) reported in their study that being overweight or obese was strongly associated with knee OA. Women consistently showed more risk for knee OA from obesity than Men. BMI > 30 leads to nearly 4 times greater odds ratio for knee OA (Manek et al 2003) Risk for knee OA in women increases 15% for every $kg/m^2 > 27$, much less effect on hip. [19]

Waist hip ratio shows the proportion of fat stored in body in the waist & hip areas. Most people have body fat distribution in two ways in which one is around the middle of the body known as apple shaped while another one is around the hip known as pear. The world health organization states that abdominal obesity is defined as a waist hip ratio above 0.90 for males & above 0.85 for females, or a body mass index above 30.0.The National institute of diabetes, digestive & kidney diseases states that women with waist hip ratio more than 0.8, & men with more than 1.0,are at increased health risk because of their fat distribution. In this study, result showed that there is insignificant positive correlation of WHR with BMI in OA knee. [20]

K.L. Holliday et al (2010) reported in their study with Lohmander et al. that WHR and other measures of obesity were poorly associated with OA once BMI had been accounted for. Gender differences in the risk for knee OA conferred by BMI were evident. They mostly suggest that body fat distribution is not associated with OA, independently of BMI, as with global observations of WHR. Numerically, WHR did not vary greatly between cases and control. In conclusion, they stated that BMI, is a major risk factor for OA, with the extent of the risk differing due to the affected joint, duration of exposure and possibly gender & WHR was not an independent risk factor for lower limb OA, after accounting for BMI.

I Janssen & AE Mark (2006) [21] reported in their study that when both BMI and waist circumference were used as variables to predict knee osteoarthritis, BMI and waist circumference did not have independent effects on either arthritis or knee osteoarthritis. Waist circumference did not add to the predictive ability of BMI measures when predicting osteoarthritis risk. When BMI and waist circumference are categorized, the strength of the relation between them is reduced. Therefore, BMI and waist circumference are more likely to have independent effects on arthritis. In the light of these findings and previous findings based on other obesity-related outcomes, they recommend that health-care practitioners measure waist circumference in conjunction with BMI.

Above study shows that there is overlapping of BMI & WHR as a risk factor for primary OA knee means that these two independent risk factors are also a interdependent risk factors for primary OA knee as body fat increases (increase in WHR) there is increment in BMI which is ultimately a risk factor for primary OA knee & these might be a possible explanation of result of my study.

Yasayuki Mizuno et al (2001) reported that for a large Q-angle, the patellar lateral shift, could predispose the knee to patellar subluxation or dislocation & kinematically a large Q-angle increase the lateral patellofemoral contact pressure which was clinically justified in symptomatic OA knee patients.

Also, the present study shows that there is insignificant negative correlation between WHR & Q-angle means that as

there is increment in WHR, there is decrement in Q-angle in case of primary OA knee. It also shows that these two interdependent risk factors are not dependent risk factors for primary OA knee means that alone they are the risk factors for OA knee but together both are not a risk factor for the same because in this study most of the subjects had grade 2 OA & there is very little variation in Q-angle in grade 2 as this is initial stage where degenerative changes is difficult to detect which might be possible explanation of result of my study.

This study shows that statistically there is insignificant positive correlation between BMI & WHR i.e there is overlapping of these two variables in primary OA knee, insignificant negative correlation between WHR & Q-ANGLE i.e. if there is increase in WHR, substantially there is reduction in Q-angle while significant positive correlation between BMI & Q-ANGLE with "p" value at 0.05 means that there is increase in Q-ANGLE with increase in BMI.

Overall there is statistically insignificant correlation found between BMI, WHR & Q-ANGLE in subjects with primary OA knee.

Thus, the present study concluded that there is substantially increase in Q-ANGLE as BMI increases i.e. obesity leads to alteration in Q-ANGLE predisposing the risk of OA knee means increase in the body weight leads to alteration in the Q-angle predisposing the risk of OA knee. Also, there is overlapping of BMI & WHR i.e. BMI & WHR both are equally risk factor for OA knee as BMI increase, WHR also increases. Also, as there are increment in Q-ANGLE, there is decreasing tendency in WHR means that lesser the Q-angle, higher the WHR.

CONCLUSION

In conclusion, the present study provided evidence to support that the BMI & Q-angle together are a risk factors for primary OA knee. It clinically signifies that as weight increases, there is increased axial loading on the knee joint causing alteration in Q-angle which ultimately causes lateral pull of patella predisposing the risk of OA knee.

Present study also support that BMI & WHR are also a dependent risk factors for the OA knee as there is increase in fat mass of the body (WHR) causing increase in the weight & increase weight causes alteration in BMI which ultimately causing OA knee.

Also present study support that dependently WHR & Q-ANGLE are not significant risk factors for OA knee as there is increment in WHR, there is decrement in Q-ANGLE.

Therefore, the study concludes that BMI, WHR & Q-ANGLE being a independent risk factors for primary OA knee, these three variables are dependently also a risk factors for the same.

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REFERENCES

1. Roach. H, Tilley S, In:Bronner F, Farach -Carson M .The pathogenesis of osteoarthritis., Bone and Osteoarthritis. London: Springer. 2007; 4:1-18.
2. Lane N, Wallace D. All about Osteoarthritis: The definitive resource for arthritis patients BMC Musculoskeletal Disorders 2002;13: 180.
3. A Mahajan, S Verma, V Tandon. Osteoarthritis .JAPI 2005;53:634-641.
4. HaqAS, Davatchi F. Osteoarthritis of the knee in COPCORD world. International Journal of Rheumatic disease 2011;14:122-129.
5. Carol David, Jill Lloyd, Chadwick A. Rheumatological Disorders. Rheumatological physiotherapy 1999;14:83-95
6. Goldman Ausiello. Cecil textbook of medicine. Elseviers2004;22(2):1698-1700

7. Silman AJ, Hochberg MC. Epidemiology of the rheumatic diseases. Oxford: Oxford University Press:1993.
8. Srikanth VK, Fryer JL, Zhai G, et al. A meta-analysis of sex differences prevalence, incidence and severity of osteoarthritis. Osteoarthritis Cartilage 2005; 13:769-81.
9. Ajit NE et al .Prevalence of knee osteoarthritis in rural areas of Bangalore urban district. IJRCI 2014; 1(1):1-8.
10. Mahajan A, Jasrotia DS, Manhas AS, Jamwal SS. Prevalence of Major Rheumatic Disorders in Jammu. J K Science2003; 5(2): 63-68.
11. Rajiv Gandhi, MD, MS Herman Dhotar, MD,Dmitry Tsvetkov, BSc Nizar N. Mahomed, MD, ScD :The relation between body mass index and waist–hip ratio in knee osteoarthritis,2010, 53:151-54
12. Ajediran I. Bello, Jeffrey A.Danso, Emmanuel Bonney, Oppong-Yeboah Bertha: The Influence of Body Mass Index, Quadriceps angle and Tibiofemoral Alignment on the Clinical Deficits of Osteoarthritis of the Knee.2015.1 (1) : 1-7
13. A. Thelin et al. Knee osteoarthritis and body mass index: a population-based case–control Study,2004: 59-64
14. Waist circumference & waist hip ratio; Report of a WHO expert consultation , Dec 2008,Geneva 8-11
15. Jehoon Lee, PT, PhD, Hwangjae Lee, PT, MSc, Wanhee Lee, PT, PhD. Effect of Weight-bearing Therapeutic Exercise on the Quadriceps angle and Muscle Activity Onset Times of Elite Athletes with Patellofemoral Pain Syndrome: A Randomized Controlled Trial. 2014 , 26: 989–992,
16. Dr. Danny Tong. Higher Q angle in women increases chances of having knee pain. Oct 23, 2010
17. Jha A, Raza HKT. Variation in Quadriceps angle according to sex, height, weight and interspinous distance - A survey. Ind J Ortho 2000;34:99-101
18. Felson et al, American rheumatism 1991 Jan;34(1):124-5
19. K.L. Holliday, Lifetime body mass index, other anthropometric measures of obesity and risk of knee or hip osteoarthritis in the GOAL case-control study, Osteoarthritis and Cartilage 19 (2011) 37-43.
20. Waist circumference & waist hip ratio; Report of a WHO expert consultation, Geneva 8-11 Dec 20011
21. Lohmander LS, Incidence of severe knee and hip osteoarthritis in relation to different measures of body mass: a population-based prospective cohort study, Ann Rheum Dis. 2009 Apr;68(4):490-6. doi: 10.1136/ard.2008. 089748.

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