



**BIOMECHANICAL IMPACT OF BODY MASS INDEX ON KNEE JOINT LOADING,
FUNCTION, AND EARLY OSTEOARTHRITIC CHANGES IN ADULTS**

Muhammad Hassam*, Ali, Maha Tanveer, Tehreem, Misha Fatima, Eman Tahir, Romaha Saleem, Fatima Noor, Ifrah Nadeem, Zonab Farima

Affiliation (Allied Health Sciences, Superior University Faisalabad, Pakistan).



***Corresponding Author: Muhammad Hassam**

Affiliation (Allied Health Sciences, Superior University Faisalabad, Pakistan).

DOI: <https://doi.org/10.5281/zenodo.19508057>

How to cite this Article: Muhammad Hassam*, Ali, Maha Tanveer, Tehreem, Misha Fatima, Eman Tahir, Romaha Saleem, Fatima Noor, Ifrah Nadeem, Zonab Farima. (2026). Biomechanical Impact Of Body Mass Index On Knee Joint Loading, Function, And Early Osteoarthritic Changes In Adults. European Journal of Biomedical and Pharmaceutical Sciences, 13(4), 404–412.

This work is licensed under Creative Commons Attribution 4.0 International license.



Article Received on 15/03/2026

Article Revised on 05/04/2026

Article Published on 10/04/2026

ABSTRACT

Body Mass Index (BMI) is an important factor influencing knee biomechanics, pain, and functional performance, yet its early impact in young adults remains insufficiently understood. This study aimed to examine the biomechanical impact of BMI on knee joint function, pain, stair-climbing performance, and lower limb alignment in young adults. A cross-sectional observational study was conducted among 54 participants recruited through convenience sampling. Data were collected using a structured proforma including anthropometric measures, the International Knee Documentation Committee (IKDC) score, Numeric Pain Rating Scale (NPRS), Stair Climb Test, and lower limb alignment assessment. Statistical analysis included descriptive statistics, Pearson correlation, simple and multiple regression, and two-way ANOVA, with significance set at $p < 0.05$. The mean BMI was 22.18 ± 3.63 kg/m², mean NPRS score was 5.28 ± 2.13 , and mean IKDC score was 65.23 ± 12.72 . BMI did not significantly predict IKDC score ($F(1,52) = 0.665$, $p = 0.419$; $R^2 = 0.013$), but it showed a strong positive correlation with Stair Climb Test time ($r = 0.856$, $p < 0.01$) and Risk Score ($r = 0.742$, $p < 0.01$). Multiple regression showed BMI as the only significant predictor of stair performance ($B = 0.779$, $\beta = 0.860$, $p < 0.001$), explaining 74.2% of variance ($R^2 = 0.742$). Two-way ANOVA showed significant effects of BMI category ($p = 0.026$), alignment ($p = 0.003$), and their interaction ($p = 0.035$) on IKDC score. In conclusion, BMI was strongly associated with poorer functional performance and higher biomechanical risk, while lower limb alignment significantly influenced knee function. Early BMI screening, functional assessment, weight management, strengthening, and alignment-focused physiotherapy are recommended to reduce future knee osteoarthritis risk in young adults.

KEYWORDS: Body Mass Index (BMI), Knee Biomechanics, Functional Performance, Knee Pain, Lower Limb Alignment.

1. INTRODUCTION

The knee joint is a highly mechanically loaded and largest synovial joint in the human body, and this joint is vital in locomotion, stability and weight transmission during daily routines of walking, negotiating stairs, and squatting. The normal gait has forces that are two to three times body weight on the knee, and even greater loads during strenuous functional tasks (Kutzner et al., 2010). Due to this burden bearing role, the knee is very vulnerable to changes in body weight and biomechanical position. Overweight and obesity have become a particular issue in the world in recent decades, with

young adults being particularly vulnerable to the problem (World Health Organization [WHO], 2023; WHO, 2025).

The Body Mass Index (BMI) which is calculated by dividing the weight in kilograms by the height (in meters squared, kg/m²) is a common method of categorizing people into weight groups and determining how much of a health risk one is. High BMI has always been reported as one of the largest risk factors of knee osteoarthritis (OA) which is a significant cause of disability in the whole world (Blagojevic et al., 2010; Felson et al.,

1988). Although OA has long been seen as an issue of aging, the promising news is that mechanical and metabolic changes due to increased body weight have started to affect the state of knee joints much earlier in life, even prior to the appearance of clinical symptoms or radiographic changes (Adouni *et al.*, 2024; MacLean *et al.*, 2016).

Biomechanically, it has been shown that excess body mass is a major contributor of compressive and shear forces on the tibiofemoral and patellofemoral compartments. It is also approximated that every extra kilogram of body mass leads to the increment of compressive force across the knee to about four kilograms when walking (Messier *et al.*, 2005). This increased loading changes cartilaginous stress distribution and can speed up degenerative processes. There is also an association between higher BMI and larger external knee adduction moments (KAM), a major surrogate of medial compartment strain and OA development (Sharma *et al.*, 1998). Notably, body mass and gait mechanics, as well as limb alignment influence KAM implying a complicated interplay between structural and functional determinants (Dorjrvandan *et al.*, 2026).

In addition to mechanical loading, obesity also causes OA via metabolic and inflammatory systems. Adipose tissue is an active endocrine gland, which releases adipokines and pro-inflammatory cytokines that could affect cartilage metabolism, synovial inflammation, and remodelling of subchondral bone (Berenbaum *et al.*, 2013; Courties *et al.*, 2019). The recent findings reveal that low-grade systemic inflammation caused by obesity has the potential to combine with mechanical stress and promote cartilage destruction and joint pathology (Sampath *et al.*, 2023). This two-mechanism theory highlights the fact that degeneration of the knee among people with high SMI is not only attributed to high load but also reflects systemic biological reactions.

The impact of BMI on lower limb biomechanics and especially during gait has been studied in significant amounts of literature. The people who have increased BMI generally exhibit different gait patterns such as slower walking speed, longer stance phase, and distorted joint kinematics and kinetics (DeVita & Hortobágyi, 2003). More recent experiments with more sophisticated methods like 3D motion capture and musculoskeletal modelling have then proven that obesity interferes with muscle-induced and passive loading of the joint (Adouni *et al.*, 2024). There are also systematic reviews that attest to the presence of consistent differences in spatiotemporal and kinematic gait parameters between obese and normal-weight individuals (Scataglini *et al.*, 2024). Those modified movement patterns can help to increase the stability but in the long run, the redistribution of loads and the elevated stress levels of a joint can be observed.

Although gait analysis can offer a lot of valuable information, more strenuous functional activities like stair negotiation, squatting, and sit-to-stand movements can display more explicit biomechanical dissimilarities. Such activities involve more knee extensor moments and elevated patellofemoral and tibiofemoral joint loading. In recent research, it has been revealed that the knee joint moments of young adults with obesity differ considerably during stair tasks relative to those with normal weight, which suggests functional activities as the possible tool to better reflect early biomechanical impairments (Leutzinger *et al.*, 2024). As well, sensor-related studies based on wearing garments identified obesity-related changes in three-dimensional joint kinematics and kinetics, and the functional effect of extra body mass (Capodaglio *et al.*, 2021).

Besides biomechanical changes, increased BMI is linked to the disabilities of muscle strength, neuromuscular control, and functional performance. The weakness of the quadriceps and the change in muscle functions of the hip may affect dynamic knee stability and load distribution, which may further increase the stress on the joint (Palmieri-Smith *et al.*, 2008). Higher BMI among young adults has been associated with lower functional ability, worse muscle functioning and augmented vulnerability to disorders such as patellofemoral pain (Ferreira *et al.*, 2023). Functional performance indicators, walking speed, balance and stair tests are clinically relevant markers of impairment in the early stages and could be indicative of biomechanical change (Koinis *et al.*, 2024).

Lower limb posture also alters the loading of the knee joint and can have an interaction with BMI to affect the risk of OA. Valgus and varus alignment respectively enhance medial and lateral and patellofemoral stress distribution. Traditional research proves that malalignment enhances the response of mechanical load to degeneration of joints (Sharma *et al.*, 2001). The younger age groups have provided evidence indicating that obesity might have a role in changing the patterns of alignment like more valgus tendencies, and this may predispose an individual to abnormal loading at an early age (Taylor *et al.*, 2015). These results demonstrate the significance of both the stationary alignment and dynamic movement patterns in terms of the evaluation of knee biomechanics.

Imaging techniques have also improved, which have further contributed to the comprehension of early osteoarthritic alterations with the increase in BMI. Magnetic resonance imaging (MRI) with quantitative techniques (T2 mapping) has the potential to observe early cartilage matrix pathophysiology at an earlier stage of radiographic OA. Research has revealed that people who are overweight and obese have higher rates of cartilage abnormalities progression whereas weight loss has been linked with better cartilage health products (Gersing *et al.*, 2017; Zhao *et al.*, 2022). The results

follow the idea that structural and biochemical alterations can occur early in persons of high BMI even without any evident clinical symptoms.

Although there has been extensive research on obesity and knee OA, there still exists a great gap in understanding the impact of increased BMI on the biomechanics, pain, and functional performance of the knee in young adults before the onset of the disease. Middle-aged people who are at high risk and older ones with already developed OA are the subject of much of the available literature (Khatib et al., 2022; Adouni et al., 2024). Also, a lot of biomechanical research is of small size, with a heterogenous conduct, which makes generalization difficult. Limited integration of biomechanical, functional and clinical outcomes in younger population also means that a limited scope of comprehension of early-stage joint changes is possible.

Given the rising prevalence of obesity among young adults and its potential long-term consequences, it is essential to investigate early biomechanical and functional alterations associated with increased BMI. Understanding how body mass influences knee joint loading, movement patterns, pain, and functional capacity at an early stage may help identify modifiable risk factors and inform preventive strategies. Therefore, this study aims to examine the relationship between BMI and knee joint loading, functional performance, and early indicators of degeneration in young adults, contributing to the development of early screening and intervention approaches to reduce the future burden of knee osteoarthritis.

2. METHODS

2.1 Study Design and Setting

The research design used was a cross-sectional observational design, to examine the relationship between Body Mass Index (BMI), knee function, pain, functional performance, and lower limb alignment among young adults. Cross-sectional approach allows the evaluation of the associations between the variables at one time, without the control of exposure or results, and it is appropriate to detect the association and the possible risk

factors (Levin, 2006).

The research had been carried out in a university campus and physiotherapy affiliated environments, where there was the possibility of accessing the target population. All measurements were taken within a specific duration of study under standardized conditions to guarantee uniformity in measurements. The study made no intervention or longitudinal follow and instead studied the naturally occurring changes in BMI and its biomechanical and functional implications.

2.2 Participants and Sampling

The total number of recruited participants was 54 based on the convenience sampling method, where the selection of people is facilitated by their presence and their willingness to take part (Etikan et al., 2016). The reason behind this approach was based on the practical considerations of accessibility and time.

The criteria were that, the participants should be aged 18-30 years, of both genders, capable of carrying out functional tests on their own, and should give informed consent. People were not allowed to participate in the study when the person had history of knee surgery, knee osteoarthritis, knee injury in the past half a year, neurologic or musculoskeletal limitations that impaired gait, and inflammatory joint diseases. These criteria were used to reduce confounding variables that may affect the knee biomechanics, pain or functional performance on its own.

Table 1 presents the descriptive statistics of the sample. The analysis involved 54 participants. The sample mean age was 24.46 ± 10.51 years, BMI 14.3 to 29.5 kg/m² mean 22.18 3.63 kg/m². The mean time taken in Stair Climb Test was 8.94 +/- 3.29 seconds, which is a reasonable range of functional performance variability. The mean pain intensity by NPRS was 5.28 +/- 2.13, which is moderate knee pain, and the mean IKDC score amounted to 65.23 +/- 12.72, which is moderate knee functioning. Mean Risk Score was 6.19 with a standard deviation of 1.77 which whole-brainly represented a moderate biomechanical risk profile.

Table 1: Descriptive Statistics of Demographic and Clinical Variables.

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	54	18	61	24.46	10.51
Gender	54	1	2	1.44	0.5
BMI (kg/m ²)	54	14.3	29.5	22.18	3.63

2.3 Data Collection and Outcome Measures

A structured patient data collection proforma specifically designed to collect the data was used to collect the data. Proforma contained demographic data, anthropometric measurements, pain data, 6 knee functions test, functional performance test, alignment test and risk scoring.

Height and weight were measured using standard clinical

procedures, and BMI was calculated using the formula:

$$BMI = \frac{Weight(kg)}{Height(m)^2}$$

Participants were categorized into normal weight, overweight, and obese groups according to World Health Organization (WHO) criteria (WHO, 2023).

The function of the knee was measured by use of International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, which is a validated instrument that has 18 items with a range of 0 to 100 with a higher score indicating better knee functioning (Irrgang *et al.*, 2001). The intensity of pain was on a Numeric Pain Rating Scale (NPRS), a 0-10 scale that is consistent and commonly applied in musculoskeletal studies (Hawker *et al.*, 2011).

Three standardised tests were used to measure functional biomechanical performance; Stair Climb Test (measures lower limb strength and movement), Timed Up and Go (TUG) test (measures dynamic balance and mobility), and 30-Second Chair Stand Test (measures lower limb strength and endurance) (Podsiadlo and Richardson, 1991; Jones *et al.*, 1999; Almeida *et al.*, 2010).

Such an assessment was made visually and was classified as varus, valgus, or neutral in relation to the lower limbs. Knee joint loading modifier, which is known as alignment, has been linked with the development of osteoarthritis (Sharma *et al.*, 2001).

To obtain a composite Knee Biomechanical Risk Score (0-12), the results of the BMI category, pain level, IKDC score, and functional performance were added together. Based on predetermined criteria, participants were categorized as low (4-5) moderate (6-8) or high (9-12) risk group.

2.4 Statistical Analysis and Ethics

Statistical analysis was done with SPSS (Version 25) and Microsoft Excel. The demographic and clinical characteristics were summarized using descriptive

3. RESULTS

Table 1: Descriptive Statistics of Main Study Variables.

	N	Minimum	Maximum	Sum	Mean	Std. Error	Std. Deviation	Variance
Stair climb Test	54	5	17	483	8.9444	0.44738	3.28758	10.808
BMI Category	54	1	3	78	1.4444	0.09773	0.71814	0.516
NPRS	54	1	9	285	5.2778	0.29008	2.13167	4.544
IKDC Score	54	39	90	3522.5	65.2315	1.73118	12.72151	161.837
Alignment	54	1	3	137	2.537	0.10479	0.77003	0.593
Risk Score	54	1	10	334	6.1852	0.24094	1.77056	3.135
Risk Level	54	1	3	101	1.8704	0.07951	0.58427	0.341

The mean Body Mass Index (BMI) was 22.18 ± 3.63 kg/m², ranging from 14.3 to 29.5 kg/m², suggesting that most participants fell within the normal to overweight categories (mean BMI category = 1.44 ± 0.72).

The average Stair Climb Test time was 8.94 ± 3.29 seconds (range: 5–17), reflecting moderate variability in functional performance. The mean NPRS pain score was 5.28 ± 2.13 (range: 1–9), indicating moderate knee pain among participants. The mean IKDC score was 65.23 ± 12.72 (range: 39–90), suggesting overall moderate knee

statistics; mean, standard deviation, frequencies and percentages.

Inferential analyses were carried out to analyse association between variables. The ability of BMI to predict IKDC scores was evaluated by simple linear regression. The multiple regression analysis was performed in order to assess the impact of the BMI, age, and gender on the Stair Climb Test results. The ANOVA was a one-way test of comparison of the pain and functional outcome of BMI categories. The Pearson correlation analysis was used to evaluate the relationships between functional performance, risk scores, and BMI. Two-way ANOVA (univariate analysis) was also applied to test the interaction effect between BMI category and lower limb alignment on the outcome of the knee function.

All the analyses were taken to have a level of significance of $p < 0.05$. Normality, homogeneity of variance (Levene test) and linearity were examined before carrying out inferential tests.

Approval was taken regarding the ethical issues of the study by the concerned institutional authority. Informed consent was given in writing by all the participants who had been informed in detail about the study procedures. Data and all the information were kept secret by giving specific identification code and all information were stored in a secure place. The participants were advised that they had the right to withdraw any time without any consequence. The research was conducted in accordance with the principles of the ethical standards of the Declaration of Helsinki (World Medical Association, 2013).

function.

Lower limb alignment had a mean value of 2.54 ± 0.77 , while the mean Risk Score was 6.19 ± 1.77 (range: 1–10), corresponding to an average Risk Level of 1.87 ± 0.58 . Overall, the data demonstrate variability in BMI, pain intensity, functional performance, and knee function across the sample.

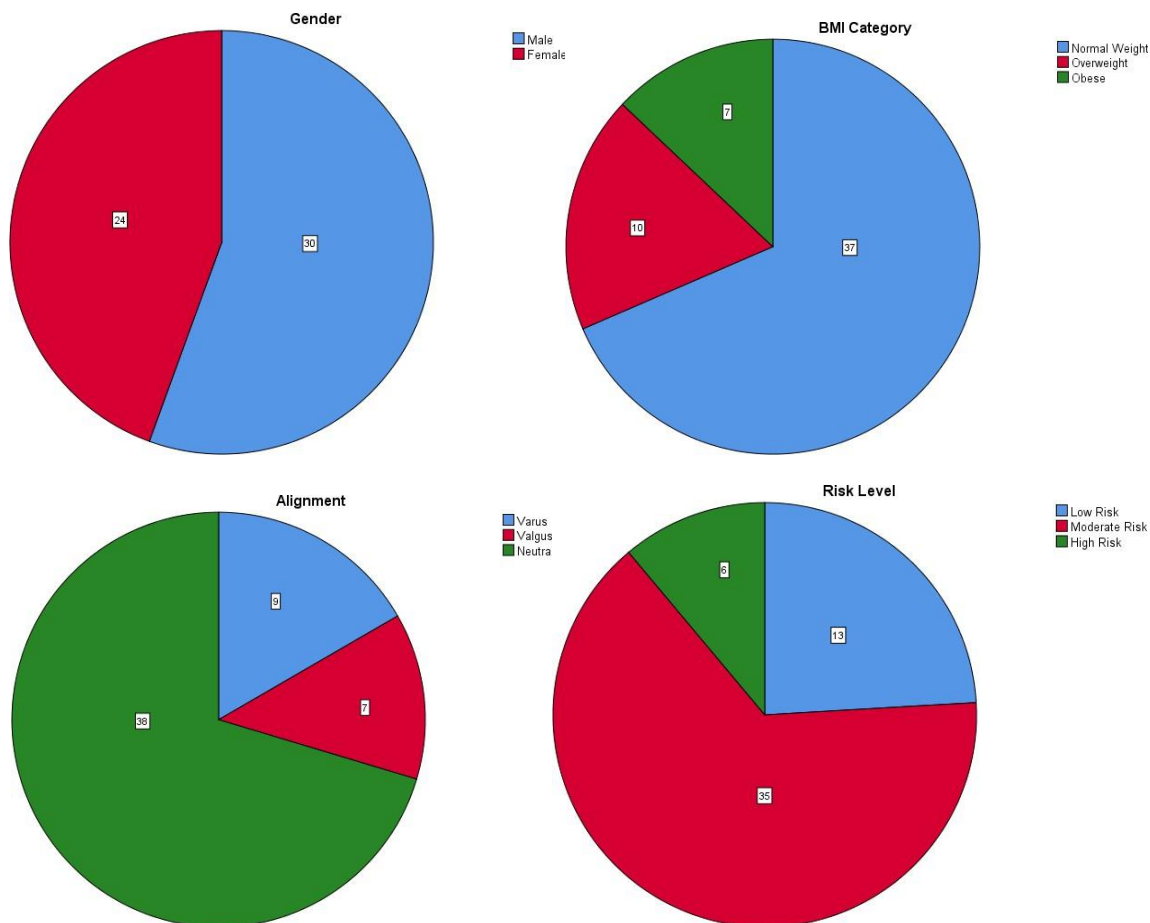


Figure 1: Distribution of participant characteristics across gender, BMI categories, lower limb alignment, and risk levels.

Figure 1 shows the distribution of the key variables of study in 54 participants. The male percentage was 55.6 and female was 44.4. The majority of the participants had a normal weight (68.5%), but the number of overweight and obese participants was lower. The dominant types of alignment were neutral (70.4), and the majority of the participants were classified to moderate risk (64.8).

The first objective was fulfilled by conducting a simple

linear regression to assess whether knee function as assessed by IKDC score was significantly predicted by BMI. The total model did not show any statistical significance $F(1, 52) = 0.665, p = 0.419$, and BMI was only able to explain 1.3 percent of the variance in IKDC score ($R^2 = 0.013$). The regression coefficient of BMI was negative ($B = -0.394$), which suggests that BMI increase was correlated with a slight decrease in the IKDC scores but this effect was insignificant.

Table 3: Linear regression analysis predicting IKDC score from BMI.

Predictor	B	SE	β	t	p
Constant	73.969	10.854	—	6.815	<0.001
BMI	-0.394	0.483	-0.112	-0.815	0.419

Model statistics: $R^2 = 0.013; F = 0.665; p = 0.419$.

These findings indicate that BMI alone was not a significant predictor of subjective knee function in this sample. Pearson correlation analysis was used to investigate the relationship between BMI and biomechanical performance regarding BMI, Stair Climb Test time, and Risk Score. The BMI was positively correlated with the performance at the Stair Climb Test ($r = 0.856, p < 0.01$) which means that individuals with higher BMI took more time to complete the stair climbing activity. Risk Score was also significantly

positively correlated with BMI ($r = 0.742, p < 0.01$), indicating that the higher was the BMI, the more was the biomechanical risk. There was a moderate correlation between Stair Climb Test time and Risk Score ($r = 0.673, p < 0.01$) indicating that the worse the functional performance was the higher the risk.

Table 4: Correlation Matrix for BMI, Stair Climb Test, and Risk Score (p < 0.01).

Variable	BMI	Stair Climb Test	Risk Score
BMI	1	0.856**	0.742**
Stair Climb Test	0.856**	1	0.673**
Risk Score	0.742**	0.673**	1

A multiple regression model was subsequently employed to compute whether Stair Climb Test performance was predicted by BMI, age and gender. This model was significant ($F(3, 50) = 47.948$, $p < 0.001$) and it accounted 74.2 per cent of the variance in Stair Climb

Test scores ($R^2 = 0.742$; adjusted $R^2 = 0.727$). BMI was the only variable that was found to be significant among the predictors ($B = 0.779$, $SE = 0.860$, $p < 0.001$). There were no major predictors of age and gender.

Table 5: Multiple regression analysis predicting Stair Climb Test performance from age, gender, and BMI.

Predictor	B	SE	β	t	p
Constant	-7.115	1.742	—	-4.085	<0.001
Age	-0.027	0.023	-0.087	-1.195	0.238
Gender	-0.39	0.477	-0.06	-0.818	0.417
BMI	0.779	0.066	0.86	11.894	<0.001

Model statistics: $R = 0.861$; $R^2 = 0.742$; Adjusted $R^2 = 0.727$; $F = 47.948$; $p < 0.001$.

These results show that BMI was the strongest determinant of functional stair performance, while age and gender had minimal influence in this sample.

The two-way ANOVA was conducted with IKDC score being a dependent variable to test the influence of BMI classification and lower limb position on knee functioning. The overall model was found to be important, $F(6, 47) =$

4.720, $p = 0.001$. The alignment and BMI category had significant main effects on IKDC score. The BMI category also had a significant impact on knee functioning, $F(2, 47) = 3.952$, $p = 0.026$ and the alignment had a greater impact, $F(2, 47) = 6.586$, $p = 0.003$. Moreover, the BMI category and alignment interaction were found to be significant, $F(2, 47) = 3.623$, $p = 0.035$, which means that the alignment effect on the knee functional performance was not uniform in the BMI categories.

Table 6: Two-Way ANOVA for Effects of BMI Category and Alignment on IKDC Score.

Source	df	F	p	Partial Eta Squared
BMI Category	2	3.952	0.026	0.144
Alignment	2	6.586	0.003	0.219
BMI Category × Alignment	2	3.623	0.035	0.134
Corrected Model	6	4.72	0.001	0.376

Descriptive patterns showed that participants with neutral alignment had the highest IKDC scores across BMI categories, whereas varus and valgus alignment were associated with lower knee function. The well-functioning of the knee was best observed in normal-weight individuals who were neutrally aligned (mean $IKDC = 69.8 \pm 11.0$). In comparison, participants having either varus or valgus alignment tended to have poor results. It was also established by estimated marginal means that neutral alignment had a positive relationship with good knee functioning (mean = 67.74) as compared to varus (56.00) or valgus (56.78) alignment.

In general, the findings indicate that, in the case of linear regression, BMI alone was not very relevant in predicting IKDC score, but BMI category became significant when it was analysed with lower limb alignment. Alignment seemed to be a clinically significant predictor of knee performance, and its combination with BMI indicates

that structural and anthropometric characteristics need to be assessed together to determine the health of the knees in young adults.

4. DISCUSSION

The current research examined the association between Body Mass Index (BMI), knee functioning, pain level, functional performance, and lower limb alignment in young adults. The data show that BMI was highly correlated with objective functional performance and biomechanical risk compared to weak and not significant changes between BMI as a continuous variable and self-reported knee functioning (IKDC). The findings are in line with available literature hypothesizing that the longer the body mass the higher the mechanical loading at the knee, which will affect the movement patterns and the outcomes of the functioning process, but the effects on perceived functioning may differ among younger populations (Felson et al., 1988; Messier et al., 2005;

Sharma *et al.*, 2001).

Descriptive results indicated that the sample was mainly comprised of young adults with normal to overweight BMI, moderate pain and moderate knee functioning. It is clinically pertinent because the knee joint forces during everyday activities can be many times the body weight, and thus even small increases in the BMI can lead to the cumulative joint forces (Kutzner *et al.*, 2010). Even so, the neutral lower limb position was found in the majority of the participants which is typically attributed to better loading distribution. Nonetheless, there was a significant percentage that had varus or valgus position that is known to change compartmental loading and cause functional impairment (Sharma *et al.*, 2001).

Concerning the primary objective, the IKDC scores were not significantly predicted by BMI. Though there was negative trend, but this relationship was weak and insignificant. This could indicate that perceived knee function is maintained in young adults not coming to extraordinary BMI ranges despite increased mechanical loading. Compensation process may be performed by young individuals in neuromuscular adjustments, which postpones the development of functional limitations. Additionally, IKDC though validated might lack sensitivity to early biomechanical alterations in subjects with no or a mild manifestation (Irrgang *et al.*, 2001). This is contrary to that of older age groups where the prolonged exposure to higher BMI is highly linked with deterioration in functionalities and propagation of osteoarthritis (Blagojevic *et al.*, 2010).

Conversely, BMI proved to have a significant correlation with pain in BMI categories. The respondents who had high BMI reported increased levels of pain which supported the hypothesis that the higher the joint loading the more the symptoms develop. This is in line with biomechanical findings that indicate that extra body weight adds significant compressive forces of the knee joint, which may result into discomfort during weight doing exercise (Messier *et al.*, 2005). The relatively low levels of pain noticed in this relatively young group indicate that the symptoms could be present early, which shows the need to intervene early.

The most effective evidence of the effects of BMI was made through functional performance results. There existed a positive correlation between BMI and Stair Climb Test time with close to a very strong correlation, meaning that people with large BMI recorded low functional performance. This observation fits well into existing literature that has shown that obesity is related to reduced gait speed, distorted movement patterns, and high execution of locomotion (Spyropoulos *et al.*, 1991; DeVita and Hortobaghi, 2003). The multiple regression analysis also supported the value of BMI as the main predictor of stair performance and age and gender did not play an important role. This highlights the prevailing role of the body mass on functional mobility among young

adults.

Moreover, the composite biomechanical risk score had a strong correlation with BMI, which supports the idea that the greater the body mass, the more likely the person is at risk of musculoskeletal problems. The correlation of functional performance and risk score indicate that objective measures of performance can be useful predictors of early biomechanical dysfunction.

There was also an effect of lower limb alignment. BMI category and alignment were found to have independent effects on IKDC scores and the interaction of both indicated further that alignment does alter the effects of BMI on knee functioning. The sample of participants who were neutrally aligned always showed improved functional results relative to those who were varus or valgus aligned. This confirms other past studies that malalignment remodels the distribution of loads at the knee joint and could contribute to the impact of the mechanical stress (Sharma *et al.*, 2001). The interaction effect will imply that alignment can reduce the impact of BMI on knee function or increase it, which indicates that both factors should be taken into account in the assessment.

In general, the results suggest that BMI is a significant factor of functional performance and biomechanical risk among young adults despite no significant perceived knee functional alterations. Functional limitations and pain seem to be observed sooner than objective subjective knee scores deteriorate. Notably, lower limb alignment is a crucial factor of knee functioning and interacts with BMI, which is extremely important in the clinical context. This outcome ratios the application of early preventive interventions which are weight-based, functional strengthening and correction of the knee gait thus minimizing the long-term risk of knee osteoarthritis (Blagojevic *et al.*, 2010; Sharma *et al.*, 2001).

5. CONCLUSION

This research examined the correlation among Body Mass Index (BMI), knee functioning, pain, functional performance and lower limb alignment in young adults. The results show that BMI was statistically related to both functional performance and biomechanical risk especially in stair climbing ability but was not found to be a significant predictor of self-reported knee function (IKDC) when treated as a continuous variable. There was a significant difference in the level of pain based on the BMI categories which indicates that higher body mass correlates to more symptoms even among younger people. It is remarkable that BMI turned out to be the most significant predictor of functional performance, which accounts a considerable amount of variance in the stair climbing ability, whereas age and gender did not play a significant role. These findings emphasize that functional deficits associated with augmented BMI could be revealed sooner than quantifiable decreases in perceived knee performance.

The alignment of the lower limbs was found to be one of the determinants of knee functioning: independent and in relation to BMI. The study also showed that participants who had neutral alignment had better functional results than the ones with varus or valgus alignment, hence structural factors are important in knee biomechanics. The dependence between BMI and alignment indicates that joint alignment alters the effect of body mass on knee function, which supports the idea that a global clinical evaluation should be performed. In general, this research highlights the significance of early preventive interventions aimed at weight control, functional strengthening, and alignment correction to minimize biomechanical load and the possible risk of knee osteoarthritis in young adults in the future.

REFERENCES

- Adouni, M., Aydelik, H., Faisal, T. R., & Hajji, R. (2024). The effect of body weight on the knee joint biomechanics based on subject-specific finite element-musculoskeletal approach. *Scientific Reports*, 14(1): 13777.
- Almeida, G. J., Schroeder, C. A., Gil, A. B., Fitzgerald, G. K., & Piva, S. R. (2010). Interrater reliability and validity of the stair ascend/descend test in subjects with total knee arthroplasty. *Archives of physical medicine and rehabilitation*, 91(6): 932-938.
- Berenbaum, F., Eymard, F., & Houard, X. (2013). Osteoarthritis, inflammation and obesity. *Current opinion in rheumatology*, 25(1): 114-118.
- Blagojevic, M., Jinks, C., Jeffery, A., & Jordan, I. (2010). Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. *Osteoarthritis and cartilage*, 18(1): 24-33.
- Capodaglio, P., Gobbi, M., Donno, L., Fumagalli, A., Buratto, C., Galli, M., & Cimolin, V. (2021). Effect of obesity on knee and ankle biomechanics during walking. *Sensors*, 21(21): 7114.
- Courties, A., Sellam, J., & Berenbaum, F. (2019). Metabolic syndrome-associated osteoarthritis. *Current opinion in rheumatology*, 29(2): 214-222.
- DeVita, P., & Hortobágyi, T. (2003). Obesity is not associated with increased knee joint torque and power during level walking. *Journal of biomechanics*, 36(9): 1355-1362.
- Dorjravdan, M., Mori, K., Ushikubo, T., Kubo, T., Arima, Y., Mano, N., ... & Hase, K. (2026). Biomechanical properties required for the reduction of knee adduction moment using gait modification in individuals with obesity. *Archives of Rehabilitation Research and Clinical Translation*, 100591.
- Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics*, 5(1): 1-4.
- Felson, D. T., Anderson, J. J., Naimark, A., Walker, A. M., & Meenan, R. F. (1988). Obesity and knee osteoarthritis: the Framingham Study. *Annals of internal medicine*, 109(1): 18-24.
- Ferreira, A. S., Mentiplay, B. F., Taborda, B., Pazzinatto, M. F., de Azevedo, F. M., & de Oliveira Silva, D. (2023). Overweight and obesity in young adults with patellofemoral pain: impact on functional capacity and strength. *Journal of sport and health science*, 12(2): 202- 211.
- Gersing, A. S., Schwaiger, B. J., Nevitt, M. C., Joseph, G. B., Chanchek, N., Guimaraes, J. B.,... & Link, T. M. (2017). Is weight loss associated with less progression of changes in knee articular cartilage among obese and overweight patients as assessed with MR imaging over 48 months? Data from the Osteoarthritis Initiative. *Radiology*, 284(2): 508-520.
- Hawker, G. A., Mian, S., Kendzerska, T., & French, M. (2011). Measures of adult pain: Visual analog scale for pain (vas pain): numeric rating scale for pain (nrs pain): mcgill pain questionnaire (mpq): short-form mcgill pain questionnaire (sf-mpq): chronic pain grade scale (cpgs): short form-36 bodily pain scale (sf-36 bps): and measure of intermittent and constant osteoarthritis pain (icoap). *Arthritis care & research*, 63(S11): S240-S252.
- Irrgang, J. J., Anderson, A. F., Boland, A. L., Harner, C. D., Kurosaka, M., Neyret, P., ... & Shelborne, K. D. (2001). Development and validation of the international knee documentation committee subjective knee form. *The American journal of sports medicine*, 29(5): 600-613.
- Jones, C. J., Rikli, R. E., & Beam, W. C. (1999). A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. *Research quarterly for exercise and sport*, 70(2): 113-119.
- Khatib, F. A., Gouisse, A., Mbarki, R., & Adouni, M. (2022). Biomechanical Characteristics of the Knee Joint during Gait in Obese versus Normal Subjects. *IJERPH*, 19(2): 1-14.
- Koinis, L., Maharaj, M., Natarajan, P., Fonseka, R. D., Fernando, V., & Mobbs, R. J. (2024). Exploring the influence of BMI on gait metrics: a comprehensive analysis of spatiotemporal parameters and stability indicators. *Sensors*, 24(19): 6484.
- Kutzner, I., Heinlein, B., Graichen, F., Bender, A., Rohlmann, A., Halder, A., ... & Bergmann, G. (2010). Loading of the knee joint during activities of daily living measured in vivo in five subjects. *Journal of biomechanics*, 43(11): 2164-2173.
- Leutzinger, T. J., Kingston, D. C., Dinkel, D. M., Wellsandt, E., & Knarr, B. A. (2024). Differences in knee joint moments between individuals who are living with obesity and those of a healthy weight when negotiating stairs. *The Knee*, 49: 217-225.
- Levin, K. A. (2006). Study design III: Cross-sectional studies. *Evidence-based dentistry*, 7(1): 24-25.
- MacLean, K. F., Callaghan, J. P., & Maly, M. R. (2016). Effect of obesity on knee joint biomechanics

- during gait in young adults. *Cogent Medicine*, 3(1): 1173778.
23. Messier, S. P., Gutekunst, D. J., Davis, C., & DeVita, P. (2005). Weight loss reduces knee-joint loads in overweight and obese older adults with knee osteoarthritis. *Arthritis & rheumatism*, 52(7): 2026-2032.
 24. Palmieri-Smith, R. M., Thomas, A. C., Karvonen-Gutierrez, C., & Sowers, M. F. (2010). Isometric quadriceps strength in women with mild, moderate, and severe knee osteoarthritis. *American journal of physical medicine & rehabilitation*, 89(7): 541-548.
 25. Podsiadlo, D., & Richardson, S. (1991). The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *Journal of the American geriatrics Society*, 39(2): 142-148.
 26. Sampath, S. J. P., Venkatesan, V., Ghosh, S., & Kotikalapudi, N. (2023). Obesity, metabolic syndrome, and osteoarthritis—an updated review. *Current obesity reports*, 12(3): 308-331.
 27. Scataglini, S., Dellaert, L., Meeuwssen, L., Staeljanssens, E., & Truijen, S. (2025). The difference in gait pattern between adults with obesity and adults with a normal weight, assessed with 3D-4D gait analysis devices: A systematic review and meta-analysis. *International Journal of Obesity*, 49(4): 541-553.
 28. Sharma, L., Hurwitz, D. E., Thonar, E. J. M., Sum, J. A., Lenz, M. E., Dunlop, D. D., ... & Andriacchi, T. P. (1998). Knee adduction moment, serum hyaluronan level, and disease severity in medial tibiofemoral osteoarthritis. *Arthritis & Rheumatism*, 41(7): 1233-1240.
 29. Sharma, L., Song, J., Felson, D. T., Cahue, S., Shamiyeh, E., & Dunlop, D. D. (2001). The role of knee alignment in disease progression and functional decline in knee osteoarthritis. *Jama*, 286(2): 188-195.
 30. Spyropoulos, P., Pisciotta, J. C., Pavlou, K. N., Cairns, M. A., & Simon, S. R. (1991). Biomechanical gait analysis in obese men. *Archives of physical medicine and rehabilitation*, 72(13): 1065-1070.
 31. World Health Organization. (2023). *Obesity and overweight Key facts 2021*. WHO. Available online at: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>.
 32. World Health Organization. (2025). *Obesity and overweight*. WHO. Available online at: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>
 33. World Medical Association. (2013). Declaration of Helsinki. Available online at: <https://www.wma.net/policies-post/wma-declaration-of-helsinki/>
 34. Zhao, H., Li, H., Liang, S., Wang, X., & Yang, F. (2022). T2 mapping for knee cartilage degeneration in young patients with mild symptoms. *BMC Medical Imaging*, 22(1): 72.