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Cross-Sectional Study on Ergonomic Impacts on Lower Limb Joints Kinematics of Long-Term Standing and Sitting Workers

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Abstract

Musculoskeletal and physical changes may affect posture and movement. Functional adaptations to postural realignments can overload the main joints of the lower limbs, which results in discomfort and pain. In general, functional limitations can be the result of compensatory biomechanical adaptations caused by increased body mass, anterior displacements of the center of mass, and hormonal changes. This can result in increased hip mobility and more stress on the muscles during activities of daily living. 554 healthy volunteers were selected from the urban population through a stratified random sampling method for the study, with one group consisting of individuals with prolonged sitting positions (e.g. drivers, software professionals, and bank employees of both sexes), and the other consisting of individuals with prolonged standing (e.g. traffic police, building constructors, and salespeople in shops and textile industries of both sexes). An unpaired t-test was used to compare values between prolonged standing and sitting workers. The level of significance was set at $p \leq 0.05$. In this current study, we found that long-term standing and sitting workers showed statistically significant differences in the kinematics of the lower limbs. According to all these results, stretching and strengthening exercises for the muscles that are more affected by prolonged standing and sitting occupations can prevent overuse syndrome, musculoskeletal injury, and kinematic changes in the lower limb joints. Our exploratory analyses revealed that kinematic changes are strongly associated with prolonged standing and sitting occupations, indicating the need for ergonomic interventions.

Keywords: Ergonomics, Kinematics, Lower Limb Joints, Musculoskeletal Disorders, Posture.

Introduction

Ergonomics, the science of designing workplaces to fit human capabilities, is crucial to preventing occupational injuries. When applied to the workplace and everyday activities, ergonomic principles can have a significant impact on the physical fitness and health of the lower limbs, including the knees, hips, and feet. Around 34% of workplace injuries result from poor ergonomics. Musculoskeletal disorders (MSD), responsible for 30% of all worker injury and illness cases, often stem from improper ergonomics. Physical fitness is an important concept around the world. In India, there is a rapidly growing awareness of being physically fit. Over the past few years, there has been an unprecedented increase in the number of gyms, fitness classes, and health clubs. Moreover, several physical activity campaigns and initiatives, such as the Fit India Movement, have been launched in India to promote physical fitness. Prolonged standing and sitting put excess strain on the lower limbs, particularly the feet, ankles, knees, and hips. The sheer weight of a person standing or sitting in the same position for too long can cause the ligaments and tendons in the legs to become strained and tight. This can lead to soreness, joint problems, and even musculoskeletal injuries. Additionally, the muscles in the legs can become weak and fatigued, leading to difficulty walking or performing physical activities. Human locomotion or gait is characterized by a series of coordinated movements by various body segments. Gait analysis begins with understanding of kinematics, which is the basis for identifying, diagnosing, and treating abnormalities (1). An abnormal gait pattern and physical disability are often associated with abnormal kinematics.

Musculoskeletal disorders are a group of conditions that affect the muscles, bones, and joints, which can cause pain and discomfort. They are most commonly seen in the working populati-

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on due to prolonged sitting or standing postures. MSDs can be caused by repetitive movements, force, posture, vibration, and awkward positions. Repetitive movements can cause strain on the muscles and joints, leading to conditions like tendonitis, carpal tunnel syndrome, and back pain. Forcefulness can also cause MSDs, as it can result in strains, tears, sprains, and dislocations. Prolonged postures can also reduce blood flow, causing pain, weakness, and fatigue.

Posture is the orientation, or alignment, of the human body, and it can be either static or dynamic. In a static posture, the body and its segments are aligned and maintained in certain positions. Examples of static postures include standing, sitting, lying, and kneeling. Dynamic posture refers to postures in which the body or its segments are moved for e.g. walking, running, jumping, throwing and lifting. Humans and other living creatures can arrange and rearrange body segments to form a large variety of postures, but the sustained maintenance of an erect bipedal stance is unique to humans. Erect standing posture gives us freedom in the upper limbs but has certain disadvantages. It increases the work of the heart; places increased stress on the vertebral column, pelvis, and lower extremities; and reduces stability.

Human walk is remarkably flexible on both short and long-time scales. In response to external perturbations, we have an immediate change in our movements and gait patterns (2, 3). Stability of gait is the ability of the body to maintain balance and coordination in conjunction with normal movement (4). Epidemiological studies conducted by the National Institute for Occupational Safety and Health have demonstrated the association between physical exertion at work and work-related musculoskeletal disorders (5). Several factors, such as repetitive motion, overuse, awkward or sustained postures, and prolonged standing and sitting have been associated with musculoskeletal disorders, according to previous studies (6). People who remain sedentary for eight to nine hours are subject to occupational hazards, according to the previous literature (7). Because sedentary behaviors have a negative impact on physical health (8, 9).

In determining kinematics, occupation plays a major role. Changes in muscles and soft tissues may occur due to constant adaptation to one position, changing the gait pattern. A person may be forced to adopt specific postures or become accustomed to different gait patterns according to their occupation, which may cause changes to their normal gait patterns. As an example, sailors need a wider base while sailing board a ship to increase stability. Through the continued adaptation of the hip abduction posture, the abductor may become tight, and the adductor may lengthen or elongate. When the person's muscle properties change, he or she is forced to adopt the same gait pattern for normal activities as well. In addition, soldiers with raised chests, Dhobis with kyphosis, and as well as bangle sellers with lordosis, illustrate this issue (10).

To prevent MSDs, it is important to get regular breaks from work, perform ergonomic assessments, provide job rotation and modification, and use the proper tools and equipment. Additionally, employees should be educated about proper body mechanics and how to recognize early signs and symptoms of MSDs. The causes of MSD are complex and include personal, biomechanical, and psychosocial factors. Although an initial evaluation of a job may involve identifying factors in workplace design or administrative procedures that can contribute to the development of MSDs, these are not the only areas that need assessment. We must consider that the worker is an individual in the work environment, an individual with unique beliefs and values about work. Workers' beliefs and values about work and what work requires of them have been associated with musculoskeletal discomfort at work and may well influence a worker's choice to accept and implement recommendations to improve the workplace (11). Functional adaptations to prolonged standing and sitting result in biomechanical adjustments, which are thought to alter muscle balance and restrict the range of motion in the lower limb joints. Many authors have reported kinematic changes due to osteoarthritis in the lower limb joints. As far as we know, analysis of the literature has not demonstrated the association between ergonomic influence on kinematic changes in the lower limbs among workers for prolonged standing and sitting. In order for this study to be done, the association between functional adaptations and prolonged standing and sitting had to be examined, as workers may experience changes in their lower limb kinematics during prolonged standing and sitting. Adjustments in kinematics may cause a change in the normalised moments at the hip, knee, and ankle joints. This may further contribute to musculoskeletal disorders. Prevalence of this physical disability and identifying the risk factors for work-related kinematic changes in this study can help as a preventive method for musculoskeletal disorders and create awareness about their functional adaptation to prolonged standing and sitting postures.

Methodology

The study design is a cross-sectional study that evaluates the prevalence of ergonomic impact on kinematics in the lower limbs, as well as the effects of prolonged standing and sitting on kinematic variability. 554 healthy volunteers were selected from an urban population through the stratified random sampling method for the study, with one group consisting of individuals with prolonged sitting positions (e.g. drivers, software professionals, and bank employees of both sexes), and the other consisting of individuals with prolonged standing (e.g. traffic police, building constructors, and salespersons in shops and textile industries of both sexes).

The inclusion criteria were individuals of both sexes who had worked in their respective professions for at least two years, and who reported spending a minimum of four hours per day in either a prolonged standing or sitting position. The exclusion criteria for the study were individuals who had a history of musculoskeletal disorders or injuries in the lower limbs, those who had recently undergone surgery in the lower limbs, those who had any other medical conditions that could affect their lower limb function, and those who were pregnant. Additionally, individuals who were unable to complete the required assessments or who did not provide informed consent were also excluded from the study.

Goniometer Measurements

A goniometer is a measuring tool that is commonly used in health research to assess joint range of motion, as well as in clinical practice for diagnosis and treatment planning. The body of the goniometer resembles a full-circle protractor body and consists of 0º to 360º and 360º to 0º readings. Measurement of the joint is done with the goniometer axis over the joint axis. Different types of goniometers are available, and the present study used a universal goniometer as shown in Figure 1. It has a stationary arm, a movable arm, and a body.

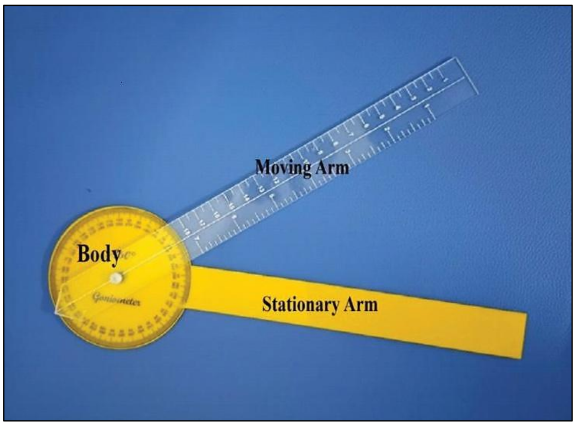


Figure 1: Shows Universal Goniometer

In this study on the ergonomic impact on lower limbs in prolonged standing and sitting employees, the active range of motion (AROM) of all lower extremity joints was measured using a universal transparent goniometer. To ensure accurate and reliable measurements, standardized guidelines and instructions prescribed by Norkin and White were followed during measurements (12). It is important to note that a person's position and measurement technique may affect the range of motion, and therefore, proper training and adherence to guidelines are critical for obtaining valid measurements (12-14).

In the hip joint, the flexion ROM was assessed with the person lying in a supine position. The patient was asked to bring his thigh close to the abdomen with a flexed knee. The axis was placed over the greater trochanter of the femur, the stable arm was placed over the midline of the lateral aspect of the lower trunk and the movable arm was placed over the midline of the lateral aspect of the thigh. The extension of the hip joint was measured in a similar way but the participants were in a prone position with their knees extended. Abduction of the hip joint was measured by a person lying supine moving the limb away from the midline of the body. The pelvis is stabilized by placing the examiner's hand on the opposite anterior superior iliac spine (ASIS). The axis was two inches below the ASIS, the movable arm was placed over the midline of the anterior aspect of the thigh and the stable arm was placed at 90° to the movable arm. Adduction was assessed in a similar way to the person in a supine position, and the pelvis was stabilized. The subject was asked to move the limb to the opposite side as much as possible. Adduction strength was assessed by beginning with the hip in an abducted position and asking the person to return it to the midline. The internal and external rotation of the hip joint was assessed in a sitting position and evaluated at the end of the couch while the legs were kept hanging. The axis was at the apex of the patella, the stable arm was placed in a straight line to the movable arm and the movable arm was placed over the midline of the anterior aspect of the leg.

The flexion and extension of the knee joint was done by placing the participants in a prone position. The axis was placed at the lateral aspect of the knee joint, the stable arm was placed over the midline of the lateral aspect of the thigh and the movable arm was placed over the midline of the lateral aspect of the leg. The plantarflexion and dorsiflexion of the ankle movements were measured while sitting with the flexed knee. The dorsiflexion was done from the neutral position (foot at the right angle to leg) to the sole of the foot facing forward and similarly, the plantar flexion was done with the sole of the foot facing backward. The axis was at the tip of the medial malleolus. The stable arm was placed over the midline of the medial aspect of the leg and the movable arm was placed 90° to the stable arm.

The participants were positioned in a supine position to measure the true or functional shortening of the limb. Their legs were kept parallel to each other, 15 to 20 cm apart, and the measurement was taken from the ASIS to the distal end of the medial malleolus using a non-stretchable, flexible measuring inch tape as shown in Figure 2. Apparent leg length discrepancies may be caused by asymmetric hip or knee fixed flexion deformity, as well as soft tissue shortening or contracture. A difference of less than 1.0 to 1.5 cm between the two legs is considered normal and does not produce any significant functional problems.

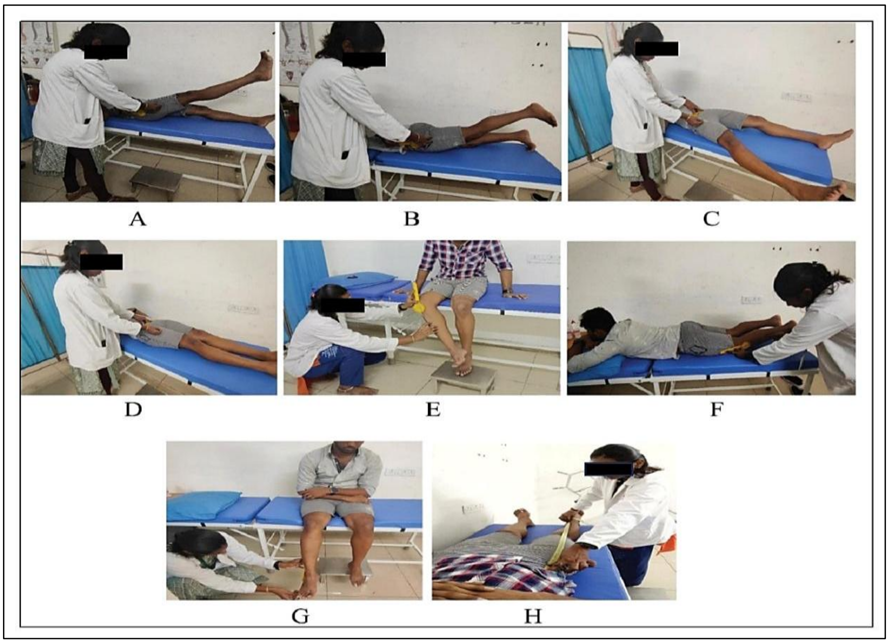


Figure 2: Showing the Goniometric Measurements of Lower Limb Joints and Lower Limb Length. (A) Hip Flexion, (B) Hip Extension, (C) Hip Abduction, (D) Hip Adduction, (E) Hip Internal and External Rotation, (F) Knee Joint Flexion and Extension, (G) Ankle Joint Plantarflexion and Dorsiflexion, (H) Measurements of Lower Limb Length

Results

Descriptive statistics in the form of mean and standard deviation were used to present the measured parameters. An unpaired t-test was used to compare the values between prolonged standing and sitting workers. The level of significance was set at $p \leq 0.05$. In this current study, we found that long-term standing and sitting workers showed statistically significant differences in the kinematics of the lower limbs. Range of motion is a crucial variable in musculoskeletal healthcare. When interpreting ROM, comparing active ROM values to normative data is the standard method. Hence, our study aimed to establish normative active ROM and compared the values of active ROM for lower extremity joints in prolonged standing and sitting workers. We found statistically significant differences in the active ROM values of lower extremity joints in standing and sitting workers using an unpaired t-test as shown in Table 1 and 2 and Figure 3 and 4.

Table 1: Statistical Analysis of Subject Characteristics and Anthropometric Variables

Variables	Group		t-value	P-value*
	Standing	Sitting		
Age (in years)	40.87±8.63	41.56±8.20	-0.954	0.341
Height (in cms)	160.72±8.52	161.33±6.38	-0.954	0.341
Weight (in Kgs)	66.10±10.58	67.91±8.40	-2.233	0.026
BMI	20.30±8.36	18.89±8.23	-1.347	0.179
Work hours (per day)	9.57±1.44	9.66±1.46	-0.702	0.483
Work experience (in years)	20.30±8.36	18.89±8.23	1.976	0.049

Table 2: Shows Comparison of Active ROM of Hip, Knee, Ankle Joints and Lower Limb Length in Long-Term Standing and Sitting Workers

ROM	Group		t-value	P-value*
	Standing	Sitting		
Hip Flexion - 120°	106.61±7.72	115.09±8.64	-12.181	<0.001
Hip Extension - 30°	26.03±3.68	20.34±4.56	16.152	<0.001
Hip Abduction - 45°	35.13±4.16	41.79±3.35	-20.772	<0.001
Hip Adduction - 30°	24.46±4.59	19.49±4.35	13.058	<0.001
Hip Medial rotation - 45°	40.47±4.01	35.78±4.65	12.726	<0.001
Hip Lateral rotation - 45°	35.11±3.66	42.55±3.34	-24.978	<0.001
Knee Flexion-135	116.86±8.42	122.78±8.32	-8.324	<0.001
Knee Extension-0	1.88±2.43	0.45±1.44	8.421	<0.001
Ankle Plantar flexion-50	46.55±3.53	45.25±4.12	3.989	<0.001
Ankle Dorsiflexion-20	13.27±3.11	15.81±3.66	-8.824	<0.001
Right limb length	85.99±5.02	87.04±3.13	-2.959	0.003
Left limb length	85.31±5.60	86.46±4.07	-2.777	0.006

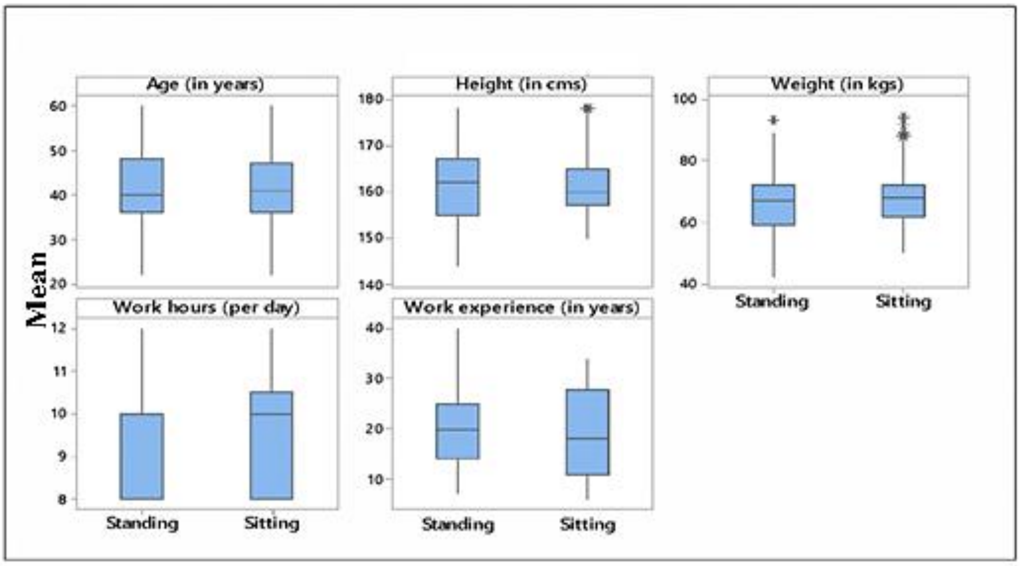


Figure 3: Anthropometric Measurements of Study Participants and Other Characteristics

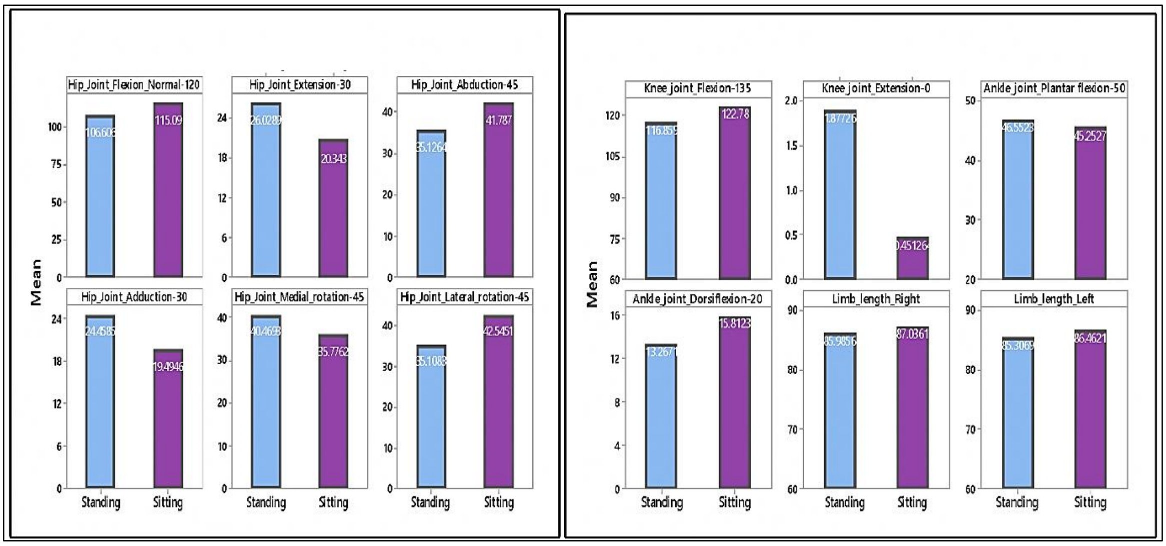


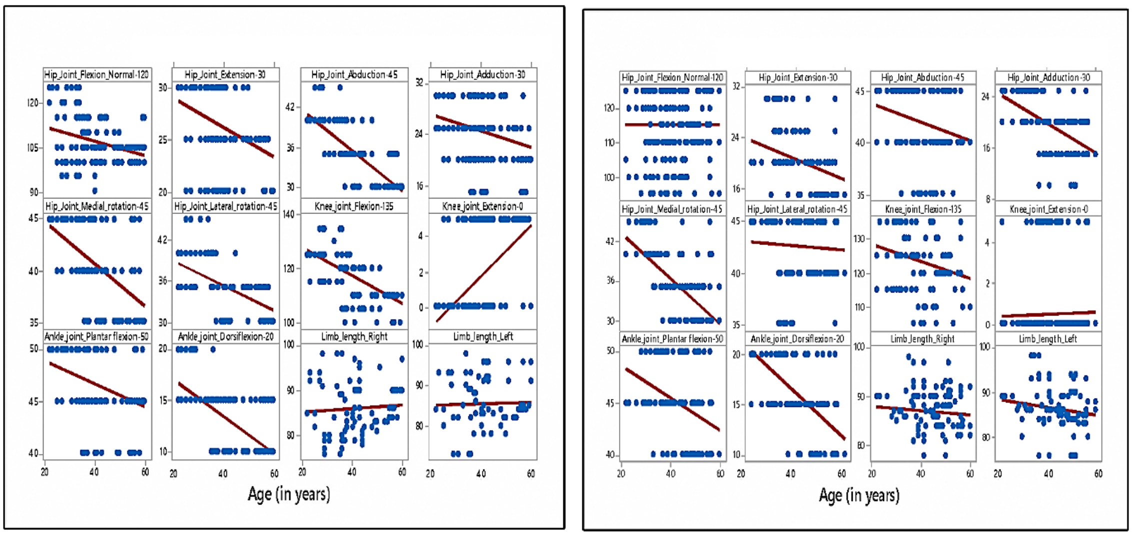
Figure 4: Comparison of ROM of Hip, Knee, Ankle Joints and Lower Limb Length in Long-Term Standing and Sitting Workers

Correlation between Age, Weight, Work Hours and Years of Experience and Lower Limb Joints ROM in Prolonged Standing and Sitting Workers

In the extension, abduction, and medial rotation movements of the hip joint and flexion of the knee joint, there is a negative correlation with age in both standing and sitting positions. Also, standing employees' hip flexion, lateral rotation, and knee extension showed negative correlations, whereas sitting employees' hip adduction showed a negative correlation. This suggests that as individuals age, their range of motion tends to decrease in these joint movements. These correlations are statistically significant (indicated by the low p-values), suggesting that they are unlikely to have occurred by chance. Older individuals tend to have reduced rotational range of motion in their lower limb joints which is also statistically significant. Both plantar flexion and dorsiflexion of the ankle joint also exhibit negative correlations with age in both standing and sitting positions. This suggests that as individuals get older, their ability to flex their feet diminishes (plantar flexion and dorsiflexion). Interestingly, limb length does not show a strong correlation with age in either standing or sitting positions as shown in Table 3 and Figure 5. The p-values for these correlations are relatively high, indicating that the relationship between limb length and age is not significant in this study. These findings highlight the importance of considering age-related changes in joint mobility when assessing the well-being and physical capabilities of workers who spend extended periods standing or sitting. In previous studies similar results were found (15, 16).

Table 3: Correlation between Age and Lower Limb Joints Roms and Lower Limb Length in Prolonged Standing and Sitting Workers

ROM	Standing		Sitting	
	Correlation	P-value	Correlation	P-value
Hip Flexion - 120°	-.233	<0.001	-.014	.821
Hip Extension - 30°	-.335	<0.001	-.300	<0.001
Hip Abduction - 45°	-.639	<0.001	-.253	<0.001
Hip Adduction - 30°	-.185	.002	-.479	<0.001
Hip Medial rotation - 45°	-.412	<0.001	-.625	<0.001
Hip Lateral rotation - 45°	-.438	<0.001	-.050	.412
Knee Flexion-135°	-.559	<0.001	-.251	<0.001
Knee Extension-0°	.525	<0.001	.043	.474
Ankle Plantar flexion-50°	-.256	<0.001	-.304	<0.001
Ankle Dorsiflexion-20°	-.462	<0.001	-.532	<0.001
Right limb length	.047	.435	-.090	.133
Left limb length	-.059	.326	-.200	.001



A) Long-term standing employees **B) Long-term sitting employees**

Figure 5: Correlation between Age and Lower Limb Joints Roms and Lower Limb Length in Long-Term Standing and Sitting Employees

In both standing and sitting positions, there is a negative correlation between weight and the flexion and extension of the lower limb joints. This suggests that as an individual's weight increases, their ability to perform these movements decreases. These correlations are statistically significant, as indicated by the low p-values (<0.001). For hip abduction and adduction, the correlation with weight is mixed. While standing, there is a negative correlation with hip abduction but a positive correlation with hip adduction. In sitting, the correlations were not statistically significant. This suggests that weight may have a limited impact on abduction and adduction. While standing, there is a negative correlation between weight and medial rotation of the hip joint but no significant correlation with hip lateral rotation. While sitting, there is no significant correlation between either hip medial or lateral rotation. These findings indicate that weight may have a limited influence on these rotational movements. Interestingly, there is no significant correlation between weight and the plantar flexion of the ankle joint either when standing or sitting. However, in sitting, there is no significant correlation with the dorsiflexion of the ankle joint, while in standing, there is a negative correlation. This suggests that weight may have a limited effect on plantar flexion but could affect dorsiflexion to some extent. The data show that weight is positively correlated with right limb length in both standing and sitting, and with left limb length in standing as shown in Table 4 and plotted in Figure 6. These correlations are statistically significant. This suggests that individuals with higher weight tend to have longer limbs, although the effect size may be relatively small.

Table 4: Correlation between Weight and Lower Limb Joints Roms and Lower Limb Length in Long-Term Standing and Sitting Employees

ROM	Standing		Sitting	
	Correlation	P-value	Correlation	P-value
Hip Flexion - 120°	-.091	.133	-.050	.410
Hip Extension - 30°	-.246	<0.001	-.213	<0.001
Hip Abduction - 45°	-.410	<0.001	-.047	.435
Hip Adduction - 30°	-.200	.001	-.118	.050
Hip Medial rotation - 45°	-.259	<0.001	.004	.942
Hip Lateral rotation - 45°	-.507	<0.001	-.034	.578
Knee Flexion-135°	-.423	<0.001	-.163	.007
Knee Extension-0°	.213	<0.001	.018	.770
Ankle Plantar flexion-50°	.017	.777	.169	.005
Ankle Dorsiflexion-20°	-.170	.005	.012	.848
Right limb length	.270	<0.001	.097	.108
Left limb length	.148	.014	.168	.005

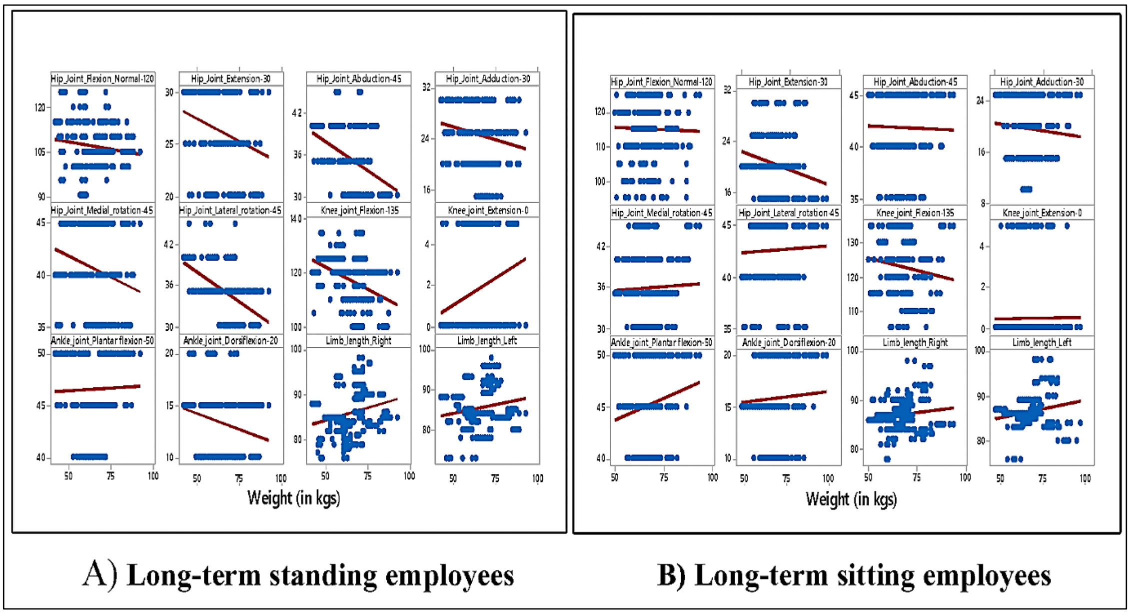


Figure 6: Correlation between Weights and Lower Limb Joints Roms and Lower Limb Length among Long-Term Standing and Sitting Employees

Summary, weight is generally negatively correlated with range of motion in several lower limb joint movements, particularly in flexion and extension. However, the relationship between weight and ROM in abduction, adduction, medial and lateral rotation, plantar flexion, and dorsiflexion is more complex and may not be statistically significant in all cases. Additionally, weight appears to be positively correlated with limb length, suggesting that heavier individuals may have slightly longer limbs. According to previous studies these results are consistent. These findings can have implications for understanding the physical capabilities and potential limitations of long-term standing and sitting employees based on their weight (17, 18).

Standing, there is a positive correlation between work hours and hip flexion but a negative correlation with hip extension. Sitting, the correlations are reversed. This suggests that the relationship between working hours and flexion or extension is dependent on position. These correlations are statistically significant, except for flexion in standing. For hip abduction there is no significant correlation between working hours either standing or sitting. However, in standing, there is a negative correlation between work hours and hip adduction, while in sitting, there is no significant correlation. This indicates that working hours may affect adduction in standing and not abduction or adduction in sitting. Additionally, there is no significant correlation between working hours and hip medial or lateral rotation in the standing position. In sitting, there is a positive correlation with hip medial rotation. This suggests that work hours may have a limited impact on rotational movements. Both standing and sitting, there was a positive correlation between work hours and the dorsiflexion of the ankle joint. This suggests that individuals who work long hours may have better dorsiflexion. In sitting, there is also a positive correlation with ankle plantar flexion shown in Table 5 and plotted in Figure 7. These correlations are statistically significant. Working hours do not show a significant correlation with limb length either standing or sitting. This suggests that the duration of working hours does not have a significant impact on limb length. Previous published studies also found similar results (19, 20). These findings suggested that the effects of work hours on lower limb joint ROM are multifaceted and may depend on various factors, including posture and the specific joint movement being examined.

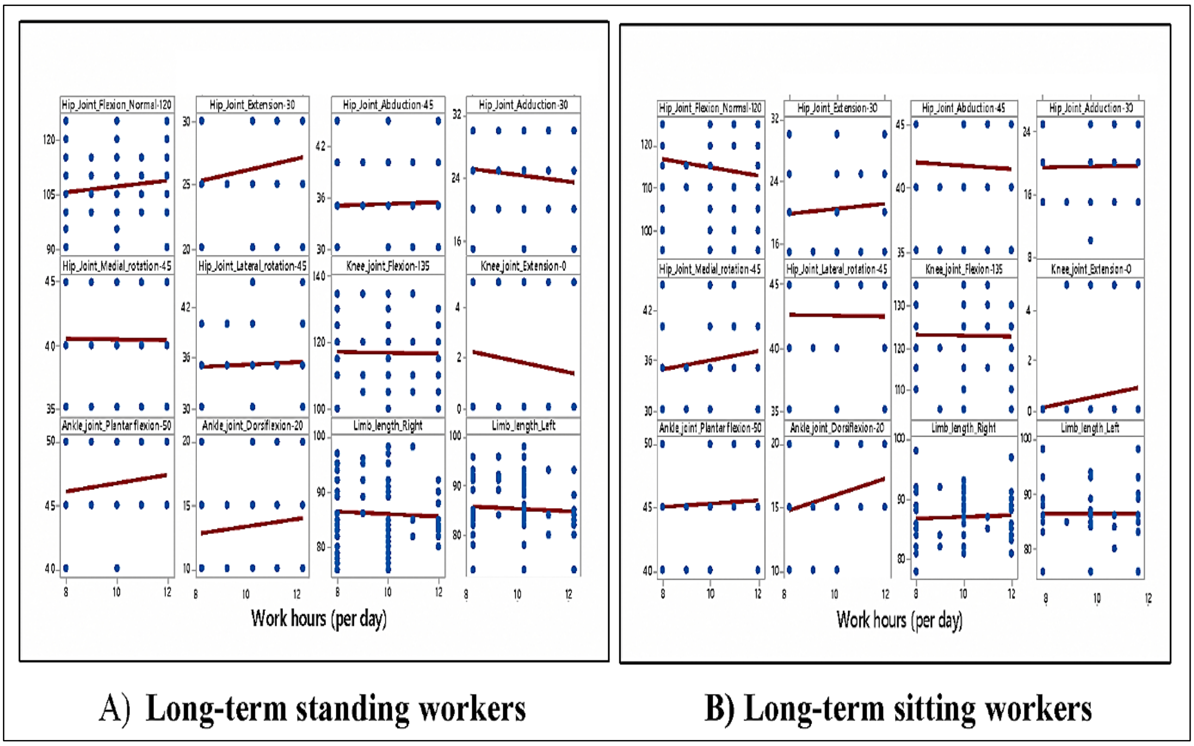


Figure 7: Correlation between Work Hours and Lower Limb Joints Roms and Lower Limb Length in Long-Term Standing and Sitting Workers

Table 5: Correlation between Work Hours and Lower Limb Joints Roms and Lower Limb Length in Long-Term Standing and Sitting Employees

ROM	Sitting		Standing	
	Correlation	P-value	Correlation	P-value
Hip Flexion - 120°	.151	.012	-.147	.014
Hip Extension - 30°	.191	.001	.094	.119
Hip Abduction - 45°	.037	.541	-.057	.346
Hip Adduction - 30°	-.131	.030	.003	.960
Hip Medial rotation - 45°	-.025	.681	.202	.001
Hip Lateral rotation - 45°	.040	.503	.031	.610
Knee Flexion-135°	-.020	.742	.028	.647
Knee Extension-0°	-.147	.014	.207	.001
Ankle Plantar flexion-50°	.111	.064	.055	.363
Ankle Dorsiflexion-20°	.138	.021	.227	<0.001
Right limb length	-.021	.723	.026	.663
Left limb length	-.072	.234	-.065	.278

Both standing and sitting, there is a negative correlation between years of work experience and the flexion and extension of the hip, knee, and ankle joints. This suggests that as individuals gain more work experience, their ability to perform these movements tends to decrease. These correlations are statistically significant, indicating that they are unlikely to have occurred by chance. Interestingly, there is a negative correlation between work experience and hip abduction and adduction in both standing and sitting. These correlations are quite strong, suggesting that individuals with more work experience tend to have reduced range of motion in these movements. Similar to hip abduction and adduction, there is a negative correlation between work experience and hip medial and lateral rotation of the joints both in standing and sitting. This indicates that individuals with more work experience tend to have a diminished rotational range of motion. Work experience is negatively correlated with plantar flexion and dorsiflexion of the ankle joints both in standing and as shown in Table 6 and Figure 8. These correlations are statistically significant, indicating that individuals with more work experience may have a reduced range of motion in these movements. The results of this study are consistent with the previous authors' study (2). These findings emphasize the importance of considering the physical effects of long-term occupational demands on joint mobility.

Table 6: Years of Work Experience Correlate with Lower Limb Joint Roms and Lower Limb Length in Long-Term Standing and Sitting Workers

ROM	Standing		Sitting	
	Correlation	**P-value**	**Correlation**	**P-value**
Hip Flexion - 120°	-.211	<0.001	-.136	.023
Hip Extension - 30°	-.277	<0.001	-.536	<0.001
Hip Abduction - 45°	-.661	<0.001	-.310	<0.001
Hip Adduction - 30°	-.307	<0.001	-.755	<0.001
Hip Medial rotation - 45°	-.374	<0.001	-.715	<0.001
Hip Lateral rotation - 45°	-.526	<0.001	-.103	.088
Knee Flexion-135°	-.537	<0.001	-.331	<0.001
Knee Extension-0°	.459	<0.001	.013	.826
Ankle Plantar flexion-50°	-.325	<0.001	-.460	<0.001
Ankle Dorsiflexion-20°	-.440	<0.001	-.718	<0.001
Right limb length	-.055	.358	-.058	.337
Left limb length	-.109	.071	-.124	.039

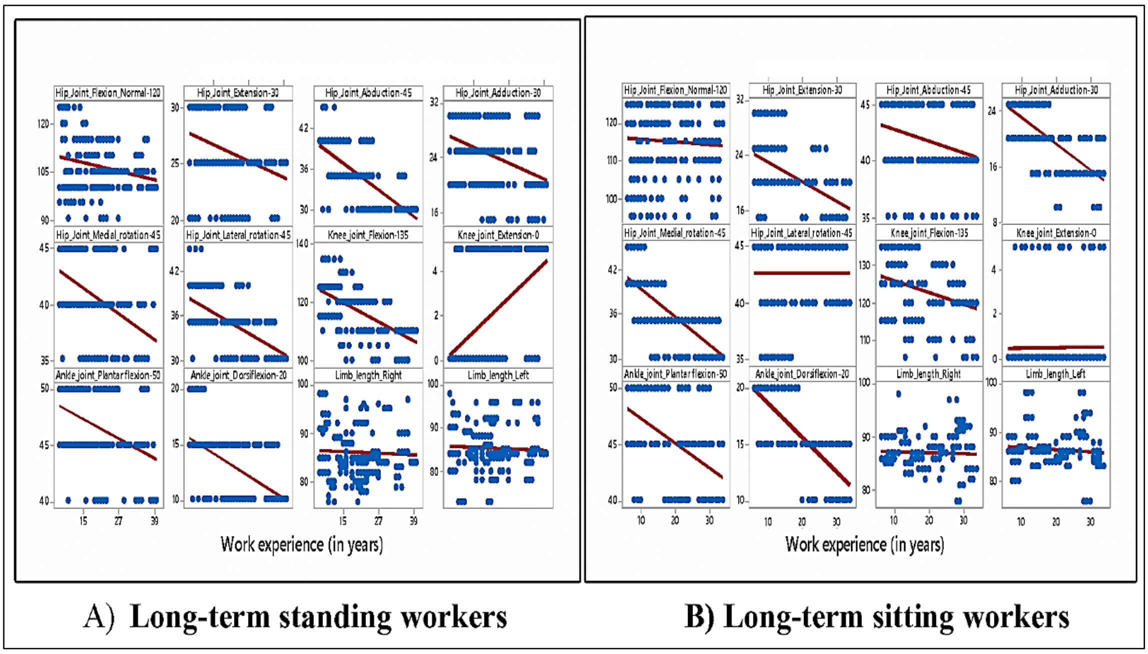


Figure 8: Correlation between Work Experience and Lower Limb Joint Roms and Lower Limb Length in Prolonged Standing and Sitting Workers

Discussion

By delving into this topic, we can enhance workplace conditions and mitigate the negative consequences of prolonged sitting and standing. The results showed that the mean age and height of long-term standing workers and long-term sitting workers were not statistically significant. However, there was a statistically significant difference in weight between the two groups. These findings are consistent with other studies that have shown the positive impact of standing workstations on reducing sitting time and maintaining a healthy weight (21, 22). The study also showed that working experience was significantly different between prolonged standing and sitting workers. Another study on the relationship between running and mental health found that exercise has a positive impact on mental health and well-being (23).

Implementing ergonomic principles by adjusting workstations, promoting proper posture, and providing ergonomic tools can substantially reduce these risks. Investing in ergonomic interventions not only safeguards employee health but also enhances productivity, demonstrating the imperative role of ergonomics in preventing occupational-related injuries. The present study results showed that prolonged standing workers had significantly lower hip joint ROM for flexion, abduction, lateral rotation, knee flexion and ankle plantarflexion than prolonged sitting workers. These findings are consistent with other studies that have reported negative effects of prolonged standing on musculoskeletal health (24, 25). However, it is worth noting that prolonged sitting workers had significantly lower hip joint ROM for extension, adduction, and medial rotation, and it has also been associated with negative health outcomes, such as obesity and cardiovascular disease (6, 11). The study results showed that prolonged standing workers had lower joint ROM in the knee and ankle, while prolonged sitting workers had higher muscle power in the knee and ankle. Prolonged standing and sitting both have negative effects on musculoskeletal health. While prolonged standing can cause lower back and leg pain, prolonged sitting can lead to hip joint stiffness and reduced ROM (26, 27). These findings are consistent with previous research on the negative health outcomes associated with both prolonged standing and sitting (28).

The study's results suggest that promoting physical activity and reducing sedentary behavior in the workplace is vital for maintaining musculoskeletal health. The strengths of this study are that it provides valuable insights into the impact of prolonged standing and sitting on lower limb health. Therefore, occupational health interventions should aim to promote physical activity and reduce prolonged sedentary behavior in the workplace, while also addressing the ergonomic needs of workers who stand and sit for long periods. The findings of this research project reveal significant correlations between age and the ROM of lower limb joints in both standing and sitting positions among long-term employees. The negative correlation between age and hip joint ROM in extension, abduction, and medial rotation movements, as well as hip flexion in standing employees, aligns with previous studies. Several studies have shown that aging affects hip joint structures, including cartilage thickness and stiffness, which can limit ROM (15, 16). These age-related changes are believed to contribute to diminished flexibility and mobility in the hip joint. The negative correlation between age and knee joint flexion in both standing and sitting positions, as well as knee extension in standing employees, corroborates previous research on age-related changes in knee joint function (17). With advancing age, alterations in the knee joint, such as decreased synovial fluid production and cartilage degeneration, can limit the ability to flex and extend the knee fully (18). The negative correlations observed in plantar flexion and dorsiflexion in both standing and sitting positions indicate that as individuals age, their capacity for foot movement (both pointing toes downward and lifting toes upward) diminishes. Age-related changes in the ankle joint, including reduced joint lubrication and ligament stiffness, can contribute to these limitations (19).

The significance of these correlations implies that age-related changes in joint mobility are more than just incidental. They have practical implications for an aging workforce, particularly for those in occupations requiring prolonged standing or sitting. Reduced joint mobility can increase the risk of musculoskeletal discomfort, limit job performance, and potentially contribute to workplace injuries (20). Employers and occupational health practitioners should be aware of these age-related changes and consider ergonomic interventions and exercises to mitigate their impact on employee well-being and productivity (2). The negative correlations observed in hip, knee, and ankle joint movements underscore the impact of aging on joint flexibility, which has important implications for occupational health and ergonomics.

Conclusion

In this study, we evaluated the kinematics of workers in prolonged standing and sitting positions to determine their exposure to ergonomic risks and the possibility of musculoskeletal symptoms, as well as their daily working activities and postures. Our exploratory analyses revealed that kinematic changes are strongly associated with prolonged standing and sitting occupations, indicating the need for ergonomic interventions. Functional adaptations gradually develop when individuals stand or sit for prolonged periods resulting in joint stiffness, muscle tightness, and weakness in the agonist and antagonist muscle groups of the lower limbs. In addition to musculoskeletal disorders, prolonged standing and sitting can also affect normal gait due to changes in the kinematics of the lower limb joints. Work-related musculoskeletal impairments can have a significant impact on public health.

Stretching exercises that target the muscles and soft tissues around the joints can prevent stiffness and enhance ROM. Reprogramming physical exercises, such as stretching and strengthening exercises for the lower limb muscles and joints, can protect kinematic variability in the face of functional adaptations. Knowledge of ergonomic risks is crucial for workers' health and reduces the incidence and severity of occupational-related musculoskeletal problems. This study suggests the variables to assess in future musculoskeletal evaluations of healthy workers, as well as the importance of revealing how occupational factors influence kinematic changes in lower limb joints.

Although accurate estimates of occupational kinematics are not currently possible, there is sufficient evidence to identify job-related hazards. We hope that the findings of this study will contribute to improvements in ergonomics, including the design of workstations and improving the working posture of workers who spend prolonged periods standing and sitting. This information may be useful for individuals who want to better understand and manage their own functional adaptations to the musculoskeletal system, as well as for students and researchers interested in this field.

Abbreviations

AROM: Active Range of Motion, ASIS: Anterior Superior Iliac Spine, MSD: Musculoskeletal Disorders, ROM: Range of Motion, Roms: Range of Motions.

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None.

Author Contributions

All authors contribute equally.

Conflict of Interest

Nil.

Ethics Approval

Regarding ethical considerations, the local ethical review committee guidelines were followed, and the purpose and goals of the study were explained to the participants. The confidentiality of all information was strictly maintained, and informed consent was obtained. This study has been cleared by our Institutional Ethical Committee. The consent forms were explained to them, and the participants were informed that they could withdraw at any time and that participation was entirely voluntary.

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