
Determinants of Hamstring Flexibility Among Manual Cigarette Workers

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Abstract. The production of cigarettes involves manual labor, and some workers experience issues such as pain and cramping in the back of the thigh. These are symptoms of hamstring muscle shortening. Shortened hamstring muscles are often considered a primary risk factor for muscle injury, as well as a problem related to muscle health or the musculoskeletal system. The aim of this study is to determine the relationship between work posture, length of service, and individual characteristics and hamstring muscle flexibility. A cross-sectional study was conducted among 55 cigarette factory workers in Kudus, Indonesia, selected by proportional random sampling. Data on age, exercise habits, and years of experience were collected using questionnaires, while work position, BMI, and hamstring flexibility were assessed through observation, anthropometric measurements, and the V-Sit and Reach Test. Bivariate analysis used the Chi-square test at a 5% significance level. The mean age of the respondents was 46.51 years, with an average exercise frequency of 1.31 times per week. A total of 56.4% of respondents fell into the normal category, and 61.8% had a tenure of less than 4 years. Chi-square analysis showed the following results: age ($p=0.020$), BMI ($p=0.205$), exercise habits ($p=0.000$), work posture ($p=0.273$), and tenure ($p=0.386$). Conclusion: Age and exercise habits are risk factors associated with hamstring muscle flexibility among cigarette workers in Kota Kudus District, Kudus Regency. Age and exercise habits were significantly associated with hamstring flexibility. Workplace programs should promote regular physical activity, active breaks, mobility exercises, and stretching, particularly for older workers.

Keywords: Hamstring Flexibility, Cigarette Factory Workers, Exercise Habits, Age, Occupational Health

INTRODUCTION

Muscle flexibility is a crucial component in maintaining optimal movement capacity, postural stability, and musculoskeletal function. One muscle group that plays a crucial role in lower extremity mobility is the hamstring muscle. Hamstring flexibility describes the ability of this muscle group to undergo optimal lengthening, reflected in the range of motion at the associated joints ⁽¹⁻³⁾. Functionally, the hamstrings play a role in various daily activities and activities that require physical capacity, such as walking, running, jumping, sitting, standing, and maintaining postural control ⁽⁴⁻⁶⁾. Therefore, changes in hamstring flexibility are not only a localized problem in the muscle tissue but can also impact movement patterns and overall musculoskeletal function.

The hamstrings are a muscle group that is susceptible to shortening, especially when held in static positions or without adequate stretching stimulation ^(7,8). Hamstring shortening or stiffness can cause biomechanical changes in the lower extremities and pelvis, increasing tissue tension, reducing range of motion, and altering normal movement patterns ^(9,10). This decreased flexibility also has the potential to affect posture and body alignment and contribute to musculoskeletal disorders, including spinal problems ^(11,12). Therefore, hamstring flexibility can be used as an important indicator in assessing functional capacity and musculoskeletal health.

From an occupational health perspective, reduced hamstring flexibility becomes increasingly important in jobs involving static postures, repetitive movements, and long work durations. Limited flexibility can reduce workers' ability to perform optimal functional movements and increase the mechanical load on musculoskeletal structures ⁽¹³⁾. Hamstring shortening can also increase susceptibility to injury when workers suddenly change positions or move with a large range of motion ⁽¹⁴⁾. If ergonomic risk factors persist unchecked, these conditions can develop into musculoskeletal disorders that impact worker comfort, work capacity, and productivity.

Epidemiologically, hamstring flexibility issues have a relatively high prevalence. Previous studies reported a prevalence of hamstring shortening of 43.4% in Malaysia and 51.2% in Sri Lanka, and demonstrated a relationship between physical activity levels and hamstring flexibility ⁽¹⁵⁾. Individuals with higher levels of physical activity tend to have better hamstring flexibility than those with lower levels ^{(2), (13), (16)}. This suggests that hamstring flexibility is a multifactorial musculoskeletal characteristic, influenced by individual characteristics, activity patterns, and job demands. Several factors that potentially influence hamstring flexibility include age, body mass index (BMI), exercise habits, work position, and length of service ^(17–19). Aging can cause physiological changes in muscles, tendons, and connective tissues, including decreased elasticity and increased tissue stiffness, which can ultimately reduce joint range of motion ^(20–22). Increasing BMI has also been reported to be associated with decreased hamstring flexibility. In junior soccer athletes, excess body weight has been shown to be negatively associated with flexibility, indicating that increased body mass may affect the muscle's ability to undergo optimal lengthening ^(23,24).

Conversely, regular physical activity and exercise have the potential to be protective factors against decreased flexibility. Individuals who exercise regularly tend to have better hamstring flexibility than those who rarely exercise ^{(3), (16)}. Conversely, prolonged exposure to static postures can cause tissue adaptations that increase muscle stiffness and shortening. Prolonged sitting causes the hamstrings to remain in a relatively constant position with minimal stretching stimulation. If repeated over the long term, this condition can reduce flexibility and increase the risk of musculoskeletal disorders ^(25,26). This risk may be greater in workers with monotonous and repetitive movement patterns and long work periods due to accumulated ergonomic exposure ^(27,28).

Tobacco industry workers, particularly those in manual production processes, are at risk of hamstring flexibility impairment due to ergonomic exposure. Cigarette Factory X in Kudus City District has 121 workers with varying job characteristics. Rolling workers engage in static sitting for approximately four hours with minimal position changes, walking, or stretching. This condition has the potential to increase biomechanical stress, muscle stiffness, and decrease hamstring flexibility. Initial findings indicate complaints of pain and cramping in the posterior thigh, limited range of motion when walking, and pain when the leg is straightened. Although hamstring shortening cannot yet be diagnosed, these complaints indicate potential impairments in lower extremity flexibility and musculoskeletal function that require objective assessment.

Research on hamstring flexibility is still dominated by athletes, students, and individuals with general physical activity, while evidence in industrial workers exposed to static postures and repetitive

work is limited. Studies integrating occupational factors, such as position and length of service, with individual factors, including age, BMI, and exercise habits, are also needed. Therefore, this research is crucial to identify factors associated with hamstring flexibility as a basis for early detection of musculoskeletal disorders and the development of ergonomic interventions, such as posture variation, active breaks, and stretching. This study aims to analyze the relationship between work position, length of service, age, BMI, and exercise habits with hamstring flexibility in cigarette factory workers in Singocandi Village, Kudus Regency, as a basis for developing promotive and preventive strategies to maintain workers' health and functional capacity.

METHODS

This is an analytical observational study with a cross-sectional design. The aim of this study was to analyze the relationship between individual characteristics and job factors with hamstring muscle flexibility in cigarette industry workers. The study was conducted among workers at cigarette factory X in Kudus City District, Kudus Regency, Indonesia. The study population consisted of 121 workers. The sample size was determined using the Slovin formula with a 10% margin of error, resulting in 55 respondents. Respondents were selected using proportional random sampling to ensure representativeness of workers based on their work department.

Inclusion criteria included workers who were in good health and willing to participate. Workers who were not present during the data collection process were excluded. The independent variables included age, body mass index (BMI), exercise habits, work position, and years of experience, while the dependent variable was hamstring muscle flexibility.

Data on age, exercise habits, and years of experience were obtained through interviews using a structured questionnaire. Exercise habits were assessed based on the frequency and type of exercise performed over the course of a week. Work postures are assessed through observation and are categorized into two types: static and dynamic. Workers who remain seated throughout their work are classified as having a static posture, whereas those who alternate between sitting and standing are classified as having a dynamic posture. BMI was calculated based on weight and height measurements. Body weight was measured using a digital scale with a maximum capacity of 180 kg and an accuracy of 0.1 kg, while height was measured using a microtoise stature meter with a measuring capacity of up to 200 cm. Hamstring muscle flexibility was measured using the V-Sit and Reach Test, using a body measuring tape.

Bivariate analysis was performed to identify the relationship between each independent variable and hamstring muscle flexibility using the Chi-Square test with a significance level of 5%. The study has obtained ethical approval from the Health Research Ethics Committee of the Faculty of Public Health, Universitas Muhammadiyah Semarang, under registration number 0040/KEPK-FKM/UNIMUS/2025.

RESULT

The distribution of numerical data is shown in Table 1.

Table 1. Numerical Distribution of Variables

Variable	N	Min	Max	Mean	Standard Deviation
Age (years)	55	26	67	46.51	11.33
BMI (kg/m ²)	55	15.01	32.89	23.37	4.02
Exercise habits (frequency/week)	55	0	4	1.31	1.26
Years of experience (years)	55	1	20	4.05	3.59
Hamstring flexibility (cm)	55	0	20	7.80	5.19

The numerical characteristics of the respondents are presented in Table 1. The respondents' ages ranged from 26–67 years with a mean of 46.51 ± 11.33 years. Body mass index (BMI) values ranged from 15.01 to 32.89 kg/m² with an average of 23.37 ± 4.02 kg/m². Exercise frequency ranged from 0 to 4 times per week with an average of 1.31 ± 1.26 times per week. Years of experience ranged from 1 to 20 years with an average of 4.05 ± 3.59 years. Meanwhile, hamstring muscle flexibility values ranged from 0 to 20 cm with an average of 7.80 ± 5.19 cm, indicating a wide variation in flexibility among respondents.

The distribution of categorical data is shown in Table 2.

Table 2. Frequency Distribution of Variables

Variables	Category	<i>f</i>	%
Age	Early adulthood	12	21,8
	Late adulthood	10	18,2
	Early elderly	18	32,7
	Late elderly	14	25,5
	Elderly	1	1,8
BMI	Underweight	6	10,9
	Normal	31	56,4
	Overweight	18	32,7
Exercise Habits	Very good	1	1,8
	Good	11	20,0
	Fair	15	27,3
	Poor	5	9,1
	Very poor	23	41,8
Work Position	Static	29	52,7
	Dynamic	26	47,3
Years of Experience	Not at risk	34	61,8
	At risk	21	38,2
Hamstring Flexibility	Very good	2	3,6
	Good	6	10,9
	Fair	11	20,0
	Poor	14	25,5
	Very poor	22	40,0

Based on the categorical distribution (Table 2), the largest age group was in the early elderly category (32.7%). Based on BMI, the majority of respondents were in the normal category (56.4%). In terms of physical activity, most respondents had very poor exercise habits (41.8%).

Regarding job characteristics, 52.7% of respondents worked in static positions, the majority of respondents (61.8%) had a years of experience that was not at risk, and 40.0% of respondents had very poor hamstring flexibility. These findings indicate that more than half of respondents had hamstring flexibility in the poor to very poor category, indicating significant flexibility issues in the study population.

Table 3. Results of the Analysis of the Relationship between Age, BMI, Exercise Habits, Work Position, and Length of Service with Hamstring Flexibility

Variables	Hamstring Flexibility				p-Value
	Good		Poor		
	<i>f</i>	%	<i>f</i>	%	
Age					
Adults (26 – 45 tahun)	12	54,5	10	45,5	0,020
Elderly (46 – 68 tahun)	7	21,2	26	78,8	
BMI					
Underweight ($\leq 18,4$)	1	16,7	5	83,3	0,205
Normal (18,5 – 25,0)	9	29,0	22	71,0	
Obese ($\geq 25,1$)	9	50,0	9	50,0	
Exercise Habits					
Good (2 – 5 times / week)	17	63,0	10	37,0	0,000
Poor (0 – 1 times /week)	2	7,1	26	92,9	
Work Position					
Static	8	27,6	21	72,4	0,273
Dynamic	11	42,3	15	57,7	
Years of Experience					
Not at risk (≤ 4 tahun)	10	29,4	24	70,6	0,386
At risk (> 4 tahun)	9	42,9	12	57,1	

Bivariate analysis was conducted to identify the relationship between age, BMI, exercise habits, work position, and work period with hamstring muscle flexibility. The results of the analysis are presented in Table 3.

The Continuity correction test regarding the relationship of age and exercise habits with hamstring muscle flexibility revealed a significant association ($p = 0.020$). In the adult group, the proportion of respondents with good hamstring flexibility reached 54.5%, compared to only 21.2% in the elderly group. Conversely, poor hamstring flexibility was more prevalent in the elderly group than in the adult group (45.5%). These findings indicate a tendency for hamstring flexibility to decline with advancing age.

Similarly, the Continuity Correction test regarding the relationship between exercise habits and hamstring flexibility yielded a p-value of 0.000, indicating a significant association. Respondents with good exercise habits showed a 63.0% proportion of good hamstring flexibility, compared to only 7.1% in the group with poor exercise habits. Conversely, poor hamstring flexibility was found in 92.9% of respondents with poor exercise habits, compared to 37.0% in the group with good exercise habits. This pattern suggests that higher exercise frequency is associated with more optimal hamstring flexibility.

In contrast to age and exercise habits, BMI (Body Mass Index), work posture, and tenure did not show a significant relationship with hamstring flexibility, with p-values of 0.205, 0.273, and 0.386, respectively. However, there were variations in flexibility proportions based on BMI categories. Poor flexibility was observed in 83.3% of underweight respondents, 71.0% of respondents with normal BMI, and 50.0% of obese respondents. Thus, the variation in flexibility based on BMI in this study did not demonstrate a statistically significant pattern of association.

Poor hamstring flexibility was found in 72.4% of respondents with static work postures and 57.7% of respondents with dynamic work postures. Although, descriptively, the proportion of poor flexibility was higher among workers with static work postures, this difference did not reach statistical significance. Regarding tenure, poor flexibility was observed in 70.6% of respondents with less than

four years of service and 57.1% of those with more than four years. These findings indicate that tenure was not a significant factor regarding hamstring flexibility in this study.

Overall, the study's key findings indicate that older age groups and workers with low exercise frequency tend to have poorer hamstring flexibility.

DISCUSSION

Hamstring muscle flexibility is a crucial component of musculoskeletal functional capacity because it plays a role in hip and knee mobility, postural stability, and various physical activities. Decreased flexibility can increase tissue stiffness, limit range of motion, and affect the body's biomechanical patterns^(29,30). Research on cigarette factory workers in Kudus City District, Kudus Regency, showed that age and exercise habits were significantly associated with hamstring flexibility, while BMI, work position, and length of service did not show a significant association.

The Relationship Between Age and Exercise Habits and Hamstring Flexibility

The results of this study indicate a significant relationship between age and exercise habits with hamstring flexibility. Adults had a higher proportion of good hamstring flexibility than the elderly, while poor flexibility was more prevalent in the elderly. These findings suggest a tendency that increasing age is associated with a decline in the capacity of musculoskeletal tissue to maintain elasticity and optimal range of motion. Age is a risk factor for musculoskeletal disorders⁽³¹⁾.

Physiologically, age-related changes stem from structural and functional alterations in muscles, tendons, and connective tissues. The aging process is associated with a decline in muscle mass, strength, and function—collectively known as sarcopenia—as well as changes in tissue mechanical characteristics^(32,33). These changes are characterized by a reduction in the size and number of muscle fibers, particularly type II fibers, ultimately leading to decreased muscle cross-sectional area and functional capacity. Changes in muscle fibers and mass progress with advancing age. Age-related loss of muscle mass, or atrophy, can contribute to altered function and characteristics of the muscle-tendon unit. In the hamstrings, such changes can affect the muscle's ability to generate and control movement at the hip and knee joints. Beyond the loss of muscle mass, aging is accompanied by alterations in the mechanical properties of muscle and tendon tissues. Systematic reviews regarding age-related changes in muscle elasticity indicate shifts in muscle stiffness during aging, particularly when the muscle is under passive stretch. Connective tissue also experiences increased stiffness due to changes in collagen structure, increased cross-linking, and decreased tissue elasticity. These changes can reduce the ability of musculoskeletal tissue to elongate, thereby limiting joint range of motion^{(21), (33)}. In addition to structural changes, aging can affect neuromuscular control and the response to the stretch reflex. Changes in the nervous system and muscle relaxation ability can lead to increased muscle tone and maintain higher levels of tissue tension, ultimately limiting flexibility^(34,35). Therefore, decreased hamstring flexibility in older workers likely results from the interaction between aging-related tissue changes and decreased neuromuscular adaptive capacity.

Thus, the reduced hamstring flexibility in the older age group in this study likely results from the interaction of several age-related changes, including declines in muscle mass and function, alterations in muscle-tendon unit characteristics, and potentially reduced physical activity. Research on older adults with hamstring tightness also indicates that changes in range of motion (ROM) may be linked to muscle-tendon unit characteristics, although acute increases in ROM are not always accompanied by changes in muscle cross-sectional area.

These findings align with research by Jonatan Magno Norte da Silva et al, which validated a model examining the relationships between occupational risk factors, Work-related musculoskeletal

disorders (WMSDs), and quality of work life (QWL) across age groups. The model demonstrated robust psychometric properties, enabling the identification of significant differences between younger and older workers ⁽³⁶⁾.

Respondents with good exercise habits had a higher proportion of hamstring flexibility than those with poor exercise habits. Conversely, poor flexibility was found in 92.9% of respondents with poor exercise habits. This significant difference in proportions suggests that regular physical activity has the potential to be a protective factor against decreased hamstring flexibility.

Physiologically, regular physical activity can maintain muscle tissue elasticity and improve muscle adaptability to changes in length during movement. Activities involving stretching can increase tolerance to muscle elongation, maintain range of motion, and reduce tissue stiffness. Conversely, low physical activity and a sedentary lifestyle can reduce mechanical stimulation of musculoskeletal tissue, resulting in stiffer muscles and decreased joint range of motion ^(37–39). In this study, respondents with a regular exercise routine generally engaged in activities such as gymnastics and walking. Although these activities are not specifically flexibility training, regular physical activity can provide movement stimulation to the lower extremities and help maintain joint mobility.

The findings of this study align with research by Agus et al, on students at Bali Khresna Health Vocational School, which demonstrated a relationship between exercise habits and physical activity levels and hamstring and lower back flexibility ⁽⁴⁰⁾. The better the exercise habits and physical activity levels, the better the muscle flexibility. These findings strengthen the argument that physical activity is a modifiable factor and a potential target for interventions to maintain musculoskeletal function.

The low frequency of exercise among most workers highlights the need for intervention strategies that not only focus on changing working conditions but also encourage active behavior outside of work hours. Regular active break programs, simple stretching exercises, work-related exercises, or mobility training can be considered as part of a workplace-based musculoskeletal disorder prevention program.

The findings of this study also require cautious interpretation. Although muscle atrophy and sarcopenia could theoretically be mechanisms explaining the decline in flexibility associated with aging, this study did not directly measure muscle mass, muscle cross-sectional area, muscle strength, or sarcopenia status. Therefore, muscle atrophy cannot be identified as the direct cause of the observed association. Rather, the results indicate an association between age and hamstring flexibility, with age-related changes serving as a possible underlying biological mechanism.

Relationship between BMI, work position and work period with hamstring muscle flexibility

The results showed that BMI, work position, and years of work were not significantly related to hamstring muscle flexibility. In the thin and normal BMI groups, the category of poor hamstring muscle flexibility was dominated, whereas in the fat BMI category the numbers were balanced between good and poor flexibility. This pattern suggests that the relationship between anthropometric status and flexibility is not linear in this study population.

BMI can influence flexibility through body composition and adipose tissue distribution. Increased fatty tissue around joints has the potential to provide mechanical resistance to movement and limit certain ranges of motion ^(41,42). However, BMI is an anthropometric indicator that cannot differentiate between fat mass and muscle mass. Two individuals with the same BMI value can have different body composition, fitness and flexibility capacity. The failure to find a significant relationship in this study could also be influenced by the dominance of respondents with normal BMI (56.4%), so that variation between groups was relatively limited. In addition, hamstring flexibility may be more influenced by physical activity, stretching exercises, age, tissue characteristics, and neuromuscular factors than BMI alone. This research is in line with Esther Liyanage's research, which concluded that

neurodynamic exercises combined with stretching and neurodynamics alone showed to be superior to the other physical therapy interventions in improving hamstring flexibility for hamstring tightness among university students, however, the reliability of the evidence is low.

Static work positions for long durations can maintain muscle length, reduce movement variation, and increase musculoskeletal tension and stiffness^(43–45). However, static positions do not always directly lead to decreased hamstring flexibility. The effect may be influenced by the duration of exposure, the frequency of position changes, the presence of active breaks, physical activity outside of work, and the characteristics of the movements performed during work. For workers in dynamic positions, position changes and walking activities can provide greater movement stimuli than static positions. This is reflected descriptively in this study, where the proportion of good flexibility was higher in dynamic workers compared to static workers. However, excessive, repetitive dynamic activities, or those performed without adequate recovery can also increase musculoskeletal load and lead to fatigue or pain⁽⁴⁶⁾.

The results of this study differ from those of Miucin et al. on office employees at the Sewaka Dharma Government Agency in Denpasar City, which found a relationship between sitting duration and work position with hamstring flexibility⁽²⁵⁾. Differences in results may be due to job characteristics, exposure duration, activity variations, respondent age, exercise habits, and different work posture measurement methods. Therefore, future work posture assessments should not only be categorized as static or dynamic, but also consider exposure duration, frequency of position changes, sitting duration, rest frequency, and specific hip and knee postures.

Based on tenure, poor flexibility was found to be more prevalent among workers with less than 4 years of service. These results suggest that the length of time a person has worked in a job does not necessarily directly reflect hamstring flexibility. One possible explanation for this finding is the relatively concentrated distribution of respondents' tenure among short-term workers. The mean tenure was only 4.05 ± 3.59 years, so differences in cumulative exposure between groups may not have been large enough to produce meaningful differences in flexibility. Furthermore, tenure is a general indicator of exposure duration and does not specifically reflect the intensity or characteristics of the biomechanical loads experienced by workers. The relationship between years of experience and hamstring flexibility is also likely mediated by other factors, particularly physical activity and exercise habits. Long-experience workers who actively engage in exercise and stretching may maintain flexibility better than newer workers with low physical activity. Conversely, prolonged work with exposure to monotonous postures, without compensatory physical activity, has the potential to increase musculoskeletal stiffness^{(40), (47)}. Thus, years of experience should not be viewed as a single determinant, but rather as an indicator of accumulated exposure that needs to be interpreted in conjunction with ergonomic and behavioral factors. These findings highlight the importance of more specific measurements of occupational exposure in future research.

Overall, this study demonstrates that hamstring flexibility in workers is determined not only by job characteristics but also by individual characteristics and health behaviors. The high proportion of workers with poor to very poor hamstring flexibility is a concern, as it could be an early indicator of decreased musculoskeletal capacity.

This study has limitations that should be considered when interpreting the results. The cross-sectional design does not allow researchers to confirm the temporal or causal relationship between the factors studied and hamstring flexibility. Furthermore, the sample size was relatively limited, and some variables had uneven distribution across categories. Measurement of exercise habits through interviews is also potentially affected by recall bias.

CONCLUSION

This study shows that age and exercise habits are associated with hamstring flexibility, while BMI, work position, and years of experience did not show a significant association. Older workers and those with low levels of exercise activity tend to have lower hamstring flexibility. Therefore, workplace-based promotive and preventative efforts through regular exercise, active breaks, mobility, and stretching are needed, especially for older workers. Future research should consider ergonomic factors, duration of static postures, workload, frequency of position changes, and stretching habits, using longitudinal or interventional designs.

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REFERENCES

1. Kellis E, Blazevich AJ. Hamstrings Force-Length Relationships And Their Implications For Angle-Specific Joint Torques: A Narrative Review. *BMC Sports Science, Medicine and Rehabilitation*. 2022;14(1):1–34. <https://doi.org/10.1186/s13102-022-00555-6>.
2. Liyanage E, Malwanage K, Senarath D, Wijayasinghe H, Liyanage I, Chellapillai D, et al. Effects of Different Physical Therapy Interventions in Improving Flexibility in University Students with Hamstring Tightness-A Systematic Review and Network Meta-analysis. *International Journal Exercise Science*. 2024;17(3):359–81. <https://pmc.ncbi.nlm.nih.gov/articles/PMC11042845/>.
3. Cai P, Liu L, Li H. Dynamic And Static Stretching On Hamstring Flexibility And Stiffness: A Systematic Review And Meta-Analysis. *Heliyon*. 2023;9(8):e18795. <https://doi.org/10.1016/j.heliyon.2023.e18795>.
4. Afonso J, Rocha-Rodrigues S, Clemente FM, Aquino M, Nikolaidis PT, Sarmento H, et al. The Hamstrings: Anatomic and Physiologic Variations and Their Potential Relationships With Injury Risk. *Frontiers in Physiology*. 2021;12(July):1–22. <https://pubmed.ncbi.nlm.nih.gov/34305648/>.
5. Huma Akhtar, Pakiza Muskan, Ramsha Amjad AKS. Correlation of Hamstring Tightness with Balance and Mobility in Young Adults. *Pakistan Journal of Medical and Health Sciences*. 2023;17(3):295–7. <https://www.researchgate.net/publication/370354772>.
6. Jenkins S, Tubbs RS. The Sciatic Nerve. In: *Surgical Anatomy of the Sacral Plexus and Its Branches*. 2020. p. 53–72. Available from: <https://www.sciencedirect.com/science/chapter/edited-volume/abs/pii/B9780323776028000118>.
7. Shamsi MB, Ahmadi A, Mirzaei M, Jaberzadeh S. Effects Of Static Stretching And Strengthening Exercises On Flexion Relaxation Ratio In Patients With LBP: A Randomized Clinical Trial. *Journal of Bodywork and Movement Therapies*. 2022;30:196–202. <https://doi.org/10.1016/j.jbmt.2022.02.023>.
8. Miçooğulları M, Özgökalp İ, Angın S. Effects Of Instrument Assisted And Functional Soft Tissue Mobilization On Hamstring Flexibility And Skinfold Thickness In Sedentary Adults. *Scientific Reports*. 2026;16(1):1–9. <https://pubmed.ncbi.nlm.nih.gov/41571821/>.
9. Guzmán-Muñoz E, Zurita-Leiva C, Gómez-Araya F, Concha-Cisternas Y, Castillo-Paredes A, Montalva-Valenzuela F, et al. Impact of Hamstring Tightness on Muscle Activation in Healthy Young Adults. *Journal of Functional Morphology and Kinesiology*. 2025;10(4):1–11. <https://pmc.ncbi.nlm.nih.gov/articles/PMC12551086/>.
10. Mohammad Bagher Shamsi, Soodeh Shahsavari, Ameneh Safari MM. A Randomized Clinical

- Trial For The Effect Of Static Stretching And Strengthening Exercise On Pelvic Tilt Angle In LBP Patients. *Journal of Bodywork and Movement Therapies*. 2020;24(3):15–20. <https://www.sciencedirect.com/science/article/abs/pii/S1360859220300243?via%3Dihub>.
11. Sassonker K, Magnezi R, Moran D. Comparing Right And Left Hamstring Flexibility And Its Association To Nonspecific Lowr Back Pain Among Women Of Different Age Groups. *Journal of Bodywork and Movement Therapies*. 2023; 36 (January):404–9. <https://doi.org/10.1016/j.jbmt.2023.07.014>.
 12. Allam NM, Ebrahim HA, Ibrahim Ateya M, Elneblawi NH, El-Sherbiny M, Fouda KZ. The Association Of Hamstring Tightness With Lumbar Lordosis And Trunk Flexibility In Healthy Individuals: Gender Analysis. *Frontiers in Bioengineering and Biotechnology*. 2023;11(September):1–8. <https://pubmed.ncbi.nlm.nih.gov/37781540/>.
 13. Liyanage E, Jayasinghe H. C. B, Samarakoon S. M. C. S. Immediate Effects Of Static Stretching And Post Isometric Relaxation On Hamstring Flexibility Among Sedentary Young Adults: A Pilot Study. *International Journal of Community and Medicine and Public Health*. 2022;9(7):2854. <https://www.ijcmph.com/index.php/ijcmph/article/view/9895>.
 14. Danielsson A, Horvath A, Senorski C, Alentorn-Geli E, Garrett WE, Cugat R, et al. The Mechanism Of Hamstring Injuries- A Systematic Review. *BMC Musculoskeletal Disorders*. 2020;21(1):1–21. <https://pubmed.ncbi.nlm.nih.gov/32993700/>.
 15. Handari HK. Hold Relax dan Static Stretching Meningkatkan Fleksibilitas Hamstring: Studi Literatur. *Physiotherapy Health Science*. 2023;5(1):8–17. <https://ejournal.umm.ac.id/index.php/physiohs/article/view/26241>.
 16. De Castro-Maqueda G, Rosety-Rodríguez MÁ, Fernández-Santos JR. Body Mass Index and Sedentary Behaviour Affect Hamstring Extensibility in Primary Education Students. *Sports*. 2025;13(4). <https://www.mdpi.com/2075-4663/13/4/109>.
 17. Abate Daga F, Panzolini M, Allois R, Baseggio L, Agostino S. Age-Related Differences in Hamstring Flexibility in Prepubertal Soccer Players: An Exploratory Cross-Sectional Study. *Frontiers of Psychology*. 2021;12(November):1–6. <https://pubmed.ncbi.nlm.nih.gov/34795614/>.
 18. Gite AA, Mukkamala N, Parmar L. Relationship between Body Mass Index and Flexibility in Young Adults. *Journal of Pharmaceutical Research International*. 2021;33:119–26. <https://journaljpri.com/index.php/JPRI/article/view/2554>.
 19. Priya S, Babu LG, Davis A. Correlation between Bmi , Hamstring Flexibility and Physical Activity in Desktop Workers. *International Journal for Multidisciplinary Research (IJFMR)*. 2026;8(4):1–6. <https://www.ijfmr.com/papers/2026/4/83524.pdf>.
 20. Kwan KYC, Ng KWK, Rao Y, Zhu C, Qi S, Tuan RS, et al. Effect of Aging on Tendon Biology, Biomechanics and Implications for Treatment Approaches. *International Journal of Molecular Sciences*. 2023;24(20). <https://pubmed.ncbi.nlm.nih.gov/37894875/>.
 21. Fede C, Fan C, Pirri C, Petrelli L, Biz C, Porzionato A, et al. The Effects of Aging on the Intramuscular Connective Tissue. *International Journal of Molecular Sciences*. 2022;23(19):1–16. <https://pmc.ncbi.nlm.nih.gov/articles/PMC9569538/>.
 22. Colman M. The Impact of Aging on Human Musculoskeletal Anatomy: A Comprehensive Review. *Journal of Morphology and Anatomy*. 2024;8(4). <https://www.hilarispublisher.com/open-access/the-impact-of-aging-on-human-musculoskeletal-anatomy-a-comprehensive-review.pdf>.
 23. Amir TL, Sari N, Wibowo E. Hubungan Indeks Masa Tubuh dengan Tingkat Fleksibilitas Otot Hamstring Pada Pemain Sepak Bola. 2021; 18(2). <https://ejurnal.esaunggul.ac.id/index.php/Formil/article/view/4321>.

24. Primasoni N. Hubungan antara Indeks Massa Tubuh (IMT) dengan fleksibilitas otot hamstring atlet sepak bola junior Daerah Istimewa Yogyakarta. *Jorpres (Jurnal Olahraga Prestasi)*. 2022;18(2). <https://garuda.kemdiktisaintek.go.id/documents/detail/3348301>.
25. Putri Miucin, Anak Ayu Nyoman Trisna Narta Dewi, Luh Putu Ratna Sundari WSU. Hubungan Antara Durasi Duduk Dan Posisi Duduk Dengan Fleksibilitas Otot Hamstring Pada Pegawai Kantor Instansi Pemerintah Sewaka Dharma Kota Denpasar. *Majalah Ilmiah Fisioterapi Indonesia*. 2020;8(3). https://www.researchgate.net/publication/346208930_Hubungan_Antara_Durasi_Duduk_Dan_Posisi_Duduk_Dengan_Fleksibilitas_Otot_Hamstring_Pada_Pegawai_Kantor_Instansi_Pemerintah_Sewaka_Dharma_Kota_Denpasar.
26. Shamsi MB, Mirzaei M, Shahsavari S, Safari A, Saeb M. Modeling The Effect Of Static Stretching And Strengthening Exercise In Lengthened Position On Balance In Low Back Pain Subject With Shortened Hamstring: A Randomized Controlled Clinical Trial. *BMC Musculoskeletal Disorders*. 2020;21(1):1–9. <https://pubmed.ncbi.nlm.nih.gov/33276764/>.
27. Gregg C, Visconti VV, Albanese M, Gasperini B, Chiavoghilefu A, Prezioso C, et al. Work-Related Musculoskeletal Disorders: A Systematic Review and Meta-Analysis. *Journal of Clinical Medicine*. 2024;13(13). <https://pubmed.ncbi.nlm.nih.gov/38999528/>.
28. Iqbal MA, Azeem A, Jaffar N, Arooj M, Iqbal MS, Nasir A, et al. Association of Hamstrings Tightness with Prolonged Sitting in Young Adults. *The Healer Journal of Physiotherapy and Rehabilitation Sciences*. 2026;6(3):30–7. <https://thehealerjournal.com/index.php/templates/article/view/669>.
29. Zhang X, Ren W, Duan Y, Yao J, Pu F. The Biomechanics Effect of Hamstring Flexibility on the Risk of Osgood-Schlatter Disease. *Journal of Healthcare Engineering*. 2022. May 9;2022:3733218 <https://pubmed.ncbi.nlm.nih.gov/35586681/>.
30. Lee I, Sim S, Jin S. Hamstring Stretching Significantly Changes The Sitting Biomechanics. *International Journal of Industrial Ergonomics*. 2021;84 (September 2020):103163. <https://doi.org/10.1016/j.ergon.2021.103163>.
31. Lestari HD, Sahri M. Studi Keluhan Musculoskeletal Disorder (MSDs) di UD. Berkah Alam Tahun 2021. *VISIQUES Jurnal Kesehatan Masyarakat*. 2021;20(2). <http://publikasi.dinus.ac.id/index.php/visiques/article/view/4927>
32. Granic A, Suetterlin K, Shavlakadze T, Grounds MD, Sayer AA. Hallmarks Of Ageing In Human Skeletal Muscle And Implications For Understanding The Pathophysiology Of Sarcopenia In Women And Men. *Clinical Science*. 2023;137(22):1721–51. <https://pubmed.ncbi.nlm.nih.gov/37986616/>.
33. Araújo LP, Figueiredo Godoy AC, Fortes Frota F, Barbalho Lamas C, Quesada K, Rucco Penteadó Detregiachi C, et al. Sarcopenia in the Aging Process: Pathophysiological Mechanisms, Clinical Implications, and Emerging Therapeutic Approaches. *International Journal of Molecular Sciences*. 2025;26(24):1–31. <https://pubmed.ncbi.nlm.nih.gov/41465572/>.
34. Niazi S, Gandomi F, Soufivand P, Ghazaleh L. The Effect of Tissue Stretching and Release Strategies on Neck Muscles Fatigue and Pain Intensity in Office Workers Affected by Chronic Neck Pain: A Rater-Blind, Semi-Experimental Study. *Health Science Reports*. 2025;8(4). <https://pubmed.ncbi.nlm.nih.gov/40260041/>.
35. Gustafsson T, Ulfhake B. Aging Skeletal Muscles: What Are the Mechanisms of Age-Related Loss of Strength and Muscle Mass, and Can We Impede Its Development and Progression? *International Journal of Molecular Sciences*. 2024;25(20). <https://pubmed.ncbi.nlm.nih.gov/39456714/>.

36. Silva JMN da, Teixeira R de S, Bispo LGM, Rodeghiero Neto I, Lisboa AHS, Martins VWB. Occupational risks, musculoskeletal disorders, and quality of work life: An age-based analysis. *Musculoskeletal Science and Practice*. 2026;82(February):103513. <https://doi.org/10.1016/j.msksp.2026.103513>.
37. Bina Kurniawan, Mohammad Z. Rahfiludin, Yuliani Setyaningsih, Nurjazuli Nurjazuli, Daru Lestantyo BW and SJ. Effects Of Stretching Exercises On Muscle Tension, Fatigue, Strength, And Lactic Acid Accumulation: A Pre-Experimental Study Among Fish Transport Workers. *Narra J*. 2024;4(1):5–12. <https://pubmed.ncbi.nlm.nih.gov/38798855/>.
38. Thomas E, Ficarra S, Nakamura M, Paoli A, Bellafiore M, Palma A, et al. Effects of Different Long-Term Exercise Modalities on Tissue Stiffness. *Sport Medicine - Open*. 2022;8(1). <https://doi.org/10.1186/s40798-022-00462-7>.
39. Warneke K, Thomas E, Blazeovich AJ, Afonso J, Behm DG, Marchetti PH, et al. Practical recommendations on stretching exercise: A Delphi consensus statement of international research experts. *Journal of Sport and Health Science*. 2025;14. <https://www.sciencedirect.com/science/article/pii/S2095254625000468>.
40. Wiguna, I Nyoman Agus Pradnya NMUKD. Hubungan Antara Indeks Masa Tubuh dan Tingkat Aktivitas Fisik Terhadap Fleksibilitas Otot Punggung Bawah dan Hamstring pada Siswa SMK Kesehatan Bali Kresna. *Jurnal Yoga dan Kesehatan*. 2023;6(2):189–200. <https://www.researchgate.net/publication/375528266>.
41. Bittencourt A dos S, Silva Vieira PA, Catarino Ferreira MC, Primo LL, Nara Deiro T, Roberto Avelino P, et al. The Impact of Overweight on Flexibility and Functional Capacity. *Journal of Novel Physiotherapies*. 2017;07(06). https://www.researchgate.net/publication/322596671_The_Impact_of_Overweight_on_Flexibility_and_Functional_Capacity
42. Živoder I, Hodić V, Zaplatić Degač N, Potočnjak J, Arapović M, Kuzmić A, et al. Motor Capabilities and Body Composition in Health vs. Non-Health University Students: A Pilot Study. *Life*. 2025;15(10):1–13. <https://www.mdpi.com/2075-1729/15/10/1504>.
43. Dong Y, Jiang P, Jin X, Jiang N, Huang W, Peng Y, et al. Association between long-term static postures exposure and musculoskeletal disorders among university employees: A viewpoint of inflammatory pathways. *Frontiers in Public Health*. 2022;10. <https://pubmed.ncbi.nlm.nih.gov/36530652/>.
44. Teixeira D, Cervaens M. Work-related postural risk and musculoskeletal symptoms in seamstresses: implications for ergonomic and movement-based interventions. *Journal of Bodywork and Movement Therapies*. 2026;48(July):554–61. https://www.researchgate.net/publication/408721423_Work-related_postural_risk_and_musculoskeletal_symptoms_in_seamstresses_implications_for_ergonomic_and_movement-based_interventions.
45. Hasna Nabilla Noor Salma. Analysis Of Work Posture On Musculoskeletal Disorders (Msd): Literature Review. *International Journal of Health Engineering and Technology*. 2026;4(6):2249–53. <https://afdifaljournal.com/journal/index.php/ijhet/article/view/642>.
46. Henriques JIR, Nugraha, Made Hendra Satria, Luh Made Indah Sri Handari Adiputra IVJ. Hubungan Fleksibilitas Otot Hamstring Dengan Kecepatan Berjalan Lanjut Usia Di Denpasar. *Majalah Ilmiah Fisioterapi Indonesia*. 2021;9(1). <https://garuda.kemdiktisaintek.go.id/documents/detail/1997634>.
47. Yudhaningrum HR, Pradita A, Endaryanto AH, Hargiani FX. Hubungan Fleksibilitas Otot Hamstring Dengan Nyeri Punggung Bawah Pada Pasien Poli Fisioterapi Di Rumah Sakt

Petrokimia Gresik. Jurnal Keperawatan Muhammadiyah. 2023;8(1). <https://journal.um-surabaya.ac.id/JKM/article/view/16116>