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Original Article

Physiotherapy Section

Influence of Core Strength on Hamstring Flexibility and Pelvic Tilt among Sedentary Individuals: A Cross-sectional Study

NAGAVENI HEGDE[1], SAUMYA SRIVASTAVA[2]

ABSTRACT

Introduction: The kinetic chain theory highlights the interconnectedness of the core and extremities in generating and transmitting motion and force. The core serves as the center of this chain, stabilising the body during dynamic movements. However, modern sedentary lifestyles, particularly among college students aged 18-25, often lead to hamstring stiffness, which is linked to poor core muscle coordination. Although hamstring tightness is believed to compensate for weak core muscles, little is known about the relationship between hamstring flexibility and core strength.

Aim: To ascertain whether there is a connection between core muscle strength and hamstring tightness in sedentary individuals.

Materials and Methods: A cross-sectional study was conducted at the Department of Physiotherapy, Justice KS Hegde Charitable Hospital, Mangalore, Karnataka, India, over one year (April 2021-April 2022). Ethical approval was obtained from the Institutional Ethics Committee. Seventy-eight sedentary individuals (aged 18-25 years) were recruited using purposive sampling methods. Core strength, hamstring flexibility, and pelvic tilt were assessed using a handheld dynamometer, the Active Knee Extension (AKE) test, and the Palpation Meter (PALM), respectively. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) software (version 20). Descriptive statistics were used for demographic and outcome data, while Pearson's or Spearman's correlation coefficients were employed to determine relationships between variables. Statistical significance was set at $p<0.05$.

Results: The mean age of the participants was 21.41±1.77 years, with a mean Body Mass Index (BMI) of 20.94±3.37 kg/m². Anterior pelvic tilt was observed in 91% of the participants, while posterior pelvic tilt was noted in 9%. The mean hamstring flexibility was 48.41°±9.14° (right) and 47.60°±8.67° (left), while core muscle strength ranged from 10.01±2.83 kg to 13.23±2.57 kg. Pearson's correlation analysis showed no significant relationships between core strength, hamstring flexibility, and pelvic tilt ($p>0.05$).

Conclusion: According to the present study findings, no correlation between core strength and hamstring flexibility in sedentary individuals.

Keywords: Biomechanical phenomena, Knee joint, Muscle strength, Pelvis, Postural balance, Sedentary behaviour

INTRODUCTION

Human populations are becoming increasingly sedentary due to modern lifestyles. Sedentarism is one of the main issues faced by contemporary society [1,2]. Any awake action, such as sitting or reclining, that consumes more energy than 1.5 Metabolic Equivalent Tasks (METs) is considered sedentary behavior [3]. Prolonged periods of sitting, which are common in sedentary lifestyles, have been linked to tightness of the hamstring muscles [4]. The core (lumbopelvic-hip complex) serves as the focal center of activity for the kinetic chain, facilitating load transfer to and from the limbs [5]. Core strength is vital for supporting the coordinated movement of the distal parts. To create, transfer, and regulate motion effectively within an integrated kinetic chain, core strength is the ability to control trunk alignment and movement over the pelvis and lower limbs [6]. A core stabilisation training program can enhance core muscle function and strength, addressing issues caused by sedentary lifestyles [7].

The ability of the muscles to generate force through intra-abdominal pressure and contractile force is referred to as core strength [8]. Core strength focuses on maintaining a neutral spinal posture, optimising trunk position, and transferring weight throughout the kinetic chain [9]. In addition to controlling motion in the pelvic sagittal plane, local muscles may be involved in anterior and posterior pelvic tilting [10]. Significant activation of global muscles, including the external oblique and rectus abdominis, is encouraged by pelvic tilting [11].

Core strength is related to body position, especially lumbopelvic mobility or positioning [12]. Hamstring tightness is relatively prevalent among undergraduates aged 18 to 25 [13]. Similar to Mhatre BS et al., and Tabary JC et al., also found that hamstring muscles can shorten due to hamstring tension. These musculotendinous units have a diminished capacity for elongation because of a decrease in sarcomere number or a loss of connective tissue length or elasticity [14,15]. This reduced ability to stretch the hamstring muscles is linked to the disorder. The pelvic tilt angle is also associated with hamstring tightness because the hamstring muscles originate from the pelvic sciatic tuberosity [16].

Neurological tension, lumbopelvic dysfunction, and musculoskeletal insufficiency or imbalances are all components of the complex symptoms known as hamstring tightness [17]. A weaker core is linked to increased strain on the hamstrings and other supportive muscles [18]. This hamstring shortening eventually weakens the core, raises the possibility of repeated injuries, and limits pelvic mobility, which alters the lumbar pelvic rhythm [19]. In patients with inadequate lumbopelvic/core control, hamstring activation may occur as a stabilising mechanism [20]. Since one of the roles of the hamstrings is to facilitate hip movement, the stability of the lumbopelvic region is achieved through the musculature. Increased hamstring stiffness may result in a potentially harmful process for core activation since the hamstring muscle attaches to the ischial tuberosity [21].

Hamstring stiffness could be a contributing factor to the lumbopelvic rhythm. Alterations in core strength suggest that deficiencies in core stabilisation and load transfer muscles are related to hamstring flexibility. It remains unclear how hamstring tightness and core strength are related [22]. Thus, the purpose of this study was to determine whether core strength among sedentary individuals influences hamstring flexibility.

The aim of the present study was to investigate the relationship between core strength, pelvic tilt, and hamstring flexibility in sedentary individuals. Core strength was assessed using a Hand-Held Dynamometer (HHD), hamstring flexibility was measured using the AKE test, and pelvic tilt was evaluated using a PALM.

MATERIALS AND METHODS

The present cross-sectional study was conducted at the Justice KS Hegde Charitable Hospital, Nitte Institute of Physiotherapy in Mangalore, India, over a specified study period from April 2021 to April 2022. Ethical clearance for the study was obtained from the Institutional Ethics Committee (IEC) (Ref: NIPT/IEC/Min/15/2020-2021, dated 07-04-2021). Written informed consent was obtained from all participants prior to enrollment.

Inclusion and Exclusion criteria: The inclusion criteria were individuals aged 18-25 years with a sedentary lifestyle, defined as sitting for ≥6 hours per day and having an energy expenditure of ≤1.5 METs [23]. Energy expenditure was assessed using the validated International Physical Activity Questionnaire (IPAQ), where sedentary behavior was characterised as activities performed in a sitting or reclining posture with an energy expenditure of ≤1.5 METs [24]. Both males and females were included in the study. Participants were also required to have hamstring tightness, defined as the inability to extend the knee beyond 160° with the hip in flexion or a loss of at least 15-30° of AKE when the hip was at 90° flexion [25]. Only those willing to participate voluntarily were considered eligible. The exclusion criteria included acute or chronic low back pain, hamstring injuries, soft tissue injuries around the knee joint, or a recent history of fractures involving the upper or lower limbs.

Sample size calculation: The sample size was estimated using nMaster software (version 2.0) based on a Standard Deviation (SD) of 3.63 for the primary outcome, a margin of error of 0.8, and a 95% confidence level, which yielded a required sample size of 78 [26]. A total of 98 subjects were screened, and 78 participants meeting the inclusion criteria were recruited and analysed. The sample size was calculated using the formula:

"Formula $n=(Z\times SD/E)^2$ with Z=1.96, SD=3.63, and margin of error E=0.8"

Study Procedure

Participants were screened and assessed at the Nitte Institute of Physiotherapy in Mangalore after obtaining written informed consent. Demographic details and relevant clinical history were recorded.

Hamstring flexibility was measured using the AKE test, with the hip at 90° flexion, and the angle of knee extension was measured using a goniometer. Core strength was evaluated using a plank endurance test, where the duration for which a correct plank position was maintained was recorded. Each measurement was performed three times, and the average was used for analysis to ensure reliability.

Initially, 98 participants underwent screening to determine their eligibility based on inclusion and exclusion criteria, of which 20 were excluded. These 20 did not meet the inclusion criteria because their energy expenditure was >1.5 MET and they also failed the AKE test. Using a purposive sampling technique, 78 participants who satisfied all inclusion requirements were chosen for the study. Throughout the trial, no dropouts were noted. Data collection sheets and informed consent forms were utilised to gather information from the subjects. The tools and instruments required to conduct the study included an examination table, horizontal bar, strips, handheld dynamometer, universal goniometer, and a PALM.

Subjects were screened based on inclusion criteria, given a consent form, and recruited for the study. The therapist assessed the participants' core strength and hamstring flexibility. Core strength was measured using a Hand-Held Dynamometer (HHD), and a test involving AKE was used to measure hamstring flexibility. After three iterations of the process, the average was taken for analysis. A PALM was used to quantify pelvic tilt, and the correlation between the hamstring flexibility and core strength of sedentary individuals was evaluated.

Measurement of core muscle strength using Hand-Held Dynamometer (HHD):

a. Measurement of trunk flexors strength

- Subject position: Subjects were instructed to lie supine with their knees slightly bent, arms at their sides, and head in the midline.
- Dynamometer position: The base of the dynamometer was placed in the middle of the sternum.
- Procedure: The scapula was lifted off the plinth in order to apply isometric force [Table/Fig-1] [27].

[Table/Fig-1]: Trunk flexors strength using hand held dynamometer.

b. Measurement of trunk rotators strength

- Subject position: The subjects were placed in a supine position with their heads centered, arms at their sides, and knees slightly bent.
- Dynamometer position: The dynamometer was positioned at the myotendinous region of the pectoralis muscle.
- Procedure: The participants were instructed to raise the ipsilateral side of their scapula off the plinth [Table/Fig-2] [27].

[Table/Fig-2]: Trunk rotators strength using hand held dynamometer (right and left).

c. Measurement of trunk extensors

- Subject position:* The individual was positioned prone.
- Dynamometer position: The base of the dynamometer was placed at the T4 spine.

- Procedure: The participant was directed to produce an isometric force by raising the plinth [Table/Fig-3] [27].

[Table/Fig-3]: Trunk extensors strength using hand held dynamometer.

d. Measurement of trunk lateral flexors

- Subject position: The subjects were instructed to lie with their feet off the ground on a pedestal.
- Dynamometer position: The dynamometer was positioned against the upper thoracic wall and laterally to it.
- Procedure: Participants were encouraged to side-bend the upper trunk against the dynamometer's base, bringing their elbows towards the plinth. This process was conducted three times, and the average was used for analysis [Table/Fig-4] [27].

[Table/Fig-4]: Trunk lateral flexors using hand held dynamometer (right and left).

Measurement of hamstring flexibility using the AKE test: Two therapists were involved: one held the limb while the primary investigator performed the measurement bilaterally.

- Subject position: Subjects were instructed to lie supine on a couch. The hip and knee flexion of the leg to be evaluated was set at 90 degrees, while a second therapist kept the hips flexed.
- Universal goniometer position: The moving arm was parallel to the lateral malleoli of the ankle, the fulcrum was above the lateral condyle of the femur, and the fixed arm was aligned with the femoral shaft.
- Procedure: Participants were asked to extend the knee as much as possible until a mild stretch was felt over the posterior knee. This procedure was repeated three times, and the average was obtained for analysis [Table/Fig-5] [28].

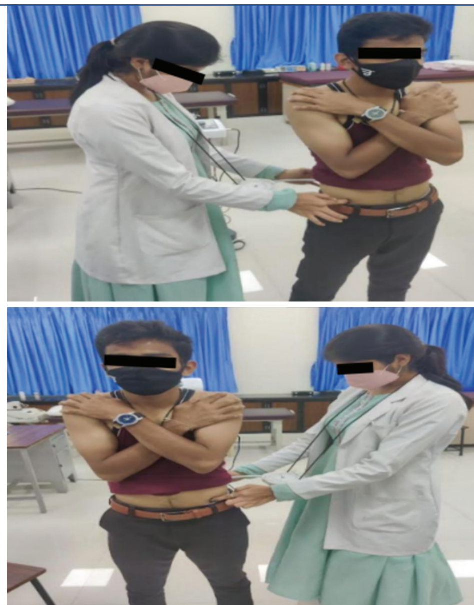
[Table/Fig-5]: Active Knee Extension (AKE) test (right and left).

Measurement of pelvic tilt using PALM: The PALM consists of an inclinometer and two caliper arms. To minimise postural sway, participants were instructed to stand on a platform that was 30 cm wide and to focus on a fixed point ahead.

As the examiner palpated the Anterior Superior Iliac Spine (ASIS) and the Posterior Superior Iliac Spine (PSIS), participants were instructed to remain erect, keep their arms folded across their chests, and maintain even weight distribution.

Using a felt-tip pen to mark the most prominent protrusion, the ASIS was located by palpating from superior to inferior. The PSIS was identified by following the iliac crest posteriorly and then moving laterally and superiorly from the sacral border to the most prominent point. The tips of the calipers were then positioned according to the designated landmarks.

The examiner read and recorded the angle of inclination directly from the inclinometer. Standing pelvic tilt was defined as the angle between a horizontal line and the line connecting the ASIS and PSIS. Anterior innominate tilts were denoted by positive degrees, while posterior tilts were represented by negative degrees. To ensure accuracy, three measurements were taken on each side, and the average value was calculated [Table/Fig-6] [29].



[Table/Fig-6]: Active Knee Extension (AKE) test (right and left).

STATISTICAL ANALYSIS

Data analysis was performed using SPSS software (Version 20.0 for Windows). The collected data were analysed using both descriptive statistics and correlation analysis. Demographic variables, including age, gender, BMI, and energy expenditure, were assessed using descriptive statistics, which included minimum, maximum, mean, and standard deviation. Correlation analysis was conducted using Pearson's correlation coefficient, with p-values less than 0.05 considered statistically significant.

RESULTS

The study comprised 78 sedentary individuals between the ages of 18 and 25. Their mean BMI was 20.94±3.37 kg/m², and their mean age was 21.41±1.77 years [Table/Fig-7]. Anterior pelvic tilt was present in 91% of subjects, while posterior tilt was present in 9%. The core muscle groups with the highest mean value were the trunk extensors (13.23±2.57 kg) and the hamstrings (48.41°±9.14° on the right and 47.60°±8.67° on the left). [Table/Fig-8] shows that the mean and standard deviation values for BMI were 20.94±3.37. The right and left hamstring flexibility were 48.41±9.14 and 47.60±8.67, respectively, and their pelvic tilt angles were 10.54°±3.03° and 10.56°±3.03°, respectively. The Pearson correlation between core strength, hamstring flexibility, and pelvic tilt angle is presented in [Table/Fig-9]. Pelvic tilt, hamstring flexibility, and core strength were negatively correlated. However, the p-value was higher than 0.05, indicating that the relationship was not statistically significant.

Age (years)	Frequency	Percentage	Mean	Standard Deviation
<20	12	15.4	21.41	1.769
20 and above	66	84.6		

[Table/Fig-7]: Represents the age distribution in all the subjects.
N: Total number of subject; N=78; Minimum age 18; Maximum age 25

Variables	N	Min.	Max.	Mean	Standard Deviation
BMI (kg/m²)	78	14.5	28.7	20.940	3.3735
Pelvic tilt (in degrees)					
Right	78	5	18	10.54	3.031
Left	78	5	17	10.56	3.031
Hamstring flexibility (in degrees)					
Right	78	26	63	48.41	9.140
Left	78	29	61	47.60	8.674
Trunk strength (kg)					
Trunk flexors	78	8	23	11.82	2.836
Trunk extensors	78	8	22	13.23	2.573
Trunk rotators-right	78	8	19	11.90	2.626
Trunk rotators-left	78	8	18	11.94	2.478
Trunk lateral flexors-right	78	6	18	10.19	2.692
Trunk lateral flexors-left	78	6	19	10.01	2.831

[Table/Fig-8]: Represents the min., max., mean and standard deviation values of BMI, pelvic tilt, hamstring flexibility and trunk strength.
N: total number of subjects Min: minimum Max: maximum

who reported no significant association between standing pelvic tilt and core strength, suggesting that while core strength contributes to trunk stability, it may not be the principal determinant of pelvic alignment in sedentary individuals [30,31].

Research indicates that core strength (in contrast to hip flexors) results in a less inclined sacrum or a more erect lumbosacral spine region. Although core muscles aid in stability, other important variables affecting pelvic tilt and general biomechanics include hip mobility, leg alignment, and muscular stiffness. The lumbar lordosis angle may also affect core strength. The body functions as a connected kinetic chain; incorrect movements at a different location either up or down the chain can have repercussions [32].

Furthermore, while core strength positively affects sacral inclination and the erectness of the lumbosacral spine, it does not solely determine pelvic tilt. Factors such as hip mobility, leg alignment, lumbar lordosis angle, and muscular stiffness contribute biomechanically within the connected kinetic chain, where dysfunction in one part can influence pelvic positioning [33].

Regarding hamstring flexibility, the present study revealed no significant effect of pelvic tilt on hamstring flexibility among sedentary individuals (p>0.05). This finding is consistent with Melya Rossa M et al., who also found no significant correlation between hamstring length and pelvic tilt [34]. Despite the hamstrings' attachment to the ischial tuberosity potentially influencing pelvic position, other muscles likely contribute to the posterior pelvic tilting forces, reducing the exclusive role of hamstring length. Similar conclusions were drawn in previous studies that showed no clear relationship between hamstring flexibility and pelvic tilt [35-38]. Additionally, hamstring flexibility is influenced by sensory feedback and hamstring-quadriceps coactivation, beyond just the effects of core strength [39].

Lower extremity biomechanics may be affected by changes in spinal alignment and deficiencies in core muscle function [40]. In the current study, core strength and hamstring flexibility among sedentary individuals did not significantly correlate (all p-values were greater than 0.05). Energy expenditure of ≤1.5 MET accounted for 100% of the total energy expenditure. The calculated average age was 21.41±1.77 years, and the BMI calculation resulted in a mean and standard deviation of 20.94±3.37 kg/m².

Previous research has revealed contradictory results, suggesting that core strength and hamstring flexibility may differ significantly. Baxi HD and Sheth MS reported that participants who were inactive, had low back pain, and presented with a high BMI (ages 18-65) demonstrated significant differences in core strength and flexibility. This may explain the contradictory findings of previous studies; in such cases, a core strength evaluation becomes essential [41]. The contrasting findings of Baxi HD and Sheth MS, which showed significant differences in core strength and

Correlations	Hamstring flexibility (in degrees)-right	Hamstring flexibility (in degrees)-left	Pelvic tilt (in degrees) - right	Pelvic tilt (in degrees) - left
Trunk flexors (in kg)	r=-0.140, p=0.220	r=-0.065, p=0.574	r=-0.221, p=0.052	r=-0.183, p=0.109
Trunk extensors (in kg)	r=-0.090, p=0.435	r=-0.093, p=0.418	r=-0.174, p=0.127	r=-0.182, p=0.111
Trunk rotators (in kg)-right	r=-0.137, p=0.233	r=-0.075, p=0.512	r=-0.022, p=0.846	r=0.004, p=0.972
Trunk rotators (in kg)-left	r=-0.011, p=0.921	r=0.043, p=0.709	r=-0.101, p=0.380	r=-0.073, p=0.526
Trunk Lateral Flexors (in kg)-right	r=-0.020, p=0.865	r=0.040, p=0.728	r=-0.042, p=0.718	r=-0.020, p=0.863
Trunk lateral flexors (in kg)-left	r=-0.011, p=0.926	r=0.021, p=0.853	r=-0.055, p=0.631	r=-0.046, p=0.687

[Table/Fig-9]: Represents the correlation between core strength with hamstring flexibility and pelvic tilt angle.
p: p-value, r: Pearson correlation coefficient

DISCUSSION

The current investigation found that core strength did not significantly affect pelvic tilt in this population. Among the 78 sedentary participants, 71 exhibited anterior pelvic tilt, while seven showed posterior pelvic tilt. These findings align with those of Levine D et al.,

flexibility among inactive individuals with low back pain and higher BMI, underscore the importance of participant characteristics in studying these variables [42].

The study's participants were aged between 18 and 25, sedentary, pain-free, and had a normal BMI. The lack of association here may be explained by musculoskeletal adaptations related to prolonged inactivity typical of sedentary individuals, resulting in deconditioned core and hamstring muscles. Flexibility is multifactorial, influenced by muscle stiffness, neural control, and joint mobility, which may not correlate directly with core strength, especially in sedentary populations. Core muscles primarily function to stabilise the trunk, while hamstring flexibility depends on muscle length and neural factors. Furthermore, hydration status and electrolyte imbalances during activity can contribute to muscle tightness, adding complexity to their interaction [43,44].

Limitation(s)

Limitations of this study include potential measurement inaccuracies due to participant discomfort with the handheld dynamometer. Future research should include more diverse cohorts with varied BMI, exercise levels, and clinical symptomatology such as back pain. Detailed investigations into muscle conditioning, neural control processes, and hydration effects are also needed to better understand the interplay between core strength, flexibility, and pelvic tilt.

CONCLUSION(S)

This research finds that core strength does not notably affect pelvic tilt or hamstring flexibility in inactive young adults. The majority of participants exhibited anterior pelvic tilt, which is influenced more by muscle tightness and inadequate posture than by core stability. Improving hamstring flexibility and pelvic alignment necessitates a comprehensive approach that incorporates posture adjustment, mobility improvement, and lifestyle changes, rather than relying solely on core strength.

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PARTICULARS OF CONTRIBUTORS:

1. Postgraduate Student, Nitte (Deemed to be University), Nitte Institute of Physiotherapy (NIPT), Mangalore, Karnataka, India.
2. Associate Professor, Nitte (Deemed to be University), Nitte Institute of Physiotherapy (NIPT), Mangalore, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Saumya Srivastava,
Nitte (Deemed to be University), Nitte Institute of Physiotherapy (NIPT),
Mangalore, Karnataka, India.
E-mail: saumyasri2000@nitte.edu.in

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