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Correlation between lumbopelvic stability and hamstring strain recurrence in sprinters

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Abstract

Introduction. To examine the correlation between lumbopelvic stability and hamstring strain recurrence and determine how various lumbopelvic stability-related factors are associated with recurrent hamstring strain in sprinters.
Methods. A retrospective case-control study in which a sample of nineteen participants, including seven healthy sprinters and twelve sprinters with strained hamstring (mean age: 19.42 ± 2.29 and 18.58 ± 1.62 years, respectively), were examined to assess the effect of altered lumbopelvic stability using factors such as hip flexor length, sacral mobility, internal rotation range, hamstring length and neuromuscular control of the spine.
Results. Results revealed no significant correlation of neuromuscular control of the spine with the recurrence of right ($r = 0.28$, $p = 0.35$) or left ($r = 0.09$, $p = 0.71$) hamstring strain. A significant positive correlation was observed between: right hamstring length and right-side internal rotation range ($r = 0.65$, $p = 0.001$), right hamstring length and left-side internal rotation range ($r = 0.81$, p = 0.001), left hamstring length and right-side internal rotation range ($r = 0.67$, $p = 0.001$), and left hamstring length and left-side internal rotation range ($r = 0.82$, $p = 0.001$). The neuromuscular control of the spine was not significantly correlated with lumbopelvic stability-related factors. Also, no significant difference in sacral mobility was found between the groups.
Conclusions. The hip flexor length, internal rotation range and hamstring length can be considered as useful factors in assessing the risk of hamstring muscle injury in sprinters.
Key words: hamstring muscles, spine, running, athletic performance, recurrence.

Introduction

Muscular injury within the hamstring has been commonly reported in various sports, such as sprinting [1–2] at a recurrence rate of 12% to 41% [3–5]. The relationship between hamstring injuries and high-speed running seems intuitive, because the hamstring lengthening (from 50% to 90%) during the terminal swing phase due to the inertia of the swing phase and shortening during the subsequent phase makes the hamstring more susceptible to injury [6]. Hamstring strain injury (HSI) in an athlete can produce acute pain in the posterior thigh during movement due to rapid recruitment of the hamstring muscles. Other than acute pain, HSI also shows clinical signs, such as tenderness about the posterior thigh, swelling, and a potential defect within the muscle belly immediately after injury [7].

Exasperation after hamstring strains is mainly due to the prolonged duration of symptoms, poor healing responses and the high risk of re-injury rate of 12–31% [8]. A number of suggested post-HSI maladaptations are thought to contribute to the increased risk of reinjuries due to the formation of non-functional scar tissue, which is associated with an alteration in the muscle tissue lengthening mechanics, reduced flexibility, persistent reductions in eccentric strength, long-term atrophy of the injured muscle, alterations in the angle of peak knee flexor torque and alterations in lower limb biomechanics [8]. There are various reasons behind the high injury rate but the literature shows it to be caused by unchanged training for seven consecutive seasons in 23 professional European football clubs. Until now, the traditional hamstring prevention and rehabilitation programs have had an important role in the literature, but they have not been satisfactorily effective [9].

Although the relationship between strain and fatigue seems intuitive, the biological relationship that correlates the two entities is extremely useful for the development of rehabilitation and training programs. Along with the strain and fatigue, reciprocal innervation could also be an important biological principle behind hamstring injuries due to muscular imbalance. Matthew Mills et al. in 2015 compared hip extensor muscle activation, which is theorised to reciprocally inhibit (irrespective of the restricted hip flexor muscle length) the gluteus maximus (GM) and has been associated with lower extremity injuries [10]. It was also found that those with hip flexor tightness exhibited 60% less gluteus GM activation in the double squat, along with 15% increased biceps femoris activation (BF). The GM-to-BF ratio was found to be 0.88 as compared to 2.30 in the control group. Hence, there was greater activation of synergistic hip extensor muscles (BF) and reduced activation of prime mover (GM), thus indicating that net hip extension moments are not directly altered.

Therefore, the tightness of the hip flexor muscle may be a contributing factor in easing the reciprocal inhibition and an abnormal resting length of the GM, leading to greater reliance on hamstring muscles and early fatigue [10]. Also, muscle fatigue predisposes an athlete to hamstring strain injuries [4]. An earlier and higher activation of the BF during walking in patients with pelvic or low back pain has also been reported [11]. In the existing literature, hamstring strain recurrence presents a significant association in neuromuscu-

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lar (NM) control within and beyond the hamstring muscle unit, which needs to be strengthened by more research. Thus, there is a need to find the association of HSI with NM control of the spine, hip flexor length, and other spinal alignment parameters.

Neuromuscular control of the spine and pelvis with the associated muscle activation pattern also have an important role in hamstring injury risks [12]. Chumanov et al. [6] reported that the hamstring length was greatly influenced by the contralateral psoas length in comparison with the hamstring's length itself. Additionally, during sprinting, synchronisation within the peak of psoas lengthening and peak of hamstring lengthening have been seen in the stance leg and swing leg, respectively [6, 13]. Pinniger et al. [14] reported earlier activation of the BF and semitendinosus (ST) muscles during sprinting in footballers after fatigue. Low back pain and muscle fatigue during sprinting lead to similar changes in NM patterns. However, it has been seen that the stable foundation created for movement under the supervision of the central nervous system through the activation of core, lower extremity, and trunk muscles in an appropriate manner in the temporal sequence of many athletic tasks, e.g. Hodges and Richardson [15], demonstrated that core (co-contraction of the transversus abdominis and multifidus) and trunk muscles were activated before the activity of the lower extremity musculature. Panayi [16] emphasised the importance of the pelvic stabiliser muscles in the treatment of hamstring strain by utilising techniques such as lengthening the myofascial components which increase lumbar lordosis, pelvic obliquity, anterior pelvic tilt and sacroiliac mobility.

The purpose of this study was to examine the correlation of lumbopelvic stability with hamstring strain recurrence and to determine how various lumbopelvic stability-related factors (such as reduced hip flexor length, internal rotation range and hamstring length) are associated with recurrent hamstring strain in sprinters.

Subjects and methods

Participants

Invitation and written informed consent (as per the Declaration of Helsinki) forms were distributed to the sprinters to participate and a sample of seven healthy male sprinters (mean age: 19.42 ± 2.29) were recruited for the control group and twelve male sprinters (mean age: 18.58 ± 1.62) were recruited for the hamstring injury group from Jawaharlal Nehru Stadium, New Delhi, India through convenience sampling. Exclusion criteria included any spinal or hip surgery, prolapsed intervertebral disc, severe neurological compression, acute low back pain, arthritis in lower extremities, any severe tear of a muscle other than hamstrings in the past, and any acute lower extremity injuries inhibiting sports activity. Inclusion criterion for the hamstring injury group was male national level sprinters of age between 17–26 years with a history of HSI in the past 2 years. Inclusion criterion for the control group was male sprinters with at least one year of training and age between 17–26 years without any history of HSI in the past 2 years. All the research procedures were explained to the participants before proceeding towards participation. The study had ethical clearance from the Institutional Ethics Committee (proposal No.: 16/9/127/JMI/IEC/2017).

Study protocol

The study was a single blinded experiment as the participants did not know if they were part of the hamstring injury or the control group. Measurements for hamstring length, hip flexor length, internal rotation range, NM control of the spine and sacral mobility were collected by a single examiner for both the groups without disclosing to the participants the group to which they belonged. Participants were familiarised with the test prior to collection of the readings.

Hamstring length

The hamstring length was measured through a passive knee extension test. The participant laid in supine position with the contralateral lower extremity extended and the side which was to be tested in a 90° flexed hip position. The extremity to be tested was stabilised with a stool under the posterior aspect of the thigh of that extremity, which was held with the help of the participant's hands. The goniometer was then positioned perpendicular to the ground with its axis at the knee joint, the immovable arm aligned with the femur and the movable arm with the tibia. The average of three trials was used for analysis. The test has been described as a reliable clinical tool (ICC = 0.93) [17].

Neuromuscular control of the spine

NM control of the spine was measured through a leg lowering test to quantify the extent of Lower Back (LB) movement in a supine position with a pressure biofeedback unit (PBU). For this test, the BPU was placed under the LB. The PBU (Stabilizer Pressure Biofeedback-Chattanooga Group, Australia) measures pressure changes (40 mm Hg) that are exerted on the lumbar spine via a sphygmomanometer [18, 19]. The LB should be neutral (i.e., midway between the posterior and anterior tilt, and the anterior superior iliac spine (ASIS) was at a horizontal level). The participants positioned themselves in a supine position with 90° flexed hips, flexed bilaterally knee joint and relaxed upper body [19], then they were asked to actively push the LB downwards, increasing the BPU pressure to 45 mm Hg, then they were instructed to lower the feet to just above the surface of the couch. Initially, the participants were familiarised with the procedure through visual feedback from the BPU. The average of three trials without visual feedback was used for the analysis. The PBU is a reliable tool (intra-rater reliability ICC = 0.60–0.95, inter-rater reliability ICC = 0.40–0.86) [18, 19].

Hip flexor length

Hip flexor length was measured by active lumbopelvic stabilisation using the Modified Thomas Test (ALSMTT). The participant was positioned in a supine position and the researcher's hand was placed under the lumbar spine to check the lordosis (i.e., posterior rotation of the pelvis in the sagittal plane). Then, after removal of the researcher's hand, a blood pressure cuff was placed under the LB and inflated to 60 mm Hg. One of the participant's legs was lowered passively by the researcher to a position of maximum hip extension without associated changes in pelvic position-pressure [20] and during this movement, the other leg was positioned in hip-knee flexion (which was passively positioned by the researcher). The test-retest reliability of ALSMTT is higher than the Modified Thomas Test (ICC = 0.99) with good validity (r = 0.98) [20].

Internal rotation range

The participants were lying in a prone position with the goniometer's axis at tibial tuberosity, the immovable arm placed perpendicular to the ground and the movable arm parallel to the tibia. The inter-observer reproducibility of measuring hip internal rotation in a prone position was satisfactory (CCC = 0.7) [21].

Sacral mobility

This was assessed through the Gillet test. For the Gillet test, one of the examiner's thumbs was placed on the posterior superior iliac spine (PSIS) and the other thumb medial to the PSIS on the sacral base. The participant was instructed to elevate one knee towards the ceiling, to position the hip and knee in 90° flexion. Posterior rotation of the innominate on the side of the lifted knee was assessed. The participant was instructed to elevate the other knee towards the ceiling while assessing the anterior rotation of the innominate bone on the single leg support side. The direction of posterior rotation of the innominate on the contralateral side was also palpated to assess the sacral mobility [22]. Based on the assessment, the sacral mobility was categorised into mobile and non-mobile.

Statistical analysis

Data analysis was performed using Statistical Package for Social Sciences (version 25, IBM, Armonk, US). The Shapiro–Wilk test was used to assess the normality of the distribution scores, finding that the data were normally distributed. The demographic characteristics and criterion measures were compared between the healthy and hamstring injury athletes by an independent *t*-test for parametric data and the chi-squared test was used for non-parametric data. The Pearson correlation coefficient was calculated for parametric data correlation analysis.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Institutional Ethical Committee (approval No.: 16/9/127/JMI/IEC/2017).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

A comparison of general characteristics between the two groups (control and hamstring injury group) is shown in Table 1.

Correlation between NM control of the spine and hamstring strain recurrence

The results revealed that there was no significant correlation between NM control of the spine on right hamstring strain recurrence with *p* (0.35) and *r* (0.28) or on the left side with *p* (0.71) and *r* (0.09), as shown in Table 2.

Table 1. Comparison of general characteristics between the two groups using independent *t*-test

Variables	Control group (*n* = 7)		Hamstring injury group (*n* = 12)	
	Mean	*SD*	Mean	*SD*
Age (years)	19.42	2.29	18.58	1.62
Height (cm)	1.72	0.09	1.72	0.095
Weight (kg)	64.14	10.54	62.83	9.57
BMI (kg/m^2)	21.40	0.63	21.01	1.71
Years of training	3.35	1.37	3.75	1.96
Hamstring tear frequency	–	–	1.26	1.37

BMI – body mass index

Table 2. Correlation between NM control of the spine and hamstring strain recurrence

Variable		Hamstring strain recurrence
NM Control (R)	Pearson correlation	0.227
	Sig. (2-tailed)	0.349**
	N	19
NM Control (L)	Pearson correlation	0.091
	Sig. (2-tailed)	0.710*
	N	19

NM – neuromuscular control of the spine in mm Hg
L – left side, R – right side
** *p* is significant at 0.01, * *p* is significant at 0.05

Comparison of NM control of the spine, hip flexor length, hamstring length, sacral mobility and internal rotation range between participants with hamstring strain recurrence and healthy controls

Independent *t*-test showed significant differences between hip flexor length bilaterally [right side ($p = 0.002$), left side ($p = 0.001$)], hamstring length bilaterally [right side ($p = 0.009$), left side ($p = 0.048$)], and internal rotation on the left side ($p = 0.025$). There was no significant difference between the mean of the hamstring injury and control groups in NM control of the spine bilaterally [right side ($p = 0.38$), left side ($p = 0.52$)] or internal rotation range on right side ($p = 0.33$), as shown in Table 3.

Table 3. Summary of independent *t*-tests

Variable	Hamstring injury group (mean ± *SD*)	Control group (mean ± *SD*)	*p*-value
NM Control (R)	4.94 ± 5.93	2.76 ± 3.09	0.38
NM Control (L)	4.16 ± 5.14	2.85 ± 1.26	0.52
ALSMTT (R)	–5.92 ± 10.85	10.47 ± 6.78	0.002**
ALSMTT (L)	–6.86 ± 8.84	8.66 ± 5.61	0.001**
HAMS (R)	140.53 ± 4.41	146.48 ± 3.90	0.009**
HAMS (L)	142.89 ± 3.95	147.38 ± 5.19	0.048*
IR (R)	33.44 ± 8.50	36.81 ± 3.26	0.33
IR (L)	31.08 ± 4.41	36.09 ± 4.01	0.025*

NM – neuromuscular control of the spine (mm Hg), ALSMTT – Active Lumbopelvic Stabilisation Modified Thomas Test, HAMS – hamstring length in cm, IR – Internal rotation range [°],
L – left side, R – right side
** *p* is significant at 0.01, * *p* is significant at 0.05

Table 4. Chi square test comparing the sacrum mobility between the two groups

Group		Standing forward flexion test		Total	Gilet/stork test		Total
		Sacral mobility			Sacral mobility		
		Right side	Left side		Right side	Left side	
Hamstring injury group	count	4	8	12	5	7	12
	within-group (%)	33.3	66.7		41.7	58.3	
Control group	count	5	2	7	6	1	7
	within-group (%)	71.4	28.6		85.7	14.3	
Total	count	9	10	19	11	8	19
	within-group (%)	47.4	52.6		57.9	42.1	

No significant difference in sacral mobility between the hamstring injury and control groups was found. The Chi square test was calculated comparing the sacrum mobility (standing forward flexion test and Stork test), as shown in Table 4. No significant interaction was found in the standing forward flexion test ($p = 0.10$), but in the stork test, the p-value was close to significant ($p = 0.06$).

Correlation of altered NM control of the spine with reduced hip flexor length, sacral mobility, internal rotation range and hamstring length

Pearson correlation coefficient revealed no significant correlation between altered NM control of the spine with reduced hip flexor length, sacral mobility, internal rotation range or hamstring length, however, there was a significant positive correlation between: right hamstring length and right-side internal rotation range ($r = 0.65$, $p = 0.001$), right hamstring length and left-side internal rotation range ($r = 0.81$, $p = 0.001$), left hamstring length and right-side internal rotation range ($r = 0.67$, $p = 0.001$), and left hamstring length and left-side internal rotation range ($r = 0.82$, $p = 0.001$).

Discussion

The study investigated the correlation between altered NM control and hamstring strain recurrence in male sprinters. Our study revealed that of all the variables taken into consideration, hip flexor length, hamstring length, and internal rotation range were the most significant factors for assessing the risk of HSI. The results showed that there is no correlation of altered NM control of the spine (using leg lowering test) with hamstring strain recurrence. Also, the comparison of the leg lowering test was not found to be significantly associated between the group differences. Schuermans et al. [23] expressed that the intermuscular properties (e.g., interplay between the posterior sling muscles) are also used as crucial factors, as it is believed to produce hamstring injuries by altering the coordination. Some authors have anecdotally and non-anecdotally suggested that the interdependency that correlates the systems (i.e., muscular and skeletal system) are extremely useful for safe force transmission, therefore the sufficient pelvic stability and sacroiliac force closure are necessary for optimal GM activation. It seems that the interplay of the intermuscular properties is not enough for safe hamstring functioning, quality of muscle recruitment is also required. Basically, the muscular activity of the ST and BF depends on the biomechanical/biological demands and coordination of the ST and BF with their proximal synergists in the posterior chain is also needed to attain the particular temporal demands [23, 24].

Although a few recent studies show altered NM control in football players, there was no research found on sprinters using PBU to assess NM control of the spine. Respective studies revealed that altered activation of the core muscles is another integrant and it is also responsible for the excessive pelvic and thoracic movements throughout the respective open kinetic chain phase during sprinting. Therefore, the alerted activation of the core muscles is associated with both factors (i.e., hamstring injury occurrence and altered NM coordination) because it can be expected that the altered muscular activation influences both NM coordination as well as hamstring functioning by altering the running kinematics [24]. Taken together, the results of various studies provide a scientific basis for concluding that all determinants, such as NM control, intermuscular properties and quality of muscular activation, are important in the predisposition to hamstring injuries, however, there still remains a dearth of information in the literature regarding influential factors for hamstring injury. Apart from all the other determinants, timing differences between the GM and BF play a crucial role in hamstring injury [25].

Contradictory results were seen in a study by Daly et al. [26], who compared muscle activation ratios of the BF, bilateral GM, rectus femoris, lumbar erector spinae and external oblique along with lower limb kinematics in nine elite male Gaelic games athletes. The findings of the electromyography explained that the BF is an important muscle, but the ipsilateral erector spinae and external oblique with the contralateral rectus femoris are more activated than the BF [26]. This may be due to various reasons, such as coupling of the hip extensor and knee flexor moments decelerating the limb prior to foot contact during the late swing phase of sprinting [27]; altered NM control associated with stride-to-stride variability in hamstring stretch at high speed, which causes microdamage, resulting in hamstring injury [6, 28]; strained BF influenced from lumbopelvic musculature due to relative increased muscular activity of the ipsilateral GM, ipsilateral External Oblique, contralateral Rectus Femoris, and ipsilateral Erector Spinae. These muscular alterations may represent an adaptive process, which is known as specific dysfunction or persistent post-injury neuro-inhibition within the BF [29].

In our study, there was a significant difference in the hip flexor length between the groups, which strengthens our belief that a restricted hip flexor length leads to increased anterior pelvic tilt. The findings of this study are strengthened by previous research, which has shown that increased anterior tilt may be associated with increased risk of injury [30] because a relationship exists between reduced hip flexor length and restricted hip extension, which leads to compensatory incremented movement at the lumbar spine (i.e., lumbar hyper lordosis) to gain sufficient hip extension. The compensatory

increased movement at the lumbar spine along with the anterior pelvic tilt contributes to hamstring tissue pathology by increasing the tension of the origin of the hamstrings at ischial tuberosity [31]. Freckleton et al. [32] postulated that Afro-Caribbean and Australian Aboriginal athletes tend to adapt to an anterior tilted pelvis, explaining their increased rate of hamstring injuries.

The sacrotuberous ligament is an anatomical link between the hamstrings and the sacroiliac joint (SIJ) [33, 34] and also a passageway through which the biomechanical and neuromotor alterations of lumbopelvic function take place to influence the hamstring function [35]. As the sacral position is altered, it leads to changes in the internal rotation range through its attachment to the piriformis muscle [35] which is supported by our results showing a positive correlation of hamstring length with internal rotation range. The Stork test showed a close to significant *p* value (0.06) for sacral mobility, probably because the sample size was small for the non-parametric data. Supporting our hypothesis, Cibulka et al. [31] revealed that the SIJ mobilisation plays a pivotal role in increasing the hamstring strength within a short time duration, decreases the innominate tilts and relieves the tensity of the BF muscle. Hence, SIJ dysfunction should be considered as a contributing factor for hamstring strain. Hoskins and Pollard [36] treated two Australian footballers and found that the SIJ mobilisation, psoas release and various other treatments focusing on the spinal and pelvic region played a role in the prevention and treatment of injured hamstrings. Also, Kozina et al. [37] emphasised the effectiveness of applying an individualised training program based on the features of neurodynamic functions and biomechanical characteristics of running in order to achieve strong athletic performance in sprinters, which they observed by taking into account the neurodynamic features in the training of elite athletes with impaired vision.

Limitations

Limitations associated with this study should be addressed. The current study included only male subjects, so gender differences could not be compared. Further research can be done to determine the role of running kinematics and to assess the muscles or muscle groups recruitment during running for both genders. Secondly, there are two possible causal interpretations of the study's findings: either the decremented activation of the BF muscle increases the hip flexion and anterior pelvic tilt, or vice versa, which needs to be further investigated. Also, since the study was a retrospective study, it is difficult to conclude whether the tear may have led to the loss of neuromuscular control or vice versa, hence, future consideration regarding the same might help in providing the appropriate answer. The study did not take the side of the involved limb into consideration, which can be taken into account in future research. Lastly, the Gillet test used has a low sensitivity when applied alone, which introduced a limitation while considering it as a component of sacroiliac assessment associated with neuromuscular control. Also, the same might have incorporated the measurement bias, as it is a clinical test.

Conclusion

The results of our study indicated that a correlation exists between the risk of hamstring injury and variables such as hip flexor length, hamstring length, and internal rotation range among sprinters. These factors seem to be significant and thus should be taken into consideration when assessing the risk of injury to the hamstring muscle in runners. However, other factors, such as neuromuscular control of the spine and sacral mobility, were not found to be correlated with the risk of hamstring injury in this population. These factors need to be explored further to check for their association in a larger population group. It can be concluded that multiple modifiable factors could increase the risk of injury to the hamstring muscle in sprinters, therefore, the risk of injury should not be assessed or treated locally.

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Disclosure statement

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Conflicts of interest

The authors state no conflict of interest.

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