

Clinical Commentary/Current Concept Review

# Hamstring Injury Rehabilitation and Prevention in the Female Athlete

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Hamstring injuries (HSIs) are common in female athletes and are associated with a lengthy recovery period and a high rate of reinjury. Currently, the majority of existing literature investigating HSI rehabilitation has been conducted using male participants. However, female athletes display intrinsic anatomical and biomechanical differences compared to males that influences the way this population experiences HSIs and HSI rehabilitation. HSI rehabilitation and injury prevention guidelines for female athletes must take these differences into account. Female athletes display anatomical differences such as increased anterior pelvic tilting, gluteus maximus weakness, an increased pelvic width-to-femoral length ratio, and an increased degree of femoral anteversion, all of which can predispose females to HSIs. Maneuvers designed to strengthen the gluteal musculature and transverse abdominis can overcome these risk factors. Females show increased joint laxity and a greater range of motion of hip flexion and internal rotation compared to males. Females have lower passive hamstring stiffness than males, therefore hamstring flexibility exercises may not be as necessary during rehabilitation for females as in the male athlete population. Female athletes may instead benefit from trunk stabilization exercises and agility training due to neuromuscular control deficits that arise from the maturation and growth of the female pelvis. Existing literature on hamstring injury prevention shows consistent use of the Nordic Hamstring Exercise and balance exercises may reduce the risk of sustaining an HSI in both males and females, though more studies are needed to ascertain the optimal regimen for injury prevention in the female athlete population specifically. The goal of this clinical commentary is to discuss sex-specific anatomic and biomechanical differences of the lumbar, pelvic, and hip regions with the aim of providing guidelines for rehabilitation and injury prevention of HSIs in female athletes.

### Level of Evidence

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## INTRODUCTION

Hamstring injuries consistently rank as one of the most frequent injuries sustained by female athletes and can result in lengthy amounts of time off from sport.<sup>1-4</sup> Women are underrepresented in many sports and exercise medicine studies, including those focused on hamstring injury rehabilitation and prevention.<sup>5</sup> Male-only research studies may

not translate effectively due to sex-based differences in biomechanical properties, hormones, and sporting environments.<sup>6</sup> O'Sullivan et al. have emphasized the importance of recognizing intrinsic differences between males and females in the risk factors that lead to hamstring injury.<sup>7</sup> Female athletes demonstrate increased hamstring flexibility, lower hamstring musculotendinous stiffness, and increased resistance to skeletal muscle fatigue compared to male athletes.<sup>7</sup> These differences, along with the high incidence and

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burden of hamstring injuries in this population, demonstrate the need for implementation of effective female-specific rehabilitation and injury prevention programs.

Proper prevention and rehabilitation are especially crucial for HSIs because the rate of re-injury is so high. Approximately 1/3<sup>rd</sup> of all HSIs result in reoccurrence and athletes are 4.8 times more likely to sustain an HSI if an HSI had occurred within the previous season.<sup>8,9</sup> Additionally, athletes often experience significant and persistent deficits in the injured hamstring after sustaining an HSI.<sup>10,11</sup> No studies directly compare the extent of injured limb deficits in male athletes versus female athletes and how that may impact rehabilitation. Therefore, the purpose of this clinical commentary is to discuss sex-specific anatomic and biomechanical differences of the lumbar, pelvic, and hip regions with the goal of providing guidelines for rehabilitation and injury prevention of HSIs in female athletes.

## HAMSTRING INJURY REHABILITATION

A strong rehabilitation program should focus on restoring an athlete's pre-injury functionality and performance as well as correct for any deficits that may have led to the injury. Eccentrically strengthening the injured hamstring muscle has been shown to reduce the time to return to play in both men and women, as well as decreasing the risk of reinjury.<sup>12,13</sup> Strengthening during HSI rehabilitation and prevention includes facilitation of muscle hypertrophy in the hamstring musculature as well as addressing functional requirements of the hamstrings through eccentric loading and stretch/shorten cycle exercises.<sup>14,15</sup> Of equal importance is identifying impairments that may contribute to increased provocative load on the hamstrings.<sup>15</sup> Increasing flexibility and neuromuscular control of the lumbopelvic region has also been shown to be beneficial for HSI rehabilitation.<sup>16</sup> Consideration of the sex-specific anatomical and biomechanical features in the lumbopelvic and hip region are necessary when building effective HSI rehabilitation and prevention programs for female athletes.

### ANTERIOR PELVIC TILT

The acetabulum exhibits sexual dimorphism. Acetabular anteversion is significantly greater in females, ranging from 21-23 degrees compared to 17-18 degrees in males.<sup>17-19</sup> A greater degree of acetabular anteversion is thought to be compensated for by increasing the degree of anterior pelvic tilt.<sup>20,21</sup> In fact, females are found to have increased anterior pelvic tilting compared to men, both while standing and during the gait cycle.<sup>22-25</sup> The increased degree of anterior pelvic tilt in the female pelvis has been linked to HSI.<sup>15,26-29</sup> Due to the proximal attachment of the hamstrings to the ischial tuberosities of the pelvis, an increased anterior pelvic tilt places the hamstrings in a relatively lengthened position. This will also lengthen the gluteus maximus (GMax) and gluteus medius (GMed) muscles due to their distal attachments to the femur and posterior orientation on the innominate.<sup>15</sup>



**Figure 1. Glute sets in prone with a pillow. Activate TrA isometrically by performing the abdominal drawing in maneuver then activate GMax isometrically without engaging the hamstrings.**

TrA: transversus abdominis, GMax: gluteus maximus

Restricted hip flexor muscle length can be associated with a more pronounced anterior pelvic tilt in the female pelvis. Shortened hip flexors will limit hip extension, decrease primary hip extensor recruitment and increase reliability on the secondary hip extensors.<sup>30</sup> In the presence of GMax weakness, there is an increased dependency on the hamstrings to work. This is referred to as “synergistic dominance” and places greater stress on the hamstring tissue resulting in higher risk of HSI.<sup>30</sup> Identifying and addressing shortened hip flexors will facilitate GMax recruitment and strengthening in order to reduce provocative load on the hamstrings.

The abdominal drawing-in maneuver combined with hip strengthening exercises has been found to increase activation of the gluteal musculature.<sup>31</sup> Activating the TrA can help to stabilize against compensatory movements in the lumbar spine and pelvis including lumbar hyperextension and excessive anterior pelvic tilt, minimize lengthening of the GMax, GMed and hamstrings and maximize recruitment of the GMax and GMed. TrA activation through the abdominal drawing-in maneuver is an essential modification to hip strengthening in female-specific HSI rehabilitation and prevention programs.

GMax strengthening is initially addressed through isometrics and initiated in early HSI rehabilitation.<sup>32,33</sup> Glute sets in prone with a pillow under the pelvis (Figure 1) to reduce an anterior pelvic tilt promotes TrA activation and facilitates GMax activation. Once GMax activation is properly established, dynamic strengthening is initiated. As the hip is abducted to 15-30 degrees, GMax activation increases and hamstring activation decreases.<sup>34</sup> Hamstring activation is the greatest with the hip in neutral alignment. The bridge exercise, which has high levels of EMG activity in the GMax, is performed in 15-30 degrees of hip abduction to encourage GMax activation and discourage hamstring recruitment. This can be facilitated in the female athlete by placing a band just proximal to the knees to promote hip abduction (Figure 2).

### HIP ABDUCTOR STRENGTH

Compared to the adult male pelvis, the adult female pelvis is broader with a wider pelvic outlet and a wider and more



**Figure 2. Gluteal bridge. Place heels close to buttocks with hips abducted to 15-30 degrees with a band just proximal to the knees. Press through the heels and abduct hips isometrically against the band while lifting hips and pelvis by engaging the GMax.**

GMax: gluteus maximus

circular pelvic inlet.<sup>35-37</sup> The larger pelvic width-to-femoral length ratio in the female anatomy is in part a reason why females tend to have weaker hip abductors compared to their male counterparts.<sup>38,39</sup> Greater degrees of femoral anteversion in females have been associated with decreased utilization of the gluteus medius muscles.<sup>17-19,40</sup> Weakness in the GMed has been associated with HSI suggesting that an increase in hip adduction and difficulty controlling contralateral pelvic drop places additional strain on the hamstrings. Female athletes with stronger hip abductors and external rotators have been shown to be less likely to experience lower extremity injury.<sup>41</sup>

In the female athlete, activation of the TrA to stabilize the pelvis and lumbar spine and minimize anterior pelvic tilting has been shown to maximize GMed strengthening.<sup>31</sup> Side stepping with a resistance band in a squat position (Figure 3) has been shown to increase GMed recruitment and decrease hip flexor activity which can be an effective modification during HSI rehabilitation and prevention for female athletes with hip flexor length deficits.<sup>42</sup>

#### HAMSTRING STRENGTH

Guidelines for hamstring strengthening during rehabilitation and injury prevention programs are similar for females and males; however basic modifications to exercises are given to correct for any proximal alignment and trunk control needs specific to the female anatomy and biomechanics. Females are at higher risk for lower extremity injury when there is a knee flexor/knee extensor ratio of less than 0.75. Knapik et al studied 138 female collegiate athletes, 40% of whom experienced one or more lower extremity injuries.<sup>43</sup> This imbalance between knee extensors and flexors highlights how relative posterior kinetic chain weakness contributes to lower extremity injury and the importance of fully rehabilitating the injured hamstring in order to reduce risk of injury prior to return to sport in the female athlete.<sup>39</sup>

The Nordic hamstring exercise (NHE) (Figure 4) is the most popular eccentric loading exercise for both HSI rehabilitation and prevention. When performed with good trunk

control, this exercise produces the highest activation levels in all three of the hamstring muscles when compared with other common hamstring eccentric exercises like the deadlift and ball leg curl.<sup>44</sup> With an increase in anterior pelvic tilt, a higher degree of femoral and acetabular anteversion and higher likelihood of joint hypermobility, there needs to be more emphasis on establishing adequate trunk control in order for the female athlete to effectively perform the NHE.

The 45-degree hip extension exercise (Figure 5) is another commonly prescribed eccentric hamstring loading exercise. Messer et al. evaluated hamstring muscle activation during the NHE and the 45-degree hip extension exercise in women. While they found that both the 45-degree hip extension exercise and the NHE produced activation of all three hamstring muscles, the NHE elicited higher activation in the semitendinosus with the 45-degree hip extension exercise eliciting a higher biceps femoris long head to semitendinosus activation ratio.<sup>45</sup> The long head of the biceps femoris has been shown to be more active at the hip, and when strained, is associated with persistent deficits in muscle activation.<sup>46,47</sup> Furthermore, it has been proposed that the semitendinosus may play a more significant role than the other hamstrings in unloading the ACL,<sup>24</sup> due to its role in preventing excessive anterior tibial translation and knee valgus which are movement patterns associated with non-contact ACL injury.<sup>48</sup> Both the NHE and 45-degree hip extension exercise should be considered in HSI rehabilitation and prevention programs for female athletes. When prescribing these two exercises, another consideration is to place a band just proximal to the knees to promote hip abduction further reducing the tendency to collapse into hip adduction and femoral internal rotation.

#### HYPERMOBILITY

Hypermobility and differences in laxity of surrounding soft tissue structures in the hip have been described in the female athlete. Females tend to show greater range of motion in hip flexion and hip internal rotation at 90 degrees of flexion than males.<sup>18</sup> This can place additional demand on the





**Figure 3. Side stepping with a resistance band in a squat position. Place a band around the feet standing in a mini squat position. Take steps laterally maintaining stability through the lumbopelvic region and maintaining resistance on the band without dragging the feet.**



**Figure 4. Nordic hamstring exercise. Begin in a tall kneeling position with a band proximal to the knees and hips abducted isometrically against the band. Using a partner to stabilize the feet and ankles, lower the trunk with control maintaining neutral lumbopelvic and hip alignment using the arms to break the “fall”.**

muscles of the posterior kinetic chain to control excessive hip internal rotation including the biceps femoris. Though not as well understood in regard to hip injury and dysfunction in the female athlete, females are also more likely to have generalized joint laxity, lower passive hamstring stiffness, and higher tolerance to stretch.<sup>49-52</sup> Furthermore, instability and laxity of the sacroiliac joint may contribute to hamstring muscle pathology and injury.<sup>53-55</sup> Knee and hip range of motion along with hamstring flexibility are commonly addressed during HSI rehabilitation; however, feelings of hamstring “tightness” is a common report in the female athlete when the hamstrings are repetitively over-

loaded.<sup>56</sup> In the presence of joint hypermobility, lower passive hamstring stiffness and normal hamstring length, the tendency to incorporate flexibility exercises for the hamstrings should be avoided with female athletes.

#### BIOMECHANICAL/NEUROMUSCULAR CONTROL

The neuromuscular control differences between females and males have been well documented with a focus on how these differences impact non-contact knee injuries, but the relationship to hip and hamstring injuries have not been commonly described. Deficits in neuromuscular



**Figure 5. 45-degree hip extension. Begin in a standing position. Lower the trunk with control towards the ground.**

control have been shown to be correlated to the specific anatomical changes that occur through puberty as the female pelvis matures.<sup>38</sup>

During a single leg task, females can demonstrate the improper movement pattern of decreased trunk flexion, increased hip adduction, increased femoral internal rotation, increased knee abduction and trunk lean towards the weight bearing limb.<sup>38,39</sup> Female athletes have weaker hip abductors and decreased hip extensor moments associated with this faulty movement pattern related to an increase in femoral internal rotation and adduction. This can be exacerbated in the setting of increased anterior pelvic tilt and larger pelvic width-to-femoral length ratio. Decreases in proximal strength measures suggest that females may have a less stable foundation upon which to develop or resist force in the lower extremities.<sup>41</sup> Biomechanical studies indicate that hip muscle activation significantly affects the ability of the hamstrings to generate force or resist forces experienced by the entire leg during a single leg task.<sup>41,57</sup> This tendency for core instability has been suggested to predispose females to lower extremity injury.<sup>41,58,59</sup>

Trunk stabilization and agility training have an added benefit to HSI rehabilitation and prevention. Sherry and Best demonstrated that a rehabilitation program consisting of progressive agility and trunk stabilization exercises was more effective in promoting return to sport and preventing re-injury than isolated hamstring stretching and strengthening in males and females after sustaining an acute hamstring strain.<sup>16</sup>

## HAMSTRING INJURY PREVENTION

Neuromuscular training programs have been shown to be effective in the prevention of non-contact ACL injuries in female athletes. These programs incorporate lower extremity strengthening, eccentric hamstring loading, trunk stabilization and agility training. This highlights the importance of posterior kinetic chain strength, HS eccentric strength and trunk stability and its role in reducing lower extremity injury in female athletes.<sup>60,61</sup> The Prevent Injury and Enhance Performance (PEP) program specifically utilizes the NHE as their primary exercise for hamstring eccentric strengthening.<sup>58</sup>

Petersen et al. followed 942 male soccer players for 10 weeks; the players were either allocated to a control group and performed their usual training program or allocated to an intervention group and performed an additional 27 sessions of the NHE during the 10-week period.<sup>62</sup> The NHE program reduced the rate of new HSI injuries in the intervention group athletes by over 60%, from 8.1 injuries per 100 player-seasons in the control group to 3.1 in the intervention group.<sup>62</sup> It was also highly effective at reducing the rate of recurrent HSIs, which was 45.8 per 100 player-seasons in the control group compared to 7.1 in the NHE intervention group (an approximate 85% reduction).<sup>62</sup> While Petersen et. all performed this study with only male subjects, their results emphasize the effectiveness of the NHE.

Soligard et al., studied 1,892 female adolescent soccer players who were divided into intervention and control groups and followed for eight months. The intervention group performed a comprehensive warm-up program before every training session which included running, strength, and balance exercises, one of which was the NHE.

While there were fewer HSIs recorded in the control group (eight versus five), these results were not significant.<sup>63</sup> However, the authors did find there was a significantly lower risk of injuries overall, overuse injuries, and severe injuries in the intervention group.<sup>63</sup> A randomized controlled trial consisting of 43 professional women soccer players tested the effect of a 21-week eccentric strength training program which consisted of the Nordic Hamstring exercise and eccentric band exercises. Five players who did not undergo the training program later sustained an HSI, compared to only one player in the intervention group; the training program therefore reduced the risk of HSI by 81%. However, the results did not reach significance due to the small number of participants in the study.<sup>64</sup> As sex-specific differences exist in HSI risk factors and rehabilitation, future studies are needed to identify the optimal preventative training program to reduce hamstring injuries in female athletes.

## CONCLUSION

Effective hamstring injury rehabilitation and prevention programs are crucial considering the significant burden HSIs can place on a female athlete.<sup>1-4</sup> Existing literature regarding hamstring rehabilitation demonstrates that eccentric hamstring strengthening, flexibility training, and agility and trunk stabilization exercises may reduce return-to-play time and rates of re-injury and that use of the

Nordic Hamstring Exercise in HSI prevention programs successfully reduces the rate of HSIs.<sup>12,13,16,62-66</sup> Sex-specific hamstring injury rehabilitation guidelines that acknowledge and address anatomical differences such as increased anterior pelvic tilt, greater degree of both femoral and acetabular anteversion and greater pelvic width to femoral length ratio should be considered, as should biomechanical differences such as decreased utilization of the hip abductor muscles, decreased neuromuscular control, and hypermobility. Future comparative studies on the efficacy of sex-specific rehabilitation protocols can help optimize the management and prevention of HSI in female athletes.

## CONFLICTS OF INTEREST

Lucy R. O'Sullivan: None

Jamie A. Preszler: None

Miho J. Tanaka: Grants from Arthroscopy Association of North America and Fuji Film; Consultant Medical Reviewer at Verywell Fit; Editorial Board of ASJM and Arthroscopy Journal; Associate Editor CME Panel at JBJS; Editor at Journal of Women's Sports Medicine; Committee member at AOSSM, AANA, AAOS, ISAKOS

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