

Appendix 2. Full results of the best evidence synthesis for index and recurrent hamstring strain injuries.

Table 2. Best evidence synthesis of risk factors associated with increased risk of future index hamstring strain injury.

	Studies (n)	Subjects (n)	HSI (n)	↑Increased or ↓decreased risk	=No significant difference	Level of evidence
Non-modifiable factors						
Recent HSI	4	7303	1364	↑ ^(29,30,52,85)		Strong
Previous knee injury	2	596	62	↑ ^(46,95)		Moderate
Previous ankle ligament injury	1	367	245	↑ ⁽⁵¹⁾		Limited
Ethnicity: Indigenous Australian	1	114	34	↑ ⁽⁹⁵⁾		Limited
Architectural and structure						
Hamstrings muscle-tendon unit stiffness	1	136	14	↑ ⁽⁶⁰⁾		Limited
Leg stiffness	1	136	14	↑ ⁽⁶⁰⁾		Limited
↓Biceps femoris passive fascicle length	1	152	27	↑ ⁽²⁴⁾		Limited

↓Biceps femoris fascicle length (25% MVIC)	1	152	27	↑ ⁽²⁴⁾	Limited
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Strength

↓Strength-endurance: single leg hamstring bridge	1	482	28	↑ ⁽⁴⁶⁾	Limited
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↓Eccentric hamstring strength: HHD	1	102	16	↑ ⁽²²⁾	Limited
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↓Isometric knee extensor strength: HHD	1	102	16	↑ ⁽²²⁾	Limited
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↑Isometric: eccentric hamstring strength ratio: HHD	1	102	16	↑ ⁽²²⁾	Limited
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↓Relative isometric knee flexion: strain gauge	1	64	31	↑ ⁽⁹⁹⁾	Limited
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↓Isometric knee flexion: knee extension: strain gauge	1	64	31	↑ ⁽⁹⁹⁾	Limited
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Power and ballistic function

Non-CMJ: CMJ	1	84	14	↑ ⁽⁹⁴⁾	Limited
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↓Single leg hop for distance	1	102	16	↑ ⁽²²⁾	Limited
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Electromyography and motor control

↑Gluteus medius activity while running: 12km/hr, 15km/hr	1	26	9	↑ ⁽⁷⁴⁾	Limited
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↓Trunk muscle activity during back-swing phase of sprinting	1	51	15	↑ ⁽⁹⁰⁾	Limited
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Muscle activation pattern during prone hip extension	1	51	15	↑ ⁽⁹¹⁾	Limited
Biceps femoris dominance during 5kg eccentric prone hamstring curl to exertion: fMRI	1	54	10	↑ ⁽²¹⁾	Limited
Movement discrimination	1	20	6	↑ ⁽⁶⁸⁾	Limited
Reaction time of mental rotation	1	21	7	↑ ⁽⁹⁸⁾	Limited
Running-based measurements					
↑Anterior pelvic tilt during backswing phase of sprinting	1	29	4	↑ ⁽⁹²⁾	Limited
↑Thoracic side-bending throughout the front-swing phase of sprinting	1	29	4	↑ ⁽⁹²⁾	Limited
Average-summed 4 week high speed running distance	1	51	22	↑ ⁽²⁸⁾	Limited
Relative high speed running distance for previous 4 weeks	1	51	22	↑ ⁽²⁸⁾	Limited
Absolute week-to-week change in high speed running distance	1	220	30	↑ ⁽²⁷⁾	Limited
Relative week-to-week change in high speed running distance	1	220	30	↑ ⁽²⁷⁾	Limited
Relative high speed running distance as a percentage of distance covered over 10km/hr	1	220	30	↑ ⁽²⁷⁾	Limited
Distance covered in the week preceding the HSI	1	51	22	↑ ⁽²⁸⁾	Limited

Sports performance, match play

Player interchange characteristics	2	5656	416	↑(29,30)		Moderate
Stage of the season	2	1401	2616	↑(49,72)		Moderate
Player position: football	10	6845	2275	↑(20,45,49,55-57,97)	=(19,71,94)	Strong
Player position: American football	2	1252	1888	↑(62,72)		Moderate
Player position: rugby union	2	1445	122	↑(12,67)		Moderate
Player position: cricket	1	NP	276	↑(85)		Limited
Player position: Gaelic football	1	NP	391	↑(88)		Limited
Track running event	1	48473	118	↑(83)		Limited
Match format: cricket	1	NP	276	↑(85)		Limited
Clinical and imaging assessment						
HaOS score	1	508	61	↑(45)		Limited
Environmental factors						
Match at international venue	1	NP	276	↑(85)		Limited

HSI= hamstring strain injury, MVIC= maximum voluntary isometric contraction, HHD= hand held dynamometer, CMJ= countermovement jump, fMRI= functional MRI

Table 3. Best evidence synthesis of risk factors not associated with increased risk of future index hamstring strain injury.

	Studies (n)	Subjects (n)	HSI (n)	↑Increased or ↓decreased risk	=No significant difference	Level of evidence
Non-modifiable factors						
Height	21	7378	2460	↑ ^(49,94) , ↓ ⁽²⁵⁾	= ^(12,20,23,24,42,48,52,55-57,65,73,75,76,78,84,91,95)	Strong
Previous adductor muscle strain injury	1	1401	900		= ⁽⁴⁹⁾	Limited
Previous quadriceps muscle strain injury	4	1941	975	↑ ⁽⁴⁹⁾	= ⁽²³⁻²⁵⁾	Strong
Previous chronic groin pathology, 'osteitis pubis'	4	654	109	↑ ⁽⁹⁵⁾	= ⁽²³⁻²⁵⁾	Strong
Ethnicity: Caucasian	4	3773	1018	↓ ⁽⁹⁷⁾	= ^(12,55,56)	Moderate
Leg dominance	8	3542	1365	↑ ⁽⁷⁵⁾	= ^(20,49,55-57,84,96)	Strong
Architecture and structure						
Hamstrings muscle-tendon unit stiffness asymmetry	1	136	14		= ⁽⁶⁰⁾	Limited
Leg stiffness asymmetry	1	136	14		= ⁽⁶⁰⁾	Limited
Weight	21	7247	2410	↑ ^(52,76) , ↓ ⁽²⁵⁾	= ^(12,20,23,24,42,49,55-57,61,71,73,78,84,91,94,95,99)	Strong
Body mass index	12	5057	1379	↑ ^(52,76)	= ^(12,20,42,48,55-57,71,91,94)	Strong
↓Mid thigh girth	1	100	16		= ⁽⁷³⁾	Limited
↓Biceps femoris passive muscle thickness	1	152	27		= ⁽²⁴⁾	Limited
↓Biceps femoris muscle thickness (25% MVIC)	1	152	27		= ⁽²⁴⁾	Limited

Biceps femoris fascicle length imbalances	1	152	27		= ⁽²⁴⁾	Limited
↓Gluteus medius muscle volume	1	26	9		= ⁽⁷⁴⁾	Limited
↓Gluteus maximus muscle volume	1	26	9		= ⁽⁷⁴⁾	Limited
Percentage body fat/ skin folds assessment	2	121	20		= ^(84,94)	Moderate
Strength						
NHE strength imbalance	4	953	144	↑ ⁽²³⁾	= ^(24,25,55)	Strong
↓“Nordic hamstring strength test”	1	508	61		= ⁽⁴⁵⁾	Limited
Isokinetic strength testing: knee flexors*				↑ ⁽⁸¹⁾	= ⁽⁵⁵⁾	Strong
Isokinetic strength testing: knee extensors*					= ^(55,81)	Strong
Isokinetic strength ratios*				↑ ⁽⁸¹⁾	= ⁽⁵⁵⁾	Strong
Isokinetic peak rate of torque development: concentric hamstrings (60°/s, 300°/s) at 30, 50, 100ms	1	367	65		= ⁽⁵⁷⁾	Limited
Isokinetic peak rate of torque development: eccentric hamstrings (60°/s) at 30, 50, 100ms	1	367	65		= ⁽⁵⁷⁾	Limited
↓Isometric knee flexor strength: HHD	1	102	16		= ⁽²²⁾	Limited
Strength-endurance asymmetry: single leg hamstring bridge	1	482	28		= ⁽⁴⁶⁾	Limited
↓Strength-endurance: 5kg eccentric prone hamstring curl time to exertion	1	54	10		= ⁽²¹⁾	Limited
↓Hip extensor strength: HHD	1	102	16		= ⁽²²⁾	Limited
↓Relative isometric hip extension: strain gauge	1	64	31		= ⁽⁹⁹⁾	Limited
↓Relative isometric hip flexion strength: strain gauge	1	64	31		= ⁽⁹⁹⁾	Limited
↓Relative isometric knee extension: strain gauge	1	64	31		= ⁽⁹⁹⁾	Limited

↓Relative isometric forward leg pull: strain gauge	1	64	31		= ⁽⁹⁹⁾	Limited
↓Relative isometric backward leg pull: strain gauge	1	64	31		= ⁽⁹⁹⁾	Limited
↓1-repetition maximum: back squat	1	153	23		= ⁽⁷⁸⁾	Limited
↓Abdominal strength	1	37	6		= ⁽⁸⁴⁾	Limited
Power and ballistic function						
Mean power during loaded squat	1	306	31		= ⁽⁴²⁾	Limited
↓Power output during CMJ	2	459	54		= ^(42,78)	Moderate
↓CMJ height	6	1124	164	↑ ⁽⁷⁸⁾	= ^(42,45,50,84,94)	Strong
↓Single leg CMJ	1	306	31		= ⁽⁴²⁾	Limited
Flexibility, mobility, range of motion						
↓Passive knee extension	5	1396	220	↑ ⁽⁵⁶⁾	= ^(42,45,89,91)	Strong
↓Active knee extension	6	1104	191		= ^(47,56,75,76,89,91)	Strong
↓Passive straight leg raise	5	445	103	↑ ⁽⁹⁶⁾	= ^(50,61,75,89)	Strong
↓Active straight leg raise	1	36	14		= ⁽⁵⁰⁾	Limited
Active straight leg raise: passive straight leg raise ratio	1	36	14		= ⁽⁵⁰⁾	Limited
↓Hip flexion during standing forward bend	1	67	8		= ⁽⁶⁵⁾	Limited
↓Standing lumbar extension ROM	1	126	26		= ⁽⁷⁵⁾	Limited
↓Standing lumbar flexion ROM	2	118	23		= ^(65,91)	Moderate
Slump test	3	522	78		= ^(47,75,76)	Moderate
↓Sit and reach test	6	1012	195		= ^(19,47,75,84,89,94)	Moderate

↓Hip external rotation ROM	4	573	93	=(47,75,76,91)	Moderate
↓Hip internal rotation ROM	4	573	93	=(47,75,76,91)	Moderate
Electromyography and motor control					
Biceps femoris activity while running	1	51	15	=(90)	Limited
Medial hamstrings activity while running	1	51	15	=(90)	Limited
↓Single leg balance and proprioception	1	100	16	=(73)	Limited
Medial hamstrings onset: concentric (60°/s, 300°/s)	1	367	65	=(57)	Limited
Medial hamstrings onset: eccentric (60°/s)	1	367	65	=(57)	Limited
Biceps femoris onset: concentric (60°/s, 300°/s)	1	367	65	=(57)	Limited
Biceps femoris onset: eccentric (60°/s)	1	367	65	=(57)	Limited
Running-based measurements					
↓VO ₂ max test: treadmill	2	343	37	=(42,84)	Moderate
40m sprint test	2	545	82	=(45,84)	Moderate
↓Intermittent running fitness test: YoYo	2	120	28	=(50,94)	Moderate
↓Agility test	1	36	14	=(50)	Limited
Difference in absolute high speed running distance covered between seasons	1	51	22	=(28)	Limited
Sports performance and match play					
Weekly sprint training volume: Sprinters	1	44	12	=(61)	Limited
Playing position: Australian football	1	220	30	=(27)	Limited

Environmental factors					
Temperature	2	1607	1039	= ^(52,80)	Moderate
Playing surface	1	NS	367	= ⁽⁸⁰⁾	Limited
Altitude	1	NS	367	= ⁽⁸⁰⁾	Limited
Time zone change prior to game	1	NS	367	= ⁽⁸⁰⁾	Limited
Time of match	1	1607	672	= ⁽⁵²⁾	Limited
Maximum wind speed on game day	1	1607	672	= ⁽⁵²⁾	Limited
Rainfall	1	1607	672	= ⁽⁵²⁾	Limited
Evaporation	1	1607	672	= ⁽⁵²⁾	Limited

HSI= hamstring strain injury, MVIC= maximum voluntary isometric contraction, HHD= hand-held dynamometry, CMJ= countermovement jump, ROM= range of motion, NSAID= non-steroidal anti-inflammatory drug, *data point refers to results of a recent systematic review

Table 4. Best evidence synthesis of risk factors with an unknown association with risk of future index hamstring strain injury.

	Studies (n)	Subjects (n)	HSI (n)	↑Increased or ↓decreased risk	=No significant difference	Level of evidence
Non-modifiable factors						
Chronological age	29	11725	3467	↑(24,42,45-47,50,52,55-57,60,75,76,81,89,95,97)	=(12,19,20,23,25,27,49,61,71,84,91,94)	Conflicting
Playing age	3	545	132	↓(28)	=(19,61)	Conflicting
Previous HSI	25	11529	3234	↑(20,23,42,45-49,52,64,73,81,85,88,95)	=(19,24,25,43,55-57,68,71,84)	Conflicting
Previous ACL injury	6	6456	521	↑(29,30)	=(23-25,27)	Conflicting
Previous calf strain injury	7	9204	2063	↑(29,30,49,52)	=(23-25)	Conflicting
Previous spine-related pathology*	2			↑(102)	=(95)	Conflicting
Ethnicity: Black or Caribbean	4	3773	1014	↑(12,97)	=(55,56)	Conflicting
Strength						
↓Eccentric strength: NHE test (N)	4	953	144	↑(24,25)	=(23,55)	Conflicting
↓Eccentric strength: NHE test (N.kg)	4	953	144	↑(24,25)	=(23,55)	Conflicting
Power and ballistic function						
Non-CMJ height	3	426	59	↑(50)	=(42,94)	Conflicting
Flexibility, mobility, range of motion						
↓Hip extension: modified Thomas test	4	573	93	↑(75,76)	=(47,91)	Conflicting
↓Ankle dorsiflexion: lunge test	5	1442	184	↑(47,56)	=(46,75,76)	Conflicting

Electromyography and motor control						
Gluteus maximus activity while running	2	77	24	↑ ⁽⁹⁰⁾	= ⁽⁷⁴⁾	Conflicting
Sports performance and match play						
Limited between-match recovery, schedule congestion	3	5656	416	↑ ⁽⁶³⁾	= ^(29,69)	Conflicting
Level of competition	3	51357	975	↑ ^(83,97)	= ⁽⁴⁵⁾	Conflicting

HSI= hamstring strain injury, ACL= anterior cruciate ligament, CMJ= countermovement jump, ROM= range of motion

Table 5. Best evidence synthesis of risk factors for recurrent hamstring strain injury

	Studies (n)	HSI (n)	Recurrences (n)	↑Increased or ↓decreased risk	=No significant difference	Level of evidence	Association
Non-modifiable factors							
Chronological age	4	207	59		=(44,58,79,86)	Strong	No
Previous HSI	4	272	62	↑ ⁽⁵⁹⁾	=(44,79,87)	Conflicting	Unknown
Recent HSI	2	123	26	↑ ⁽⁵⁹⁾	=(44)	Conflicting	Unknown
The number of previous HSI	1	64	17	↑ ⁽⁴⁴⁾		Limited	Yes
Previous ACL injury	1	41	10	↑ ⁽⁷⁹⁾		Limited	Yes
Height	2	78	29		=(58,79)	Moderate	No
Gender	1	65	13		=(86)	Limited	No
Leg dominance	1	37	19		=(58)	Limited	No
Architecture and structure							
Weight	2	78	29		=(58,79)	Moderate	No
Body mass index	1	37	19		=(58)	Limited	No
Strength							
↓Strength-endurance: 5kg eccentric prone hamstring curl time to exertion	1	10	6	↑ ⁽²¹⁾		Limited	Yes
↓Isometric hamstring strength just after return to play: HHD 15° knee flexion	1	64	17	↑ ⁽⁴⁴⁾		Limited	Yes
Flexibility, mobility, range of motion							

↓Active knee extension just after return to play	1	64	17	↑ ⁽⁴⁴⁾	Limited	Yes
↓Passive straight leg raise just after return to play	1	64	17	⏟ ⁽⁴⁴⁾	Limited	No
Sports performance, match play						
Level of competition (mixed sports)	1	64	17	⏟ ⁽⁴⁴⁾	Limited	No
Clinical and imaging examination of the index HSI						
Length of recovery period following index HSI	4	173	52	⏟ ^(44,58,77,79)	Strong	No
VAS pain at the time of the index HSI	1	37	19	⏟ ⁽⁵⁸⁾	Limited	No
Running or sprinting mechanism of injury	2	123	26	⏟ ^(44,59)	Moderate	No
Pain provocation with isometric contraction (prone: 15° knee flexion) at baseline	1	59	9	⏟ ⁽⁵⁹⁾	Limited	No
Active knee extension deficit at baseline	1	59	9	⏟ ⁽⁵⁹⁾	Limited	No
Passive straight leg raise deficit at baseline	1	59	9	⏟ ⁽⁵⁹⁾	Limited	No
Positive slump test at baseline	1	59	9	⏟ ⁽⁵⁹⁾	Limited	No
>1 day to pain free walking after index HSI	1	59	9	⏟ ⁽⁵⁹⁾	Limited	No
>1 day to pain free stair ascent	1	59	9	⏟ ⁽⁵⁹⁾	Limited	No
NSAID use within 3 days of index HSI	1	59	9	⏟ ⁽⁵⁹⁾	Limited	No
Clinical site of maximum tenderness	1	37	19	⏟ ⁽⁵⁸⁾	Limited	No
Clinical grade of index HSI: II vs I	1	165	23	↑ ⁽⁸²⁾	Limited	Yes
Clinical grade of index HSI: II vs III	1	165	23	↑ ⁽⁸²⁾	Limited	Yes
Clinical grade of index HSI: I vs III	1	165	23	⏟ ⁽⁸²⁾	Limited	No
Clinical grade of index HSI and risk of early re-injury	1	165	23		Limited	No

(from: i. baseline; ii. RTP)					<u>(82)</u>		
fMRI: hamstring muscle recruitment during fatiguing eccentric exercise	1	10	6		<u>(21)</u>	Limited	No
MRI: maximum length of signal at baseline	3	109	35		<u>(58,77,79)</u>	Strong	No
MRI: maximum CSA of signal at baseline	2	72	16		<u>(77,79)</u>	Moderate	No
MRI: signal volume at baseline*					<u>(105)</u>	Strong	No
MRI: muscle(s) involved at baseline	4	207	59		<u>(44,58,79,86)</u>	Strong	No
MRI: location at baseline	3	143	42		<u>(58,79,86)</u>	Moderate	No
MRI: British Athletics Muscle Injury classification	1	65	13		<u>(86)</u>	Limited	No
MRI: distance from ischial tuberosity at baseline*					<u>(105)</u>	Moderate	No
MRI: Peetron's classification*					<u>(105)</u>	Strong	No
MRI: Intratendinous/ intramuscular tendon disruption at baseline	2	230	45	↑ ⁽⁸⁶⁾	<u>(54)</u>	Conflicting	Unknown
MRI: presence of 'waviness' at baseline	1	165	32		<u>(54)</u>	Limited	No
MRI: presence of signal at return to play*					<u>(105)</u>	Limited	No
MRI: length of signal at return to play*					<u>(105)</u>	Limited	No
MRI: fibrosis present at the time of return to play (Peetron's grade I and II injuries)	1	108	26		<u>(87)</u>	Limited	No
Self-reported 'completeness' of recovery just after return to play	1	64	17		<u>(44)</u>	Limited	No
Localised tenderness to palpation just after return to play	1	64	17	↑ ⁽⁴⁴⁾		Limited	Yes
Active knee extension discomfort just after return to play	1	64	17		<u>(44)</u>	Limited	No
Passive straight leg raise discomfort just after return to	1	64	17			Limited	No

play				⊖ ⁽⁴⁴⁾		
Discomfort with resisted isometric contraction just after return to play; HHD 15° knee flexion	1	64	17	⊖ ⁽⁴⁴⁾	Limited	No
HaOS score just after return to play	1	64	17	⊖ ⁽⁴⁴⁾	Limited	No

HSI= hamstring strain injury, ACL=anterior cruciate ligament, MVIC= maximum voluntary isometric contraction, HHD= hand held dynamometer, HaOS= Hamstring Outcome Score, fMRI= functional magnetic

resonance imaging, *data point refers to results of a recent systematic review