Supplementary file 7 Biomechanical effects of proximal retraining strategies

FINDINGS	LEVEL OF EVIDENCE
EFFECT OF CUES TO INCREASE TRUNK FLEXION	
Knee	
↓ PFJ stress and reaction force	Limited (1 HQS[1])
↑ PFJ contact area	Limited (1 HQS[1])
↓ internal knee extensor moment and knee flexion at time of peak PFJ stress	Limited (1 HQS[1])
Hip	
↑ hip flexion at foot strike (reported post hoc)	Limited (1 HQS[1])
EFFECT OF VISUAL AND VERBAL CUES TO REDUCE HIP ADDUCTION	
Ground reaction forces	
↓ VALR and VILR*	Very limited (1 MQS[2])
Hip	
↓ peak internal hip abduction moment at 1 but not 3 month follow up*	Limited (1 HQS[3])
↓ peak hip adduction at 1 month follow up*	Limited (1 HQS[3] and 1 MQS[2])
↓ peak hip adduction at 3 months follow up*	Limited (1 HQS[3])
Pelvis	
↓ contralateral pelvic drop at 1 month follow up*	Limited (1 HQS[3] and 1 MQS[2])
↓ contralateral pelvic drop at 3 months follow up*	Limited (1 HQS[3])
INCREASING STEP WIDTH	
Foot and Ankle	
↓ peak rearfoot eversion	Limited (2 MQS[4 5])
↓ peak internal ankle inversion moment	Very limited (1 MQS[4])
↓ rearfoot eversion and forefoot dorsiflexion excursion	Very limited (1 MQS[5])
Delayed peak rearfoot eversion and peak forefoot abduction	Very limited (1 MQS[5])
Earlier peak forefoot dorsiflexion	Very limited (1 MQS[5])
↑ forefoot abduction excursion	Very limited (1 MQS[5])
Lower leg/tibia	
↓ anterior tension, posterior compression and medial compression of the tibia	Very limited (1 MQS[6])

↓ shear stress on the anterior, posterior, medial and lateral tibia	Very limited (1 MQS[6])
Knee	
↓ peak internal knee abduction moment	Very limited (1 MQS[4])
↓ internal knee abduction impulse	Very limited (1 MQS[4])
↓ ITB strain and strain rate	Very limited (1 HQS[7])
Conflicting findings related to peak knee internal rotation	1 MQS[4] = ↑; 1 HQS[7] = ↓
Hip	
↓ peak hip adduction	Limited (1 HQS[7] and 1 MQ study[4])

HQS = high quality study, LQS = low quality study, MQS = moderate quality study, PFJ = patellofemoral joint, VALR = vertical average loading rate, VILR = vertical instantaneous loading rate

* Findings related to individuals with patellofemoral pain

Table Findings related to the biomechanical effects of proximal kinematic changes

Study (year)	Study design	Sample	Outcome measures	Intervention	Significant Biomechanical results
Trunk Flexion					
Teng (2014)[1]	Randomised (after preferred trunk position) within participant Over-ground running at 3.4 m/s	24 (12 M, 12 F) healthy recreational runners running approximately 20 km/week	PFJ stress	Instructed to run with flexed and extended trunk posture Preferred trunk flexion = 7.3^0 Flexed = 14.1^0 Extended = 4.0^0	↓ PFJ stress with increased trunk flexion ↓ PFJ reaction force with increased trunk flexion ↑ PFJ contact area with increased trunk flexion ↓ internal knee extensor moment at peak PFJ stress ↓ knee flexion at peak PFJ stress ↑ hip flexion at foot strike (reported post hoc)
Hip adduction					
Noehren (2011)[2]	Case series 1 month follow up	10 female runners with PFP Running at least 3 times and 6 miles per week At least 20^0 peak hip adduction	Kinematics of the hip and pelvis Vertical GRF loading rates	2 weeks (8 sessions) of visual (real time 3D feedback) and verbal faded feedback to reduce hip adduction	↓ peak hip adduction at 1 month follow up ↓ contralateral pelvic drop at 1 month follow up ↓ VALR ↓ VILR
Willy (2012)[3]	Case series 3 months follow up	10 female runners Running at least 10 km per week At least 20^0 peak hip adduction		2 weeks (8 sessions) of visual (mirror) and verbal faded feedback to reduce hip adduction	↓ peak hip adduction at 1 and 3 month follow up, although trends for return to baseline existed ↓ contralateral pelvic drop at 1 and 3 month follow up ↓ peak internal hip abduction moment at 1 but not 3 month follow up

F = females, GRF = ground reaction force, M = males, PSW = preferred step width, SW = step width, VALR = vertical average loading rate, VILR = vertical instantaneous loading rate

Table Findings related to the biomechanical effects of altering step width

Study (year)	Study design	Sample	Outcome measures	Intervention	Significant Biomechanical results
Visual feedback					
Brindle (2014)[4]	Randomised within participant Over-ground running at 3.5 m/s	30 (15 M, 15 F) healthy runners running at least 15 miles per week for 1 year	Lower limb kinematics and joint moments	Widen (20% leg length) and narrow SW (guided by tapes) PSW = 6 cm Wide = 15-16 cm Narrow = 1 cm	↓ peak hip adduction with wider SW ↑ peak knee IR with wider SW ↓ peak rearfoot eversion with wider SW ↓ internal knee abduction peak moment and impulse with wider SW ↓ internal ankle inversion moment with wider SW
Pohl (2006)[5]	Randomised within participant Over-ground running at preferred speed (not reported)	12 (6M, 6F) healthy individuals participating in at least 2 hours of running related activity per week	Lower limb kinematics Joint coupling	Instructed to run wider and with cross-over pattern (guided by tape on the floor) PSW = 5 cm Wide = 11 cm Narrow = -7 cm	↓ rearfoot eversion peak and ROM with increased SW Delayed peak rearfoot eversion with increased SW ↑ forefoot dorsiflexion and increased forefoot abduction excursion with increased SW Earlier peak forefoot dorsiflexion and later peak forefoot abduction with increased SW No changes in joint coupling between the rearfoot, forefoot and tibia

Verbal feedback					
Meardon (2012)[7]	Randomised (after PSW) within participant Overground running at preferred speed (4.04 m/s)	15 (8M, 7F) healthy runners running at least 10 miles per week	ITB strain and strain rate	+/- 5% PSW (guided by verbal cues) PSW = 2 cm Wide = 10 cm Narrow = -6 cm	↓ ITB strain and strain rate ↓ peak hip adduction ↓ peak knee internal rotation
Meardon (2014)[6]	Randomised (after PSW) within participant Over-ground running at preferred speed (4.04 m/s)	15 (8M, 7F) healthy runners running at least 10 miles per week	Tibial stress	+/- 5% PSW (guided by verbal cues) PSW = 2 cm Wide = 10 cm Narrow = -6 cm	↓ anterior tension, posterior compression and medial compression of the tibia with increased SW ↓ shear stress on the anterior, posterior, medial and lateral tibia with increased SW

F = females, M = males, PSW = preferred step width, SW = step width

1. Teng HL, Powers CM. Sagittal plane trunk posture influences patellofemoral joint stress during running. J Orthop Sports Phys Ther 2014;**44**(10):785-92.
2. Noehren B, Scholz J, Davis I. The effect of real-time gait retraining on hip kinematics, pain and function in subjects with patellofemoral pain syndrome. British Journal of Sports Medicine 2011;**45**(9):691-6.
3. Willy RW, Scholz JP, Davis IS. Mirror gait retraining for the treatment of patellofemoral pain in female runners. Clin Biomech (Bristol, Avon) 2012;**27**(10):1045-51.
4. Brindle RA, Milner CE, Zhang S, et al. Changing step width alters lower extremity biomechanics during running. Gait Posture 2014;**39**(1):124-8.
5. Pohl MB, Messenger N, Buckley JG. Changes in foot and lower limb coupling due to systematic variations in step width. Clin Biomech (Bristol, Avon) 2006;**21**(2):175-83.
6. Meardon SA, Derrick TR. Effect of step width manipulation on tibial stress during running. J Biomech 2014;**47**(11):2738-44.

7. Meardon SA, Campbell S, Derrick TR. Step width alters iliotibial band strain during running. Sports Biomech 2012;**11**(4):464-72.