Posterior Pelvic Tilt Increases Hip Range of Motion and Hip Joint Stress: A Systematic Review

Benjamin D. Kuhns, Ady H. Kahan-Rojkind, Ali Parsa, Tyler R. McCarroll, Drashti Sikligar, Benjamin G. Domb

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Disclosures

I (and/or my co-authors) have something to disclose.

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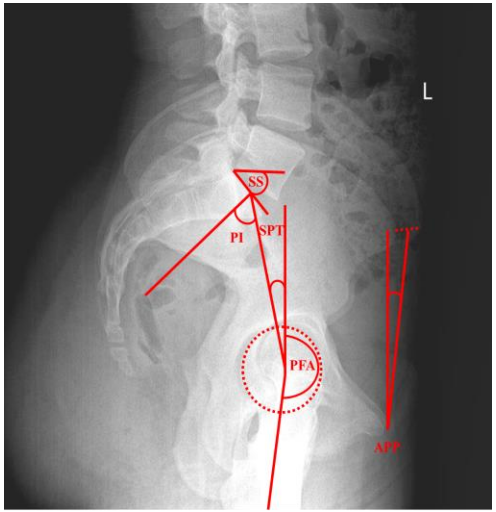
Introduction

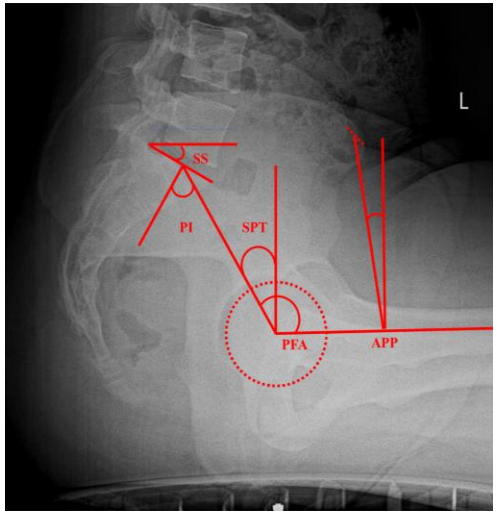
- Sagittal pelvic kinematics are a complicated topic secondary to the numerous and heterogeneously defined radiographic variables and clinical conditions involved.

- Observed hip motion is a composite of femoroacetabular and spinopelvic motion

Introduction

- Sagittal spinopelvic parameters include
  - sacral slope (SS)
  - anterior pelvic plane angle (APP)
  - spinopelvic tilt (SPT)
  - pelvic incidence (PI)
  - pelvic-femoral angle (PFA)
  - lumbar lordosis .



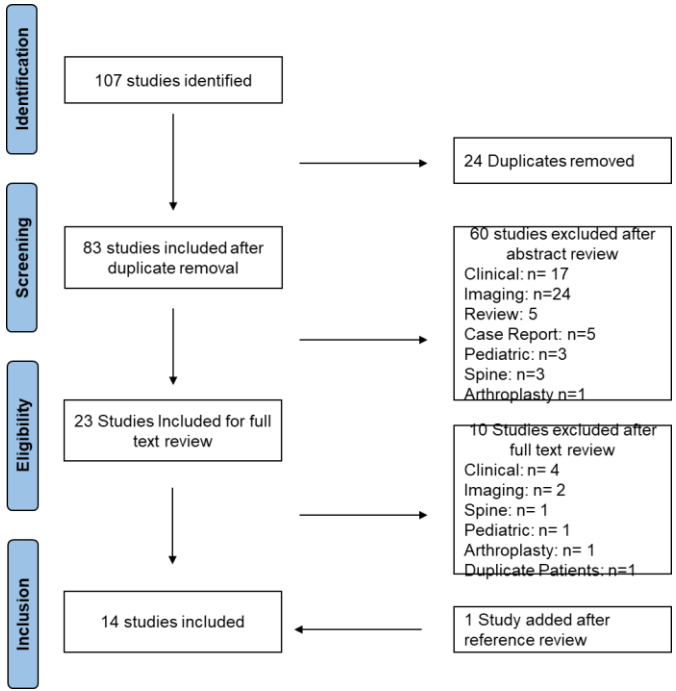


Purpose:

- To perform a systematic review of studies evaluating the effect of pelvic tilt on hip joint contact forces and range of motion in patients with femoroacetabular impingement (FAI) and acetabular dysplasia.
- We hypothesized that sagittal pelvic motion would be limited in patients with FAI while increased in patients with dysplasia

Methods

- Inclusion Criteria: Studies evaluating pelvic tilt on preoperativeh ip joint contact forces, biomecahncis, or range of motion in subjects with FAI or dysplasia.
- Exclusion criteria: Studies focusing on arthroplasty, radiographic imaging, or clinical outcomes
- Studies graded for quality according to Methodological Index for Non-Randomized Studies (MINORs) and Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I)



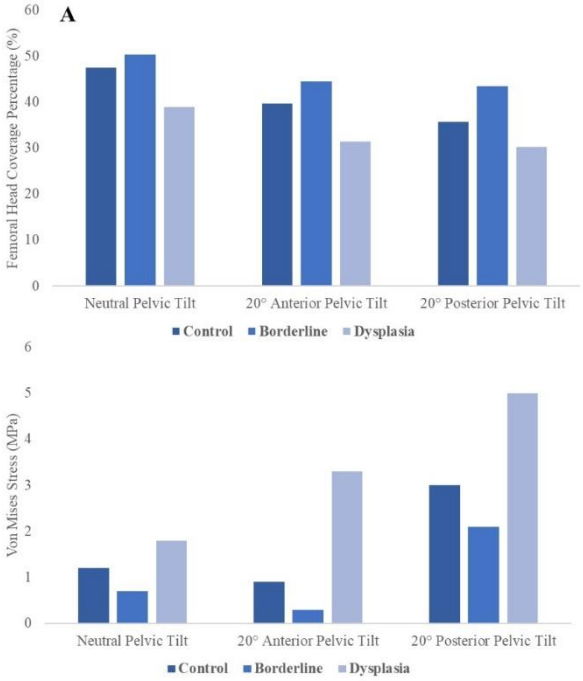
Results: Study Design and Quality Assessment

- 14 Studies included
  - Two studies involving hip joint biomechanics in acetabular dysplasia, 12 studies evaluating FAI
  - 4 studies evaluating biomechanical modeling and joint forces
  - 4 studies evaluating simulated hip and pelvic range of motion on 3D-CT creconstruction
  - 5 studies using in-vivo measurements of hip motion relative to pelvic tilt

Author	Year	Journal	Country	Study Design	Pelvic tilt reference and position	Advanced Imaging Acquired	Loading Condition	Modeling Platform	MINORS	ROBINS
Aminoff	2018	*OJSM*	Sweden	Motion Analysis	Seated Pelvis: PALM palpation inclinometer	None	Seated	None	19	Low
Atkins	2020	*JOR*	USA	Motion Analysis	Standing Pelvis: Neutral tilt referenced off vertical axis **	Dual Fluoroscopy, CT Scan	Walking	MATLAB: Mathworks	22	Low
Bagwell	2016	*Clin. Biomech.*	USA	Motion Analysis	Standing Pelvis: Global Coordinate System**	None	Deep Squat	Visual 3D (C-motion)	23	Low
Bagwell	2019	*Clin. Biomech.*	USA	Motion Analysis	Standing Pelvis: Global Coordinate System**	None	Deep Squat, High Step	Visual 3D (C-motion)	22	Low
Catelli	2018	*OJSM*	Canada	Motion Analysis	Standing Pelvis: Global Coordinate System with pelvic motion referenced off pelvic origin midway between ASIS and PSIS	CT scan	Squat	Nexus 1.8.5; Vicon Motion Systems	21	Low
Fader	2018	*JBJS: Br*	USA	Motion Analysis	Standing and Seated Pelvis: Sacral Slope	Biplanar EOS Standing/Sitting Radiographs	Stand/Sit	None	19	Low
Hasegawa	2021	*BMC Musculoskel et. Disord.*	Japan	Biomechanical Modeling	Supine Pelvis: Neutral Tilt at Anterior Pelvic Plane	CT scan	Standing	CT-based templating (ZedHip); Finite Element Analysis (Mechanical Finder)	19	Low
Kitamura	2021	*CORR*	Japan	Biomechanical Modeling	Supine Pelvis: Neutral Tilt at Anterior Pelvic Plane	CT Scan	Single Leg Stance	Finite Element Analysis (Mechanical Finder)	20	Mod
Lamontagne	2009	*CORR*	Canada	Motion Analysis	Standing Pelvis: Neutral tilt referenced off vertical axis **	None	Squat	Vicon Workstation	23	Low
Lewis	2018	*JOSPT*	USA	Motion Analysis	Standing Pelvis: Neutral tilt referenced off vertical axis **	None	Single Leg Squat	Visual 3D (C-motion)	20	Low
Ng	2018	*AJSM*	Canada	Motion Analysis	Supine Pelvis: Vertical Line from center of the bicoxofemoral head to center of the sacral endplate. Pelvic Tilt Reference for motion analysis based on standing vertical pelvis as neutral tilt	CT Scan	Walking, Squat	Nexus 1.8.5; Vicon Motion Systems	18	Mod
Patel[a]	2020	*JAAOS*	USA	Motion Analysis	Supine Pelvis: Global Coordinate system*	CT Scan	Supine hip high flexion, supine hip mid-flexion	MATLAB: Mathworks	19	Mod
Ross[a]	2014	*AJSM*	USA	Motion Analysis	Supine Pelvis: Angle between line connecting the midpoint of the sacral plate to the femoral head axis and vertical axis	CT scan	Supine hip flexion, internal rotation	Dyonics Plan	22	Low
Van Houcke	2020	*Clin. Biomech.*	Belgium	Motion Analysis	Supine Pelvis: Neutral Tilt*	None	Supine hip flexion	MATLAB: Mathworks	22	Low

Results: Hip Biomechanics in Dysplasia

- Increased anterior pelvic tilt in the standing position for dysplastic hips compared to a control population
  - May confer additional hip stability while standing
- Femoral head coverage was lower and Von Mises Stresses were significantly higher with more posterior pelvic tilt in dysplastic subjects
- Hip joint maximum contact pressure was significantly higher in the standing position with more posterior pelvic tilt in dysplastic subjects



Calculated femoral head coverage percentage (A) and Von Mises Stresses (B) in neutral, anterior, and posterior pelvic tilt reported by Hasegawa et al[10].

Results: Effect of Pelvic Tilt on Hip Motion

- In FAI three studies evaluating the impact of pelvic tilt on hip motion
- All 3 found increasing hip range of motion with posterior pelvic tilt
  - Decreasing hip motion with anterior pelvic tilt

	Loading Condition	Hip Motion° Seated; Neutral PT	Hip Motion° Lumbar Extension;Anterior PT	Hip Motion° Lumbar Flexion: Posterior PT	Anterior Pelvic Tilt 10°	Anterior Pelvic Tilt 5°	Neutral Pelvic Tilt	Posterior Pelvic Tilt 5°	Posterior Pelvic Tilt 10°
Aminoff[19]	Seated; Clinical Range of Motion	Control: IR 37.5; ER: 36.9; FAI: IR 30.3; ER: 36.0	Control: IR: 25.9; ER: 30.8; FAI: IR: 20.5; ER: 29.5	Control: IR: 41.6; ER: 36.8; FAI: IR: 34.3; ER: 35.0					
Patel[25]	Supine; High Hip Flexion: 100 Flexion; Mid Hip Flexion: 35 Flexion				High Flexion IR: -6.5±9.3*; Mid Flexion IR: 36.1±6.8	High Flexion IR: 0.2±9.3*; Mid Flexion IR: 37.0±5.2	High Flexion IR: 4.3±8.4; Mid Flexion IR: 37.2±5.3	High Flexion IR: 8.9±6.7*; Mid Flexion IR: 37.9±4.4	High Flexion IR: 12.9±5.8*; Mid Flexion IR: 38.5±3.0
Ross[26]	Supine: (IR at 90 hip flexion; FADIR (90 Flexion; 15 adduction); Maximum flexion)				IR: 26.1±13.5**; FADIR: 15.5±12.7**; Flexion: 109.3±10.9**		IR: 32.0±12.6; FADIR: 24.0±.12.9; Flexion: 119.3±10.8		IR: 37.1±12.4**; FADIR: 31.4±13.8**; Flexion: 129.3±10.8**

Results: Effect of Pelvic Tilt on Hip Motion

- In FAI nine studies evaluated dynamic sagittal hip and pelvic motion during functional maneuvers
- During squat, FAI subjects had increased anterior pelvic tilt and lower total pelvic motion compared to controls
- FAI patients had more anterior pelvic tilt during weight bearing step down and high step but not with supine hip flexion

	Loading Condition	Walk		Squat		High Step	Step Down		Supine Hip Flexion	Sit to Stand		
Author	Motion Variable	*Hip Motion* (˚)	*Pelvic Motion* (˚)	*Hip Motion* (˚)	*Pelvic Motion* (˚)	*Pelvic Motion* (˚)	*Hip Motion* (˚)	*Pelvic Motion* (˚)	*Active* (˚)	*Passive* (˚)	*Sitting* (˚)	*Standing* (˚)
Atkins	Walking		**Resting PT** FAI: 3.4; Control: 9.8*; **Change in PT:** FAI: -1.0; Control: 4.4*									
Bagwell	Deep Squat			**Hip Flexion** FAI: 106.6±14; Control: 113±6.7	**Anterior PT** FAI: 23.4±8.2; Control: 12.5±17.1*							
Bagwell	Deep Squat, High Step				**Posterior PT** FAI: 8.4±11.1 Control: 21.1±11.3 **Pelvifemoral Ratio** FAI: 0.26±0.1 Control: 0.49±0.1	**Posterior PT** FAI: 15.9±3.7 Control:20.0±7.1 **Pelvifemoral Ratio:** FAI: 0.22±0.05; Control: 0.30±0.12						
Catelli	Squat			**Sagittal Hip ROM^** FAI: 88.6±23.5 Control: 103.8±10.6˚	**Pelvic ROM^** FAI: 7.2±4.1 Control: 12.7±6.6˚							
Fader	Sit to Stand										**Sacral Slope:** FAI: 30±9; Control:14±10˚˚	**Sacral Slope:** FAI: 42±9; Control: 37±5˚
Lamontagne	Squat				**Sagittal Pelvic ROM** FAI: 14.7±8.4 Control: 24.2±6.8˚˚							
Lewis	Step Down[b]						**Hip Flexion^:** FAI Female:40.2±8.9; FAI Male: 30.9±5.9; Control Female:32.1±9.4 Control Male: 29.2±9.9	**Anterior PT^** FAI Female: 13.9±6.1; FAI Male: 6.1±4.4*; Control Female: 7.8±7.4 Control Male: 4.1±7.5*				
Ng	Walk, Squat	**Sagittal hip ROM** FAI: 45±5; Control: 51±4*	**Sagittal Pelvic ROM** FAI: 3±1; Control: 3±1	**Sagittal Hip ROM** FAI: 98±18; Control: 109±11	**Sagittal Pelvic ROM** FAI: 11±4; Control: 15±7							
Van Houcke	Supine Hip Flexion								**Posterior PT** FAI: 12.5 (11.5-13.6) Control: 9.1 (8.2-9.9)˚˚	**Posterior PT** FAI: 10.5 (8.9-12.1) Control: 10.0 (8.7-11.4)		

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Conclusions

- Hip joint stress is increased with posterior pelvic tilt in dysplastic patients, while increasing posterior pelvic tilt increases hip range of motion to impingement in patients with FAI.

- During weightbearing exercises, the ability for FAI patients to posteriorly tilt the pelvis is restricted compared to a control population.

Study	Study findings relative to pelvic tilt and sagittal pelvic motion
Aminoff	Anterior tilt restricts hip flexion and internal rotation for both FAI and control patients
Atkins	Male FAI patients have increased posterior pelvic tilt during gait. FAI patients have less pelvic motion during gait than control patients when compared to the standing position
Bagwell	FAI patients have significantly decreased posterior pelvic tilt during maximum squat compared to control patients
Bagwell	FAI patients with decreased posterior tilt and smaller pelvifemoral ratios with squat and high step compared to control patients
Catelli	FAI patients have decreased posterior pelvic tilt during the descent phase of squat compared to control patients. FAI patients have decreased hip motion during descent phase of squat compared to control patients.
Fader	FAI patients had less spine flexion and more hip flexion compared to controls when sitting. There was increased anterior pelvic tilt in FAI patients when sitting.
Hasegawa	Posterior pelvic tilt increases hip joint stress and decreases femoral head coverage in dysplastic and borderline dysplastic compared to control patients
Kitamura	Dysplastic patients have increased dynamic changes in pelvic tilt from supine to standing, indicating that postural changes in pelvic tilt affect joint contact forces. A larger posterior tilt is associated with increased hip joint contact pressure from supine to standing.
Lamontagne	FAI patients have decreased posterior pelvic tilt during maximum squat compared to controls. FAI patients have significantly decreased overall pelvic sagittal range of motion compared to controls
Lewis	FAI patients have increased hip flexion and decreased posterior pelvic tilt during step down compared to control patients.
Ng	FAI patients have restricted hip and pelvic ROM when squatting
Patel	Posterior pelvic tilt significantly increases hip internal rotation in high flexion but not mid flexion in hips with FAI morphology in the supine position
Ross	Posterior pelvic tilt significantly increases hip internal rotation in flexion and FADIR positions in hips with FAI morphology in the supine position
Van Houcke	FAI patients have increased posterior pelvic tilt during non-weight bearing in line active, but not passive hip flexion compared to control patients

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