Assessing Movement Quality: What is Important?

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Objectives

- Define movement quality
- Identify relationship between movement quality & injury risk
- Identify common movement quality deficits that have been found to lead to injury
- Discuss performance-injury conflict

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Kozlenia & Domaradzki, 2021; Wijekulasuriya et al., 2025; Dinc et al., 2023

What do we mean by movement quality?

- An individual's ability to perform a movement pattern
- Synergistic coordination of multiple muscle groups
- Having the mobility and stability to maintain a targeted movement pattern

Dorrel et al., 2018

Why do we care?

- Can help to identify impairments that MAY put the athlete at greater risk for injury

Why do we care?

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Injury Prevention and Risk Factor Screening

The Functional Movement Screen as a Predictor of Injury in National Collegiate Athletic Association Division II Athletes

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Why do we care?

Table 3. Functional Movement Screen (FMS) Cross-Tabulation for Each Injury Category

Score	Musculoskeletal Injury	No Musculoskeletal Injury	Total
FMS+ (≤ cut score)	72	72	144
FMS– (> cut score)	45	68	113
Total	117	140	257
	Overall Injury	**No Overall Injury**	**Total**
FMS+ (≤ cut score)	76	68	144
FMS– (> cut score)	48	65	113
Total	124	133	257
	Severe Injury	**No Severe Injury**	**Total**
FMS+ (≤ cut score)	13	131	144
FMS– (> cut score)	7	106	113
Total	20	237	257

Table 5. Comparison of Sensitivity, Specificity, and Area Under the Curve Findings for Predicting Injury From the Functional Movement Screen Related Research

Item	Current Study[a]	O'Connor et al[8]	Dorrel et all[11b]
Sensitivity			0.24
Any injury	0.61	0.45	
Musculoskeletal injury	0.62	NA	
Overuse injury	NA	0.12	
Severe or serious injury	0.65	0.11	
Specificity			0.85
Any injury	0.49	0.78	
Musculoskeletal injury	0.49	NA	
Overuse injury	NA	0.9	
Severe or serious injury	0.45	0.93	
Area under the curve			0.58
Any injury	0.561	0.58	
Musculoskeletal injury	0.544	NA	
Overuse injury	NA	0.52	
Severe or serious injury	0.534	0.53	

Abbreviation: NA, not applicable.

[a] National Collegiate Athletic Association Division II athletes.

[b] Systematic review and meta-analysis.

Why do we care?

- Can help to identify impairments that MAY put the athlete at greater risk for injury
- Can help assess readiness to return to sport following an injury
  - **GOAL:** reduce risk of re-injury

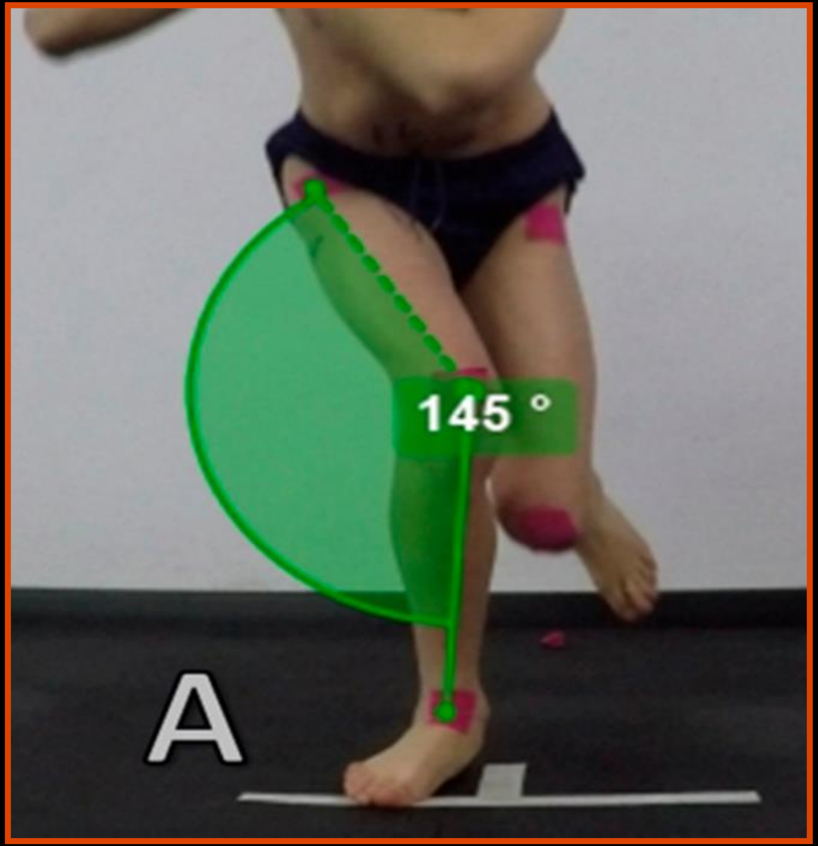
Common Examples

Andreyo et al., 2024; Chaaban et al., 2022; Wilczynski et al., 2020

Risk Factors & Movement Quality

Example – ACL Injury

- Dynamic Knee Valgus
- Poor neuromotor control during **landing**



Risk Factors & Movement Quality

Table 3. vGRF by group and limb during the impact and propulsion phases. Values are presented in multiples of body weight.

	Impact Phase Mean ± SD		Propulsion Phase Median [IQR]	
	ACLR	Control	ACLR	Control
Involved Limb	1.92 ± 0.49	2.34 ± 0.57	1.07 [1.05, 1.14]	1.19 [1.09, 1.32]
Uninvolved Limb	2.24 ± 0.53	2.30 ± 0.47	1.11 [1.09, 1.29]	1.18 [1.10, 1.37]
LSI (%)	89.2 ± 26.4	105 ± 21.8	95.3 [90.9, 99.4]	100 [94.7, 104]

The impact phase is represented as the mean ± SD. The propulsion phase is represented as the median [IQR] due to the non-normality of the distribution. ACLR, anterior cruciate ligament reconstruction. IQR, interquartile range. LSI, limb symmetry index. vGRF, vertical ground reaction force.

Andreyo et al., 2024; Chaaban et al., 2022; Wilczynski et al., 2020

Risk Factors & Movement Quality

Example - ACL Injury

- Dynamic Knee Valgus
- Poor neuromotor control during **landing**
- **Poor neuromotor control with change of direction**

Ceyssens et al., 2019

Risk Factors & Movement Quality

Example - Running Related Injuries

- Commonly reported injuries
  - Patellofemoral Pain Syndrome
  - IT Band Syndrome
  - Medial tibial Stress Syndrome
  - Achilles Tendinopathy
  - Plantar Fasciitis

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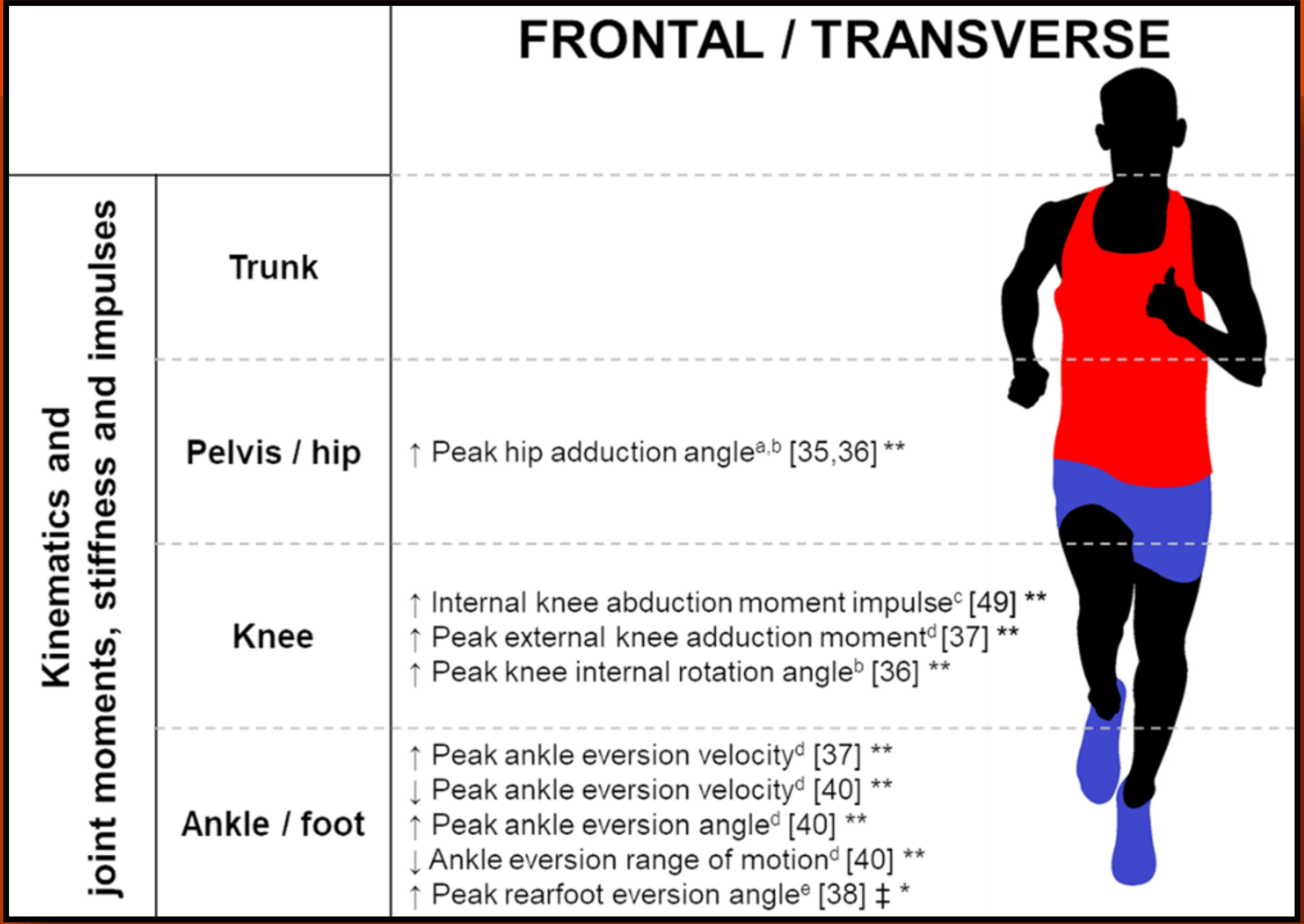
Risk Factors & Movement Quality

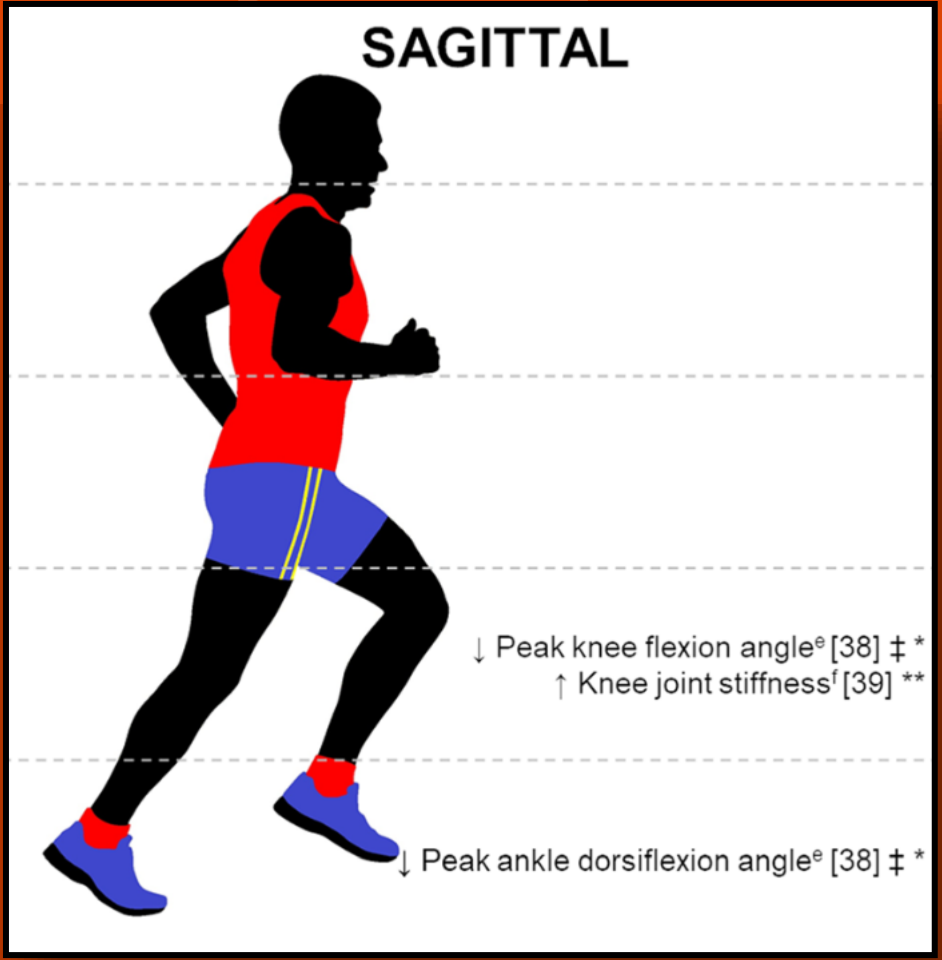
Example - Running Related Injuries

- Factors Associated with Injury
  - Kinematics
  - Kinetics
  - Spatiotemporal

Ceyssens et al., 2019

Risk Factors & Movement Quality





Ceyssens et al., 2019

Risk Factors & Movement Quality

Kinetics	Impact-related variables	↑ Vertical (average and instantaneous) loading rate[g,h] [41,42] ** ↑ Vertical impact peak[h] [42] ** ↓ Asymmetry in vertical impact peak[i] [44] ** ↑ Peak braking force[j] [43] **
	Plantar pressure variables	↑ Vertical plantar peak force (underneath MT II)[k] [45] * ↑ Vertical plantar peak force (underneath MT V)[l] [46] ** ↑ Absolute force-time integral (underneath MT V)[l] [46] ** ↓ Anteroposterior displacement of the center of force[m,l] [46] **, [47] * ↓ Velocity of anteroposterior displacement[l] [46] ** ↑ Lateral directed force distribution[m,l] [46] **, [47] * ↑ Medial directed force distribution[n] [48] * ↑ Lateral directed force displacement (at initial contact, forefoot contact, foot flat and heel-off)[l] [46] ** ↓ Velocity of mediolateral displacement[l] [46] **

- Spatiotemporal

Risk Factors & Movement Quality

Running Related Injuries

Spatio-temporal	↓ Step rate[o] [50] ** ↓ Ground contact time[g] [41] ** ↑ Asymmetry in ground contact time[i] [44] ** ↓ Time to vertical peak force (underneath lateral heel)[k] [45] *

- Spatiotemporal

Risk Factors & Movement Quality

Throwing Related Injuries

- Factors Associated with Injury
  - Kinetics
  - Kinematics
  - Spatiotemporal

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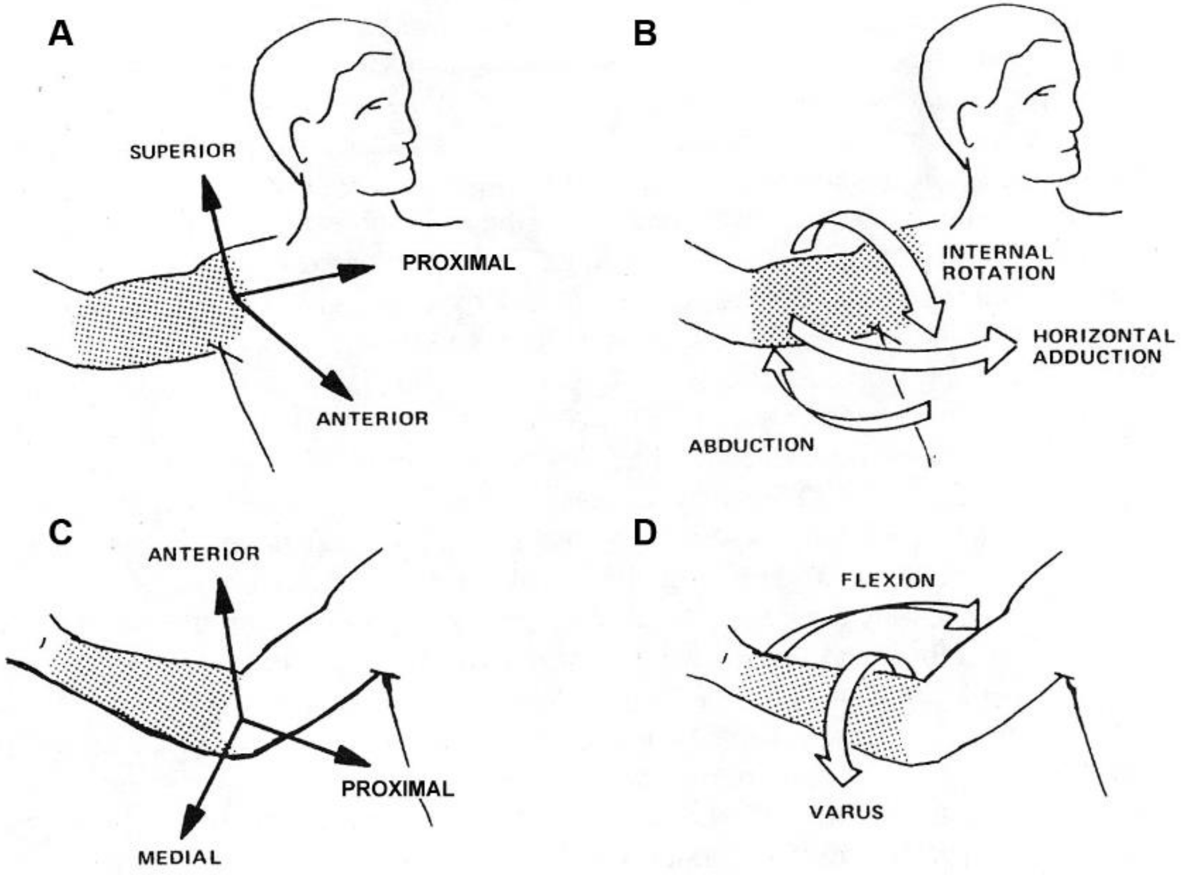

Figure 3. Definition of kinetic parameters: (A) forces applied by the trunk to the upper arm at the shoulder, (B) torques applied by the trunk to the upper arm about the shoulder, (C) forces applied by the upper arm to the forearm at the elbow, and (D) torques applied by the upper arm to the forearm about the elbow.

Risk Factors & Movement Quality

A

B

TABLE 1

Shoulder and Elbow Forces and Torques Among the Fastball, Slider, Curveball, and Changeup[a]

	Fastball (n = 18)	Slider (n = 18)	Curveball (n = 18)	Changeup (n = 18)	*P* Values for Pitch Type and Pairwise Comparisons
Arm cocking phase					
Maximum elbow varus torque, N·m	96 ± 17	95 ± 14	92 ± 18	88 ± 11	.009[b,c,d]
Maximum shoulder horizontal adduction torque, N·m	103 ± 11	110 ± 18	113 ± 17	94 ± 7	<.001[b,d,e]
Maximum shoulder internal rotation torque, N·m	97 ± 17	97 ± 15	93 ± 19	89 ± 12	.017
Maximum shoulder anterior force, N	330 ± 43	329 ± 44	345 ± 48	305 ± 24	.005[b,e]
Arm deceleration phase					
Maximum elbow flexion torque, N·m	74 ± 14	70 ± 11	68 ± 12	65 ± 12	<.001[b,c,f]
Maximum elbow proximal force, N	1085 ± 160	1105 ± 176	1075 ± 133	980 ± 159	.001[b,c,d,e]
Maximum shoulder proximal force, N	1265 ± 220	1280 ± 255	1260 ± 225	1120 ± 210	<.001[b,c,d,e]

Figure 3. Definition of kinetic parameters: (A) forces applied by the trunk to the upper arm at the shoulder, (B) torques applied by the trunk to the upper arm about the shoulder, (C) forces applied by the upper arm to the forearm at the elbow, and (D) torques applied by the upper arm to the forearm about the elbow.

Escamilla et al., 2017; Stapleton et al., 2020

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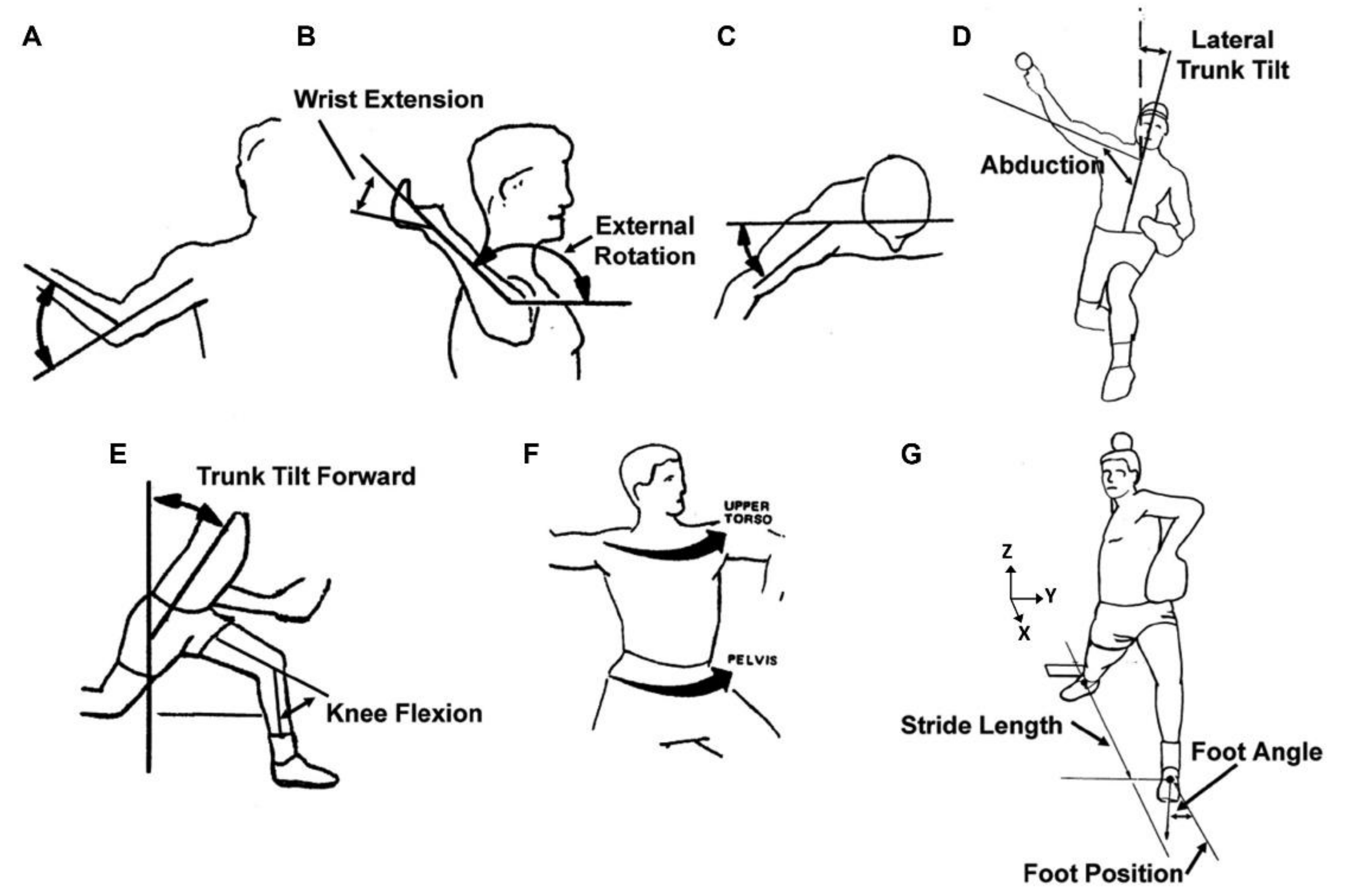

Figure 4. Definition of kinematic parameters: (A) elbow flexion, (B) shoulder external rotation, (C) shoulder horizontal adduction, (D) shoulder abduction and contralateral trunk tilt, (E) knee flexion and forward trunk tilt, (F) pelvis angular velocity and upper trunk angular velocity, and (G) stride length, foot angle, and foot position.

TABLE 2
Body Segment and Joint Positions Among the Fastball, Slider, Curveball, and Changeup[a]

	Fastball (n = 18)	Slider (n = 18)	Curveball (n = 18)	Changeup (n = 18)	*P* Values for Pitch Type and Pairwise Comparisons
Lead foot contact					
Elbow flexion, deg	94 ± 18	91 ± 21	95 ± 20	95 ± 14	.761
Shoulder external rotation, deg	48 ± 19	48 ± 19	49 ± 23	48 ± 22	.594
Shoulder abduction, deg	93 ± 9	94 ± 8	91 ± 9	92 ± 9	.377
Shoulder horizontal abduction, deg	25 ± 8	25 ± 9	25 ± 9	24 ± 9	.691
Forward trunk tilt, deg	8 ± 6	8 ± 5	8 ± 5	10 ± 6	.378
Pelvis rotation angle, deg (closed –; open +)	27 ± 10	22 ± 9	26 ± 12	28 ± 11	.070
Upper trunk rotation angle, deg (closed –; open +)	–19 ± 8	–21 ± 7	–19 ± 6	–16 ± 7	.671
Knee flexion, deg	41 ± 9	42 ± 11	41 ± 10	41 ± 10	.889
Stride length between ankles, % height	82 ± 6	80 ± 6	81 ± 7	81 ± 7	.393
Foot position, cm (closed –; open +)	19 ± 8	18 ± 7	21 ± 7	19 ± 8	.212
Foot angle, deg (closed –; open +)	–2 ± 8	–1 ± 9	–4 ± 9	–2 ± 10	.347
Arm cocking phase					
Maximum elbow flexion, deg	112 ± 14	111 ± 16	113 ± 16	113 ± 13	.829
Maximum shoulder horizontal adduction, deg	14 ± 5	13 ± 7	14 ± 6	17 ± 6	.071
Maximum shoulder external rotation, deg	174 ± 10	174 ± 10	177 ± 10	176 ± 9	.240
Ball release					
Elbow flexion, deg	31 ± 5	32 ± 6	32 ± 6	32 ± 8	.990
Shoulder abduction, deg	92 ± 7	92 ± 5	92 ± 8	90 ± 11	.816
Forward trunk tilt, deg	36 ± 9	34 ± 9	37 ± 7	31 ± 10	.006[b,c,d]
Contralateral trunk tilt, deg	21 ± 12	17 ± 10	24 ± 10	19 ± 11	.005[b,d,e]
Knee flexion, deg	34 ± 15	38 ± 13	38 ± 13	40 ± 14	.007[b,c]
Amount the knee extends from lead foot contact to ball release, deg	8 ± 8	4 ± 7	3 ± 6	1 ± 7	.009[b,c]

Risk Factors & Movement Quality

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TIMING

Risk Factors & Movement Quality

TABLE 3
Magnitude and Timing of Maximum Velocities Among the Fastball, Slider, Curveball, and Changeup[a]

	Fastball (n = 18)	Slider (n = 18)	Curveball (n = 18)	Changeup (n = 18)	*P* Values for Pitch Type and Pairwise Comparisons
Arm cocking phase					
Maximum pelvis angular velocity, deg/s	540 ± 100	520 ± 60	505 ± 95	500 ± 100	.003[b,c,d]
Time of maximum pelvis angular velocity, % delivery complete	33 ± 15	36 ± 17	35 ± 18	29 ± 11	.572
Maximum upper trunk angular velocity, deg/s	1080 ± 90	1060 ± 75	1055 ± 85	1025 ± 85	.008[b,c]
Time of maximum upper trunk angular velocity, % delivery complete	48 ± 11	51 ± 11	50 ± 12	45 ± 12	.028
Arm acceleration phase					
Maximum elbow extension angular velocity, deg/s	2120 ± 270	2040 ± 220	2105 ± 250	2075 ± 240	.304
Time of maximum elbow extension angular velocity, % delivery complete	92 ± 4	91 ± 4	92 ± 3	91 ± 5	.823
Maximum shoulder internal rotation angular velocity, deg/s	6715 ± 760	6690 ± 565	6705 ± 700	6275 ± 715	.007[b,c,e,f]
Time of maximum shoulder internal rotation angular velocity, % delivery complete	103 ± 3	104 ± 4	102 ± 4	105 ± 4	.235
Ball velocity, m/s	38.1 ± 1.4	34.3 ± 2.3	32.3 ± 1.6	33.6 ± 1.7	<.001[b,c,d,g,h]

Risk Factors & Movement Quality

Throwing Related Injuries

In summary, throwers ***NEED*** adequate:

- Mobility
- Strength & Endurance
- Dynamic Stability
- Coordination & Timing

BUT…

Risk $\neq$ Injury

Dos'Santos et al., 2021

Injury Risk vs Performance

Do the presence of risk factors always lead to injury?

Example: Cutting Mechanics

- Predictors of Performance
- "Safe" Cutting Mechanics

Dos'Santos et al., 2021

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Predictors of Performance	Effects on Knee

Dos'Santos et al., 2021; Andreyo et al., 2024

Injury Ri

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Example: Cut

- Predictors o
- “Safe” Cutti

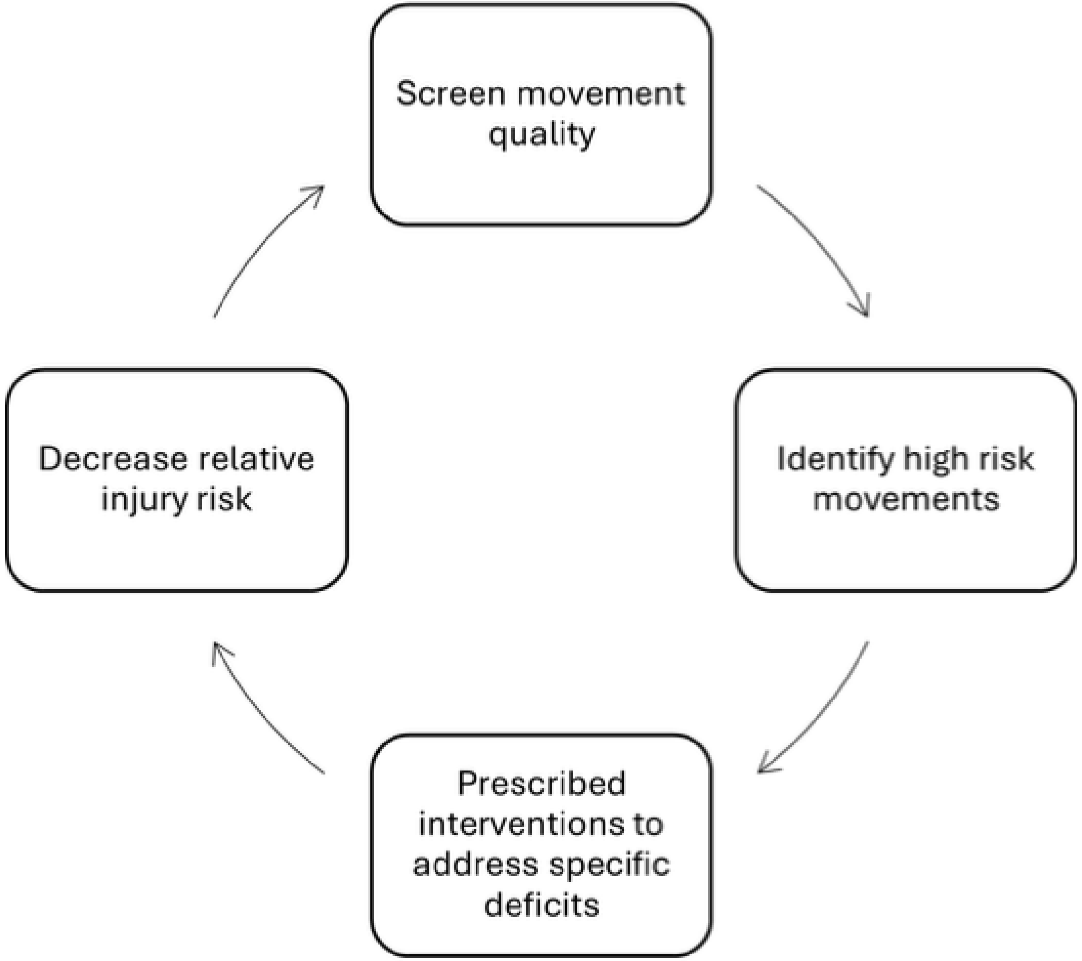

Figure 3. A process for screening movement quality and applying interventions.

Dos'Santos et al., 2021; Andreyo et al., 2024

Injury Risk vs Performance

When to intervene?

Factors to consider:

- Athlete training age
- History of Injury
- Impact on performance & the long term implications of this

Injury Risk vs Performance

1. Identify risk factors that predispose the athlete to injury
2. Assess movement quality to identify potential impairments
3. Weigh injury risk vs impact on performance
4. Implement interventions where appropriate appropriate

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