Screening Measures for Prediction of Foot and Ankle Injury

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BACKGROUND AND PURPOSE

- Approximately 12-15% of all injuries sustained by high school and college athletes are ankle ligament sprains[1,2]
- A very high degree of interdependence exists between proximal and distal factors that greatly influences injury risk
  - Excessive foot pronation or supination have been related to increased risk for ankle sprain[3]
  - Posterior tibialis weakness has been shown to increase susceptibility to ankle instability and chronic dysfunction[4]
  - History of any musculoskeletal sprain or strain has been associated with increased risk for subsequent injury[5]
- Identification of athletes with elevated injury risk is a prerequisite for implementation of risk reduction strategies
- The purpose of this study was to assess the potential value of foot width index (FWI), inversion strength, and injury history for development of an accurate multivariable model for prediction of foot and ankle sprains and strains

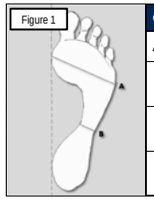
PARTICIPANT CHARACTERISTICS AND PROCEDURES

- Participants were 84 high school football players and 51 female college athletes available for pre-season screening
  - High School (HS) Football (n=84), 15.24 ±1.21, 179.48 ±8.13 cm; 80.97 ±16.50 kg
  - Women's Volleyball (n=16), 19.25 ±1.09 years; 176.05 ±8.46 cm; 66.31 ±6.70 kg
  - Women's Soccer (n=27), 20.0 ±1.17 years; 168.0 ±6.46 cm; 63.2 ±5.89 kg
  - Women's Cross-Country (n=8), 18.88 ±0.93 years; 165.74 ±7.70 cm; 59.93 ±6.23 kg
- Anthropometric measurements obtained and screening tests administered prior to first practice session
  - Body Mass Index (BMI) and Mass Moment of Inertia (MMOI) derived from height and mass measurements
  - Foot Width Index (FWI) derived from dominant footprint (ratio of midfoot width to forefoot width; Figure 1)[3]
  - Ankle inversion force (kg) recorded for both dominant and non-dominant extremities
    - Moment arm (cm) measured from base of 1st metatarsal to anterior/distal margin of tibial malleolus (Figure 2)
    - Participants were seated with leg crossed over opposite thigh with leg in horizontal position (Figure 3)
    - Isometric inversion force measured with hand dynamometer (average of 3 trials) for both ankles
    - Isometric inversion torque (Nm) calculated from force and moment arm measurements
      - Bilateral difference (% asymmetry) and average for dominant and non-dominant calculated (Nm)
- Sport Fitness Index (SFI) administered prior to start of practice sessions to quantify functional status (0-100 score)[5]
  - Self-reported sprain or strain sustained during the previous 12 months documented prior to participation
  - Self-reported foot or ankle sprain or strain sustained during sport season documented at end of season
- Receiver operating characteristic (ROC) analysis used to select cut-points for binary classification of injury risk
  - Cross-tabulation analysis used to quantify univariable associations between measures and injury occurrence
  - Logistic regression analysis used to develop multivariable models (retrospective and prospective)

RESULTS

- 23% (19/84) of HS football players reported having sustained foot/ankle injury during previous 12 months
- 11% (7/64) of HS football players available for follow-up reported foot/ankle injury having occurred during season
  - FWI, inversion asymmetry, and SFI score demonstrated both retrospective and prospective associations with injury
    - Cut-points derived from retrospective and prospective analyses differed from each other (Tables 1 and 2)
      - FWI cut-points comparable in terms of specificity; better sensitivity for prospectively-derived cut-point (Figure 4)
      - Inversion asymmetry cut-points demonstrated exceptionally strong sensitivity for both analyses (Figure 5)
      - Prospectively-derived SFI cut-point demonstrated low sensitivity, but exceptionally strong specificity (Figure 6)
- 27% (14/51) of college female athletes reported having sustained a foot/ankle injury during the previous 12 months
- 21% (9/43) of college female athletes available for follow-up reported foot/ankle injury having occurred during season
  - FWI, inversion average Nm, and SFI score demonstrated retrospective association with injury (Tables 3 and 4)
  - Prospective analysis failed to identify any substantial associations between pre-participation measures and injury
    - ROC curves for the 3 measures exhibit stronger associations with previous injury than season injury (Figures 7-9)

Figure 1



Chippaux-Smirak index[3]	
Arch Height	Index
High	≤ 0.29
Normal	0.30 - 0.39
Low	≥ 0.40

Figure 2

Figure 3

Table 1 – HS Football Retrospective Analysis (Previous injury)

Measure	Cut-Point	Sensitivity	Specificity	*P*	OR
FWI	≥ .46	58%	68%	.041	2.88
Inv. Asym.	≥ 13%	95%	31%	.018	8.00
SFI Score	≤ 84	84%	41%	.033	3.79
3-Factor Model	≥ 2+	47%	91%	.001	8.85

Table 2 – HS Football Prospective Analysis (Season injury)

Measure	Cut-Point	Sensitivity	Specificity	*P*	OR
FWI	≥ .48	71%	67%	.063	5.00
Inv. Asym.	≥ 19%	86%	46%	.118	5.03
SFI Score	≤ 64	43%	91%	.036	7.80
3-Factor Model	≥ 2+	86%	74%	.004	16.80

Figure 4

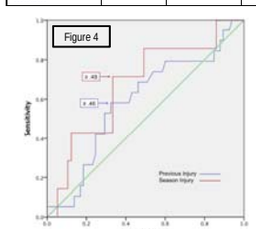


Figure 5

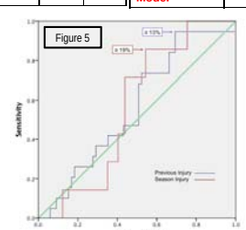


Figure 6

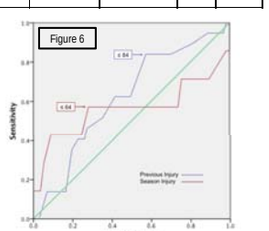


Table 3 – College Female Retrospective Analysis (Previous injury)

Predictor	Cut-Point	Sensitivity	Specificity	*P*	OR
FWI	≤ .20	29%	92%	.080	4.53
Inversion Avg.	≤ 8.5 Nm	57%	76%	.031	4.15
SFI Score	≤ 74	64%	70%	.027	4.26
3-Factor Model	Any 2+	50%	87%	.011	6.40

Table 4 - College Female Previous Injury Model

Factors +	Injury	No Injury	Incidence
0	0	19	0%
1	7	13	35%
2	7	5	58%

Figure 7

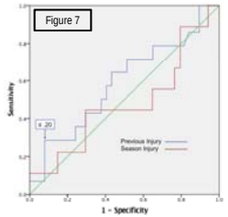


Figure 8

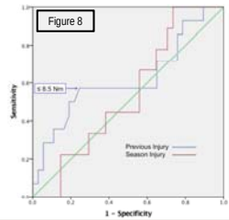
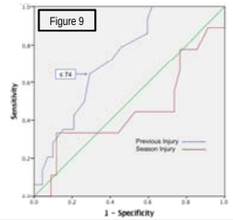


Figure 9



CLINICAL RELEVANCE

- Easily obtainable pre-participation measures demonstrated exceptionally strong injury prediction value
  - FWI demonstrated comparable association with previous and subsequent foot/ankle injury in HS football players
    - Both retrospective and prospective cut-points exceeded value defining low arch (i.e., excessive pronation)
  - FWI only demonstrated association with previous foot/ankle injury in college female athletes
    - Retrospectively derived cut-point was lower than value defining high arch (i.e., excessive supination)
  - Inversion isometric torque appears to identify both previous injury effect and elevated risk for subsequent injury
    - Bilateral asymmetry associated with both previous and subsequent foot/ankle injury in HS football players
    - Bilateral average inversion strength retrospectively associated with previous injury in college female athletes
  - SFI score cut-points varied, but strong associations with foot/ankle injury demonstrated for both groups
- Models that combine positive factors demonstrate greater discriminatory power than any single factor in isolation
  - Foot structure and inversion strength measures can identify persisting effects of previous injury and elevated risk
    - Acquisition of pre-participation measures can identify athletes likely to benefit from targeted interventions

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5. Wilkerson GB, Colston MA, Baker CS. A Sport Fitness Index for assessment of sport-related injury risk. *Clin J Sport Med*. 2016;26: DOI:0000000000000280.