



Joint Mobility and Stability Strategies for the Ankle

Independent Study
Course 29.2.5

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CONTINUING PHYSICAL THERAPY EDUCATION



REFERENCES

1. Luciano A de P, Lara LCR. Epidemiological study of foot and ankle injuries in recreational sports. *Acta Ortop Bras.* 2012;20(6):339-342. doi:10.1590/S1413-78522012000600005.
2. Doherty C, Delahunt E, Caulfield B, Hertel J, Ryan J, Bleakley C. The incidence and prevalence of ankle sprain injury: a systematic review and meta-analysis of prospective epidemiological studies. *Sports Med.* 2014;44(1):123-140. doi:10.1007/s40279-013-0102-5.
3. Ruscio B, Smith J, Amoroso P, et al. *DOD Military Injury Prevention Priorities Working Group: Leading Injuries, Causes and Mitigation Recommendations*. DTIC Document; 2006. <http://bit.ly/2MPRz6P>. Accessed November 19, 2014.
4. Cameron KL, Owens BD, DeBerardino TM. Incidence of ankle sprains among active-duty members of the United States armed services from 1998 through 2006. *J Athl Train.* 2010;45(1):29-38. doi:10.4085/1062-6050-45.1.29
5. Waterman BR. The epidemiology of ankle sprains in the United States. *J Bone Jt Surg Am.* 2010;92(13):2279. doi:10.2106/JBJS.I.01537.
6. Kristianslund E, Bahr R, Krosshaug T. Kinematics and kinetics of an accidental lateral ankle sprain. *J Biomech.* 2011;44(14):2576-2578. doi:10.1016/j.jbiomech.2011.07.014.
7. Panagiotakis E, Mok KM, Fong DT, Bull AMJ. Biomechanical analysis of ankle ligamentous sprain injury cases from televised basketball games: Understanding when, how and why ligament failure occurs. *J Sci Med Sport.* 2017;20(12):1057-1061. doi:10.1016/j.jsams.2017.05.006.
8. Fong DT, Ha SC, Mok KM, Chan CW, Chan KM. Kinematics analysis of ankle inversion ligamentous sprain injuries in sports: five cases from televised tennis competitions. *Am J Sports Med.* 2012;40(11):2627-2632. doi:10.1177/0363546512458259.
9. Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E. Recovery from a first-time lateral ankle sprain and the predictors of chronic ankle instability: a prospective cohort analysis. *Am J Sports Med.* 2016; 44(4):995-1003. doi:10.1177/0363546516628870.
10. Gribble PA, Delahunt E, Bleakley C, et al. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium. *J Orthop Sports Phys Ther.* 2013;43(8):585-591. doi:10.2519/jospt.2013.0303.
11. Hiller CE, Kilbreath SL, Refshauge KM. Chronic ankle instability: evolution of the model. *J Athl Train.* 2011;46(2):133-141. doi:10.4085/1062-6050-46.2.133.
12. Gribble PA, Bleakley CM, Caulfield BM, et al. Evidence review for the 2016 International Ankle Consortium consensus statement on the prevalence, impact and long-term consequences of lateral ankle sprains. *Br J Sports Med.* June 2016;bjsports-2016-096189. doi:10.1136/bjsports-2016-096189.
13. Wikstrom EA, Hubbard-Turner T, Guderian S, Turner MJ. Lateral ankle sprain in a mouse model: lifelong sensorimotor dysfunction. *J Athl Train.* 2018;53(3):249-254. doi:10.4085/1062-6050-365-16.
14. Houston MN, Hoch JM, Hoch MC. Patient-reported outcome measures in individuals with chronic ankle instability: a systematic review. *J Athl Train.* 2015;50(10):1019-1033. doi:10.4085/1062-6050-50.9.01.
15. Hubbard-Turner T, Wikstrom EA, Guderian S, Turner MJ. An acute lateral ankle sprain significantly decreases physical activity across the lifespan. *J Sports Sci Med.* 2015;14(3):556-561.
16. Wikstrom EA, Naik S, Lodha N, Cauraugh JH. Bilateral balance impairments after lateral ankle trauma: A systematic review and meta-analysis. *Gait Posture.* 2010;31(4):407-414. doi:10.1016/j.gaitpost.2010.02.004.
17. Munn J, Sullivan SJ, Schneiders AG. Evidence of sensorimotor deficits in functional ankle instability: A systematic review with meta-analysis. *J Sci Med Sport.* 2010;13(1):2-12. doi:10.1016/j.jsams.2009.03.004.

18. Moisan G, Descarreaux M, Cantin V. Effects of chronic ankle instability on kinetics, kinematics and muscle activity during walking and running: A systematic review. *Gait Posture*. 2017;52:381-399. doi:10.1016/j.gaitpost.2016.11.037.
19. De Ridder R, Willems T, Vanrenterghem J, Robinson MA, Palmans T, Roosen P. Multi-segment foot landing kinematics in subjects with chronic ankle instability. *Clin Biomech*. 2015;30(6):585-592. doi:10.1016/j.clinbiomech.2015.04.001.
20. Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E. Single-leg drop landing movement strategies 6 months following first-time acute lateral ankle sprain injury. *Scand J Med Sci Sports*. 2015;25(6):806-817. doi:10.1111/sms.12390.
21. Futatsubashi G, Sasada S, Tazoe T, Komiyama T. Gain modulation of the middle latency cutaneous reflex in patients with chronic joint instability after ankle sprain. *Clin Neurophysiol*. 2013;124(7):1406-1413. doi:10.1016/j.clinph.2013.01.029.
22. Burcal CJ, Wikstrom EA. Plantar cutaneous sensitivity with and without cognitive loading in people with chronic ankle instability, copers, and uninjured controls. *J Orthop Sports Phys Ther*. 2016;46(4):270-276. doi:10.2519/jospt.2016.6351.
23. Konradsen L. Factors contributing to chronic ankle instability: kinesthesia and joint position sense. *J Athl Train*. 2002;37(4):381-385.
24. Jazayeri Shooshtari SM, Didehdar D, Moghtaderi Esfahani AR. Tibial and peroneal nerve conduction studies in ankle sprain. *Electromyogr Clin Neurophysiol*. 2007;47(6):301-304.
25. Simon J, Docherty C. Slower nerve conduction velocity in individuals with functional ankle instability. *Int J Sports Med*. 2014;35(09):731-736. doi:10.1055/s-0033-1361183.
26. Nitz AJ, Dobner JJ, Kersey D. Nerve injury and grades II and III ankle sprains. *Am J Sports Med*. 1985;13(3):177-182.
27. Kleinrensink GJ, Stoeckart R, Meulstee J, et al. Lowered motor conduction velocity of the peroneal nerve after inversion trauma. *Med Sci Sports Exerc*. 1994;26(7):877-883.
28. Song K, Kang TK, Wikstrom EA, Jun H, Lee SY. Effects of reduced plantar cutaneous sensation on static postural control in individuals with and without chronic ankle instability. *J Sci Med Sport*. 2017;20(10):910-914. doi:10.1016/j.jsmams.2016.04.011.
29. Song K, Burcal CJ, Hertel J, Wikstrom EA. Increased visual use in chronic ankle instability: a meta-analysis. *Med Sci Sports Exerc*. 2016;48(10):2046-2056. doi:10.1249/MSS.0000000000000992.
30. Kim K-M, Ingersoll CD, Hertel J. Altered postural modulation of Hoffmann reflex in the soleus and fibularis longus associated with chronic ankle instability. *J Electromyogr Kinesiol*. 2012;22(6):997-1002. doi:10.1016/j.jelekin.2012.06.002.
31. Klykken LW, Pietrosimone BG, Kim K-M, Ingersoll CD, Hertel J. Motor-neuron pool excitability of the lower leg muscles after acute lateral ankle sprain. *J Athl Train*. 2011;46(3):263-269.
32. Kosik KB, Terada M, Drinkard CP, McCann RS, Gribble PA. Potential corticomotor plasticity in those with and without chronic ankle instability. *Med Sci Sports Exerc*. 2017;49(1):141-149. doi:10.1249/MSS.0000000000001066.
33. Pietrosimone BG, Gribble PA. Chronic ankle instability and corticomotor excitability of the fibularis longus muscle. *J Athl Train*. 2012;47(6):621-626.
34. Fraser JJ, Koldenhoven RM, Jaffri AH, et al. Foot impairments contribute to functional limitation in individuals with ankle sprain and chronic ankle instability. *Knee Surg Sports Traumatol Arthrosc*. 2018 July 6. doi:10.1007/s00167-018-5028-x.
35. Hiller CE, Nightingale EJ, Lin C-WC, Coughlan GF, Caulfield B, Delahunt E. Characteristics of people with recurrent ankle sprains: a systematic review with meta-analysis. *Br J Sports Med*. 2011;45(8):660-672. doi:10.1136/bjsm.2010.077404.
36. Wang Q, Whittle M, Cunningham J, Kenwright J. Fibula and its ligaments in load transmission and ankle joint stability. *Clin Orthop*. 1996;(330):261-270.
37. Herb CC, Chinn L, Dicharry J, McKeon PO, Hart JM, Hertel J. Shank-rearfoot joint coupling with chronic ankle instability. *J Appl Biomech*. 2014;30(3):366-372. doi:10.1123/jab.2013-0085.
38. Lundberg A, Svensson OK, Nemeth G, Selvik G. The axis of rotation of the ankle joint. *J Bone Joint Surg Br*. 1989;71(1):94-99.
39. Manter JT. Movements of the subtalar and transverse tarsal joints. *Anat Rec*. 1941;80(4):397-410.
40. Blakeslee TJ, Morris JL. Cuboid syndrome and the significance of midtarsal joint stability. *J Am Podiatr Med Assoc*. 1987;77(12):638-642. doi:10.7547/87507315-77-12-638.
41. McKeon PO, Hertel J, Bramble D, Davis I. The foot core system: a new paradigm for understanding intrinsic foot muscle function. *Br J Sports Med*. 2014;bjsports-2013.
42. McKenzie J. The Foot as a Half-dome. *Br Med J*. 1955;1(4921):1068-1070.
43. Fiolkowski P, Brunt D, Bishop M, Woo R, Horodyski M. Intrinsic pedal musculature support of the medial longitudinal arch: an electromyography study. *J Foot Ankle Surg*. 2003;42(6):327-333. doi:10.1053/jfas.2003.10.003.
44. Jung DY, Kim MH, Koh EK, Kwon OY, Cynn HS, Lee WH. A comparison in the muscle activity of the

- abductor hallucis and the medial longitudinal arch angle during toe curl and short foot exercises. *Phys Ther Sport*. 2011;12(1):30-35. doi:10.1016/j.ptsp.2010.08.001.
45. Kelly LA, Cresswell AG, Racinais S, Whiteley R, Lichtwark G. Intrinsic foot muscles have the capacity to control deformation of the longitudinal arch. *J R Soc Interface R Soc*. 2014;11(93):20131188. doi:10.1098/rsif.2013.1188.
46. Headlee DL, Leonard JL, Hart JM, Ingersoll CD, Hertel J. Fatigue of the plantar intrinsic foot muscles increases navicular drop. *J Electromyogr Kinesiol*. 2008;18(3):420-425. doi:10.1016/j.jelekin.2006.11.004.
47. Irwin CE. The calcaneus foot. *South Med J*. 1951;44(3):191-197.
48. Fraser JJ, Feger MA, Hertel J. Clinical commentary on midfoot and forefoot involvement in lateral ankle sprains and chronic ankle instability. part 1: anatomy and biomechanics. *Int J Sports Phys Ther*. 2016;11(6):992-1005.
49. Semple R, Murley GS, Woodburn J, Turner DE. Tibialis posterior in health and disease: a review of structure and function with specific reference to electromyographic studies. *J Foot Ankle Res*. 2009;2(1):24. doi:10.1186/1757-1146-2-24.
50. Caravaggi P, Pataky T, Günther M, Savage R, Crompton R. Dynamics of longitudinal arch support in relation to walking speed: contribution of the plantar aponeurosis. *J Anat*. 2010;217(3):254-261. doi:10.1111/j.1469-7580.2010.01261.x.
51. Hofmann CL, Okita N, Sharkey NA. Experimental evidence supporting isometric functioning of the extrinsic toe flexors during gait. *Clin Biomech*. 2013;28(6):686-691. doi:10.1016/j.clinbiomech.2013.05.006.
52. Hamel AJ, Donahue SW, Sharkey NA. Contributions of active and passive toe flexion to forefoot loading. *Clin Orthop*. 2001;(393):326-334.
53. Johnson CH, Christensen JC. Biomechanics of the first ray part I. The effects of peroneus longus function: A three-dimensional kinematic study on a cadaver model. *J Foot Ankle Surg*. 1999;38(5):313-321. doi:10.1016/S1067-2516(99)80002-7.
54. Thordarson DB, Schmotzer H, Chon J, Peters J. Dynamic support of the human longitudinal arch: a biomechanical evaluation. *Clin Orthop*. 1995;316:165-172.
55. Bojsen-Møller F. Calcaneocuboid joint and stability of the longitudinal arch of the foot at high and low gear push off. *J Anat*. 1979;129(Pt 1):165-176.
56. Konradsen L, Ravn JB, Sorensen AI. Proprioception at the ankle: the effect of anaesthetic blockade of ligament receptors. *J Bone Joint Surg Br*. 1993;75-B(3):433-436.
57. Houtz SJ, Walsh FP. Electromyographic analysis of the function of the muscles acting on the ankle during weight-bearing with special reference to the triceps surae. *J Bone Jt Surg*. 1959;41(8):1469-1481.
58. Aimonetti J-M, Roll J-P, Hospod V, Ribot-Ciscar E. Ankle joint movements are encoded by both cutaneous and muscle afferents in humans. *Exp Brain Res*. 2012;221(2):167-176. doi:10.1007/s00221-012-3160-2.
59. Grey MJ, Mazzaro N, Nielsen JB, Sinkjær T. Ankle extensor proprioceptors contribute to the enhancement of the soleus EMG during the stance phase of human walking. *Can J Physiol Pharmacol*. 2004;82(8-1):610-616.
60. Kalin PJ, Hirsch BE. The origins and function of the interosseous muscles of the foot. *J Anat*. 1987;152:83-91.
61. Wyke B. Articular neurology--a review. *Physiotherapy*. 1972;58(3):94-99.
62. Michelson J, Hutchins C. Mechanoreceptors in human ankle ligaments. *J Bone Joint Surg Br*. 1995;77-B(2):219-224. doi:10.1302/0301-620X.77B2.7706334.
63. Rein S, Hagert E, Hanisch U, Lwowski S, Fieguth A, Zwipp H. Immunohistochemical analysis of sensory nerve endings in ankle ligaments: a cadaver study. *Cells Tissues Organs*. 2013;197(1):64-76. doi:10.1159/000339877.
64. Jozsa L, Balint J, Kannus P, Järvinen M, Lehto M. Mechanoreceptors in human myotendinous junction. *Muscle Nerve*. 1993;16(5):453-457. doi:10.1002/mus.880160503.
65. Vallbo AB, Johansson RS. Properties of cutaneous mechanoreceptors in the human hand related to touch sensation. *Hum Neurobiol*. 1984;3(1):3-14.
66. Aimonetti J-M, Hospod V, Roll J-P, Ribot-Ciscar E. Cutaneous afferents provide a neuronal population vector that encodes the orientation of human ankle movements. *J Physiol*. 2006;580(2):649-658. doi:10.1113/jphysiol.2006.123075.
67. Kennedy PM, Inglis JT. Distribution and behaviour of glabrous cutaneous receptors in the human foot sole. *J Physiol*. 2002;538(Pt 3):995-1002. doi:10.1113/jphysiol.2001.013087.
68. Gilman S. Joint position sense and vibration sense: anatomical organisation and assessment. *J Neurol Neuropathol Psychiatry*. 2002;73(5):473-477. doi:10.1136/jnnp.73.5.473.
69. Mildren RL, Bent LR. Vibrotactile stimulation of fast-adapting cutaneous afferents from the foot modulates proprioception at the ankle joint. *J Appl Physiol*. 2016;120(8):855-864. doi:10.1152/japplphysiol.00810.2015.
70. Grill S E, Hallett M. Velocity sensitivity of human muscle spindle afferents and slowly adapting type II cutaneous mechanoreceptors. *J Physiol*. 1995;489(2):593-602. doi:10.1113/jphysiol.1995.sp021075.
71. Blanchard C, Roll R, Roll J-P, Kavounoudias A. Combined contribution of tactile and proprioceptive feedback to hand movement perception. *Brain Res*. 2011;1382:219-229. doi:10.1016/j.brainres.2011.01.066.

72. Sigrist R, Rauter G, Riener R, Wolf P. Augmented visual, auditory, haptic, and multimodal feedback in motor learning: A review. *Psychon Bull Rev.* 2013;20(1):21-53. doi:10.3758/s13423-012-0333-8.
73. Miall RC, Wolpert DM. Forward models for physiological motor control. *Neural Netw.* 1996;9(8):1265-1279. doi:10.1016/S0893-6080(96)00035-4.
74. Bojsen-Møller F. The human foot, a two speed construction. In: Asmussen E, Jorgensen K, eds. *Biomechanics VI-A*. Baltimore, IL: University Park Press; 1978:261-266.
75. Kobayashi T, Tanaka M, Shida M. Intrinsic risk factors of lateral ankle sprain a systematic review and meta-analysis. *Sports Health Multidiscip Approach.* 2016;8(2):190-193. doi:10.1177/1941738115623775.
76. Mok KM, Fong DT, Krosshaug T, et al. Kinematics analysis of ankle inversion ligamentous sprain injuries in sports 2 cases during the 2008 Beijing Olympics. *Am J Sports Med.* 2011;39(7):1548-1552. doi:10.1177/0363546511399384.
77. Fong DT, Ha SC, Mok KM, Chan SW, Chan KM. Kinematics analysis of ankle inversion ligamentous sprain injuries in sports: five cases from televised tennis competitions. *Am J Sports Med.* 2012;40(11):2627-2632. doi:10.1177/0363546512458259.
78. Fong DT, Chan Y-Y, Mok K-M, Yung PS, Chan K-M. Understanding acute ankle ligamentous sprain injury in sports. *Sports Med Arthrosc Rehabil Ther Technol SMARTT.* 2009;1:14. doi:10.1186/1758-2555-1-14.
79. Fraser JJ, Feger MA, Hertel J. Clinical commentary on midfoot and forefoot involvement in lateral ankle sprains and chronic ankle instability. part 2: clinical considerations. *Int J Sports Phys Ther.* 2016;11(7):1191-1203.
80. Khor YP, Tan KJ. The anatomic pattern of injuries in acute inversion ankle sprains. *Orthop J Sports Med.* 2013;1(7). doi:10.1177/2325967113517078.
81. Roemer FW, Jomaah N, Niu J, et al. Ligamentous injuries and the risk of associated tissue damage in acute ankle sprains in athletes: a cross-sectional MRI study. *Am J Sports Med.* 2014;42(7):1549-1557. doi:10.1177/0363546514529643.
82. Søndergaard L, Konradsen L, Hølmer P, Jørgensen LN, Nielsen PT. Acute midtarsal sprains: frequency and course of recovery. *Foot Ankle Int.* 1996;17(4):195-199.
83. Agnholt J, Nielsen S, Christensen H. Lesion of the ligamentum bifurcatum in ankle sprain. *Arch Orthop Trauma Surg.* 1988;107(5):326-328. doi:10.1007/BF00451515.
84. De Dea M, L Loizou C, Allen GM, et al. Talonavicular ligament: prevalence of injury in ankle sprains, histological analysis and hypothesis of its biomechanical function. *Br J Radiol.* 2016;90(1071):20160816. doi:10.1259/bjr.20160816.
85. Fallat L, Grimm DJ, Saracco JA. Sprained ankle syndrome: Prevalence and analysis of 639 acute injuries. *J Foot Ankle Surg.* 1998;37(4):280-285. doi:10.1016/S1067-2516(98)80063-X.
86. Hertel J. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *J Athl Train.* 2002;37(4):364-375.
87. Hershkovich O, Tenenbaum S, Gordon B, et al. A large-scale study on epidemiology and risk factors for chronic ankle instability in young adults. *J Foot Ankle Surg.* 2015;54(2):183-187. doi:10.1053/j.jfas.2014.06.001.
88. Hubbard TJ, Hertel J. Anterior positional fault of the fibula after sub-acute lateral ankle sprains. *Man Ther.* 2008;13(1):63-67. doi:10.1016/j.math.2006.09.008.
89. Vicenzino B, Branjerdporn M, Teys P, Jordan K. Initial changes in posterior talar glide and dorsiflexion of the ankle after mobilization with movement in individuals with recurrent ankle sprain. *J Orthop Sports Phys Ther.* 2006;36(7):464-471. doi:10.2519/jospt.2006.2265.
90. Cosby NL, Koroch M, Grindstaff TL, Parente W, Hertel J. Immediate effects of anterior to posterior talocrural joint mobilizations following acute lateral ankle sprain. *J Man Manip Ther.* 2011;19(2):76-83. doi:10.1179/2042618610Y.0000000005.
91. Collins N, Teys P, Vicenzino B. The initial effects of a Mulligan's mobilization with movement technique on dorsiflexion and pain in subacute ankle sprains. *Man Ther.* 2004;9(2):77-82. doi:10.1016/S1356-689X(03)00101-2.
92. Denegar CR, Hertel J, Fonseca J. The effect of lateral ankle sprain on dorsiflexion range of motion, posterior talar glide, and joint laxity. *J Orthop Sports Phys Ther.* 2002;32(4):166-173. doi:10.2519/jospt.2002.32.4.166.
93. Beazell JR, Grindstaff TL, Sauer LD, Magrum EM, Ingersoll CD, Hertel J. Effects of a proximal or distal tibiofibular joint manipulation on ankle range of motion and functional outcomes in individuals with chronic ankle instability. *J Orthop Sports Phys Ther.* 2012;42(2):125-134. doi:10.2519/jospt.2012.3729.
94. Wheeler TJ, Basnett CR, Hanish MJ, et al. Fibular taping does not influence ankle dorsiflexion range of motion or balance measures in individuals with chronic ankle instability. *J Sci Med Sport Sports Med Aust.* 2013;16(6):488-492. doi:10.1016/j.jsams.2013.02.012.
95. Drewes LK, McKeon PO, Casey Kerrigan D, Hertel J. Dorsiflexion deficit during jogging with chronic ankle instability. *J Sci Med Sport.* 2009;12(6):685-687. doi:10.1016/j.jsams.2008.07.003.
96. Harkey M, McLeod M, Wells A, et al. The immediate effects of an anterior-to-posterior talar mobilization on neural excitability, dorsiflexion range of motion, and dynamic balance in patients with chronic ankle instability. *J Sport Rehabil.* 2014;23(4):351-359. doi:10.1123/jsr.2013-0085.

97. Kerkhoffs GMMJ, Blankevoort L, van Poll D, Marti RK, van Dijk CN. Anterior lateral ankle ligament damage and anterior talocrural-joint laxity: an overview of the in vitro reports in literature. *Clin Biomech.* 2001;16(8):635-643. doi:10.1016/S0268-0033(01)00054-7
98. Hertel J, Denegar CR, Monroe MM, Stokes WL. Talocrural and subtalar joint instability after lateral ankle sprain. *Med Sci Sports Exerc.* 1999;31(11):1501.
99. Bahr R, Pena F, Shine J, et al. Mechanics of the anterior drawer and talar tilt tests. A cadaveric study of lateral ligament injuries of the ankle. *Acta Orthop Scand.* 1997;68(5):435-441.
100. Hubbard TJ. Ligament laxity following inversion injury with and without chronic ankle instability. *Foot Ankle Int.* 2008;29(3):305-311. doi:10.3113/FAI.2008.0305.
101. Croy T, Koppenhaver S, Saliba S, Hertel J. Anterior talocrural joint laxity: diagnostic accuracy of the anterior drawer test of the ankle. *J Orthop Sports Phys Ther.* 2013;43(12):911-919. doi:10.2519/jospt.2013.4679.
102. Hubbard-Turner T. Relationship between mechanical ankle joint laxity and subjective function. *Foot Ankle Int.* 2012;33(10):852-856. doi:10.3113/FAI.2012.0852.
103. Jennings J, Davies GJ. Treatment of cuboid syndrome secondary to lateral ankle sprains: a case series. *J Orthop Sports Phys Ther.* 2005;35(7):409-415.
104. Durall CJ. Examination and treatment of cuboid syndrome: a literature review. *Sports Health Multidiscip Approach.* 2011;3(6):514-519. doi:10.1177/1941738111405965.
105. Fraser JJ, Koldenhoven RM, Saliba SA, Hertel J. Reliability of ankle-foot morphology, mobility, strength, and motor performance measures. *Int J Sports Phys Ther.* 2017;12(7):1134-1149. doi:10.16603/ijsp20171134.
106. Bennell K, Talbot R, Wajswelner H, Techovanich W, Kelly D, Hall A. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Aust J Physiother.* 1998;44(3):175-180. doi:10.1016/S0004-9514(14)60377-9.
107. Gribble PA, Hertel J, Plisky P. Using the star excursion balance test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train.* 2012;47(3):339-357.
108. Powell MR, Powden CJ, Houston MN, Hoch MC. Plantar cutaneous sensitivity and balance in individuals with and without chronic ankle instability. *Clin J Sport Med.* 2014;24(6):490-496. doi:10.1097/JSM.0000000000000074.
109. Hoch MC, McKeon PO, Andreatta RD. Plantar vibrotactile detection deficits in adults with chronic ankle instability. *Med Sci Sports Exerc.* 2012;44(4):666-672. doi:10.1249/MSS.0b013e3182390212.
110. Hoch MC, McKeon PO. Peroneal reaction time after ankle sprain: a systematic review and meta-analysis. *Med Sci Sports Exerc.* 2014;46(3):546-556. doi:10.1249/MSS.0b013e3182a6a93b.
111. Kavanagh JJ, Bisset LM, Tsao H. Deficits in reaction time due to increased motor time of peroneus longus in people with chronic ankle instability. *J Biomech.* 2012;45(3):605-608. doi:10.1016/j.jbiomech.2011.11.056.
112. Rosen AB, Needle AR, Ko J. Ability of functional performance tests to identify individuals with chronic ankle instability: a systematic review with meta-analysis. *Clin J Sport Med.* 2017 December 22. doi:10.1097/JSM.0000000000000535.
113. Docherty CL, Valovich McLeod TC, Shultz SJ. Postural control deficits in participants with functional ankle instability as measured by the balance error scoring system. *Clin J Sport Med.* 2006;16(3):203-208. doi:10.1097/0000000000000003.
114. Doherty C, Bleakley CM, Hertel J, Caulfield B, Ryan J, Delahunt E. Laboratory measures of postural control during the star excursion balance test after acute first-time lateral ankle sprain. *J Athl Train.* 2015;50(6):651-664. doi:10.4085/1062-6050-50.1.09.
115. Gribble PA, Hertel J, Denegar CR. Chronic ankle instability and fatigue create proximal joint alterations during performance of the Star Excursion Balance Test. *Int J Sports Med.* 2007;28(3):236-242.
116. Hoch MC, Gaven SL, Weinhandl JT. Kinematic predictors of star excursion balance test performance in individuals with chronic ankle instability. *Clin Biomech.* 2016;35:37-41. doi:10.1016/j.clinbiomech.2016.04.008.
117. Basnett CR, Hanish MJ, Wheeler TJ, et al. Ankle dorsiflexion range of motion influences dynamic balance in individuals with chronic ankle instability. *Int J Sports Phys Ther.* 2013;8(2):121-128.
118. Cote KP, Brunet ME, Gansneder BM, Shultz SJ. Effects of pronated and supinated foot postures on static and dynamic postural stability. *J Athl Train.* 2005;40(1):41-46.
119. Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E. Gait biomechanics in participants, six months after first-time lateral ankle sprain. *Int J Sports Med.* 2016;37(07):577-583. doi:10.1055/s-0035-1564172.
120. Gigi R, Haim A, Luger E, et al. Deviations in gait metrics in patients with chronic ankle instability: a case control study. *J Foot Ankle Res.* 2015;8(1). doi:10.1186/s13047-014-0058-1.
121. Drewes LK, McKeon PO, Paolini G, et al. Altered ankle kinematics and shank-rear-foot coupling in those with chronic ankle instability. *J Sport Rehabil.* 2009;18(3):375.
122. Chinn L, Dicharry J, Hertel J. Ankle kinematics of individuals with chronic ankle instability while walking

- and jogging on a treadmill in shoes. *Phys Ther Sport.* 2013;14(4):232-239. doi:10.1016/j.ptsp.2012.10.001.
123. Delahunt E, Monaghan K, Caulfield B. Altered neuromuscular control and ankle joint kinematics during walking in subjects with functional instability of the ankle joint. *Am J Sports Med.* 2006;34(12):1970-1976. doi:10.1177/0363546506290989.
 124. Hopkins JT, Coglianese M, Glasgow P, Reese S, Seeley MK. Alterations in evertor/invertor muscle activation and center of pressure trajectory in participants with functional ankle instability. *J Electromyogr Kinesiol.* 2012;22(2):280-285. doi:10.1016/j.jelekin.2011.11.012.
 125. Koldenhoven RM, Feger MA, Fraser JJ, Saliba S, Hertel J. Surface electromyography and plantar pressure during walking in young adults with chronic ankle instability. *Knee Surg Sports Traumatol Arthrosc* 2016;24(4):1060-1070. doi:10.1007/s00167-016-4015-3.
 126. Schmidt H, Sauer LD, Lee SY, Saliba S, Hertel J. Increased in-shoe lateral plantar pressures with chronic ankle instability. *Foot Ankle Int.* 2011;32(11):1075-1080. doi:10.3113/FAI.2011.1075.
 127. Koldenhoven RM, Feger MA, Fraser JJ, Hertel J. Variability in center of pressure position and muscle activation during walking with chronic ankle instability. *J Electromyogr Kinesiol.* 2018;38:155-161. doi:10.1016/j.jelekin.2017.12.003.
 128. Monaghan K, Delahunt E, Caulfield B. Ankle function during gait in patients with chronic ankle instability compared to controls. *Clin Biomech.* 2006;21(2):168-174. doi:10.1016/j.clinbiomech.2005.09.004.
 129. Morrison KE, Hudson DJ, Davis IS, et al. Plantar pressure during running in subjects with chronic ankle instability. *Foot Ankle Int.* 2010;31(11):994-1000. doi:10.3113/FAI.2010.0994.
 130. Doherty C, Bleakley C, Hertel J, et al. Lower extremity coordination and symmetry patterns during a drop vertical jump task following acute ankle sprain. *Hum Mov Sci.* 2014;38:34-46. doi:10.1016/j.humov.2014.08.002.
 131. van Rijn RM, van Os AG, Bernsen RMD, Luijsterburg PA, Koes BW, Bierma-Zeinstra SMA. What is the clinical course of acute ankle sprains? A systematic literature review. *Am J Med.* 2008;121(4):324-331.e7. doi:10.1016/j.amjmed.2007.11.018.
 132. Fraser JJ, Hertel J. Preinjury to postinjury disablement and recovery after a lateral ankle sprain: a case report. *J Athl Train.* 2018;53(8):776-781. doi:10.4085/1062-6050-114-17.
 133. Houston MN, Hoch JM, Hoch MC. College athletes with ankle sprain history exhibit greater fear-avoidance beliefs. *J Sport Rehabil.* 2018;27(5):419-423. doi:10.1123/jsr.2017-0075.
 134. Hubbard-Turner T, Turner MJ. Physical activity levels in college students with chronic ankle instability. *J Athl Train.* 2015;50(7):742-747. doi:10.4085/1062-6050-50.3.05.
 135. Delahunt E, Bleakley CM, Bossard DS, et al. Clinical assessment of acute lateral ankle sprain injuries (ROAST): 2019 consensus statement and recommendations of the International Ankle Consortium. *Br J Sports Med.* June 2018;bjssports-2017-098885. doi:10.1136/bjssports-2017-098885.
 136. Martin RL, Davenport TE, Paulseth S, Wukich DK, Godges JJ. Ankle stability and movement coordination impairments: ankle ligament sprains: Clinical Practice Guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. *J Orthop Sports Phys Ther.* 2013;43(9):A1-A40. doi:10.2519/jospt.2013.0305.
 137. Stiell I. Ottawa ankle rules. *Can Fam Physician.* 1996;42:478-480.
 138. Amtmann D, Cook KF, Johnson KL, Cella D. The PROMIS Initiative: examples of applications in rehabilitation. *Arch Phys Med Rehabil.* 2011;92(10 0):S12-S19. doi:10.1016/j.apmr.2011.04.025
 139. Lentz TA, Sutton Z, Greenberg S, Bishop MD. Pain-related fear contributes to self-reported disability in patients with foot and ankle pathology. *Arch Phys Med Rehabil.* 2010;91(4):557-561. doi:10.1016/j.apmr.2009.12.010.
 140. Hapidou EG, O'Brien MA, Pierrynowski MR, de las Heras E, Patel M, Patla T. Fear and avoidance of movement in people with chronic pain: psychometric properties of the 11-Item Tampa Scale for Kinesiophobia (TSK-11). *Physiother Can.* 2012;64(3):235-241. doi:10.3138/ptc.2011-10.
 141. Garcia CR, Martin RL, Drouin JM. Validity of the foot and ankle ability measure in athletes with chronic ankle instability. *J Athl Train.* 2008;43(2):179-183. doi:10.4085/1062-6050-43.2.179.
 142. Redmond AC, Crosbie J, Ouvrier RA. Development and validation of a novel rating system for scoring standing foot posture: The Foot Posture Index. *Clin Biomech.* 2006;21(1):89-98. doi:10.1016/j.clinbiomech.2005.08.002.
 143. Williams DS, McClay IS. Measurements used to characterize the foot and the medial longitudinal arch: reliability and validity. *Phys Ther.* 2000;80(9):864-871.
 144. McPoil TG, Vicenzino B, Cornwall MW, Collins N, Warren M. Reliability and normative values for the foot mobility magnitude: a composite measure of vertical and medial-lateral mobility of the midfoot. *J Foot Ankle Res.* 2009;2(1):6. doi:10.1186/1757-1146-2-6.
 145. Rasmussen O. Stability of the ankle joint: analysis of the function and traumatology of the ankle ligaments. *Acta Orthop Scand.* 1985;56(sup211):1-75. doi:10.3109/17453678509154152.

146. Kovaleski JE, Hollis JM, Heitman RJ, Gurchiek LR, Pearsall AW. Assessment of ankle-subtalar-joint-complex laxity using an instrumented ankle arthrometer: an experimental cadaveric investigation. *J Athl Train.* 2002;37(4):467-474.
147. Bohannon RW. Manual muscle testing: does it meet the standards of an adequate screening test? *Clin Rehabil.* 2005;19(6):662-667. doi:<http://dx.doi.org.prx-usa.lirn.net/10.1191/0269215505cr873oa>.
148. Abe T, Tayashiki K, Nakatani M, Watanabe H. Relationships of ultrasound measures of intrinsic foot muscle cross-sectional area and muscle volume with maximum toe flexor muscle strength and physical performance in young adults. *J Phys Ther Sci.* 2016;28(1):14-19. doi:10.1589/jpts.28.14.
149. Crofts G, Angin S, Mickle KJ, Hill S, Nester CJ. Reliability of ultrasound for measurement of selected foot structures. *Gait Posture.* 2014;39(1):35-39. doi:10.1016/j.gaitpost.2013.05.022.
150. Fraser JJ, Mangum LC, Hertel J. Test-retest reliability of ultrasound measures of intrinsic foot motor function. *Phys Ther Sport.* 2018;30:39-47. doi:10.1016/j.ptsp.2017.11.032.
151. Barber MA, Conolley J, Spaulding CM, Dellen AL. Evaluation of pressure threshold prior to foot ulceration. *J Am Podiatr Med Assoc.* 2001;91(10):508-514. doi:10.7547/87507315-91-10-508.
152. Hiller CE, Refshauge KM, Herbert RD, Kilbreath SL. Balance and recovery from a perturbation are impaired in people with functional ankle instability. *Clin J Sport Med.* 2007;17(4):269-275. doi:10.1097/JSM.0b013e-3180f60b12.
153. Plisky PJ, Gorman PP, Butler RJ, Kiesel KB, Underwood FB, Elkins B. The reliability of an instrumented device for measuring components of the Star Excursion Balance Test. *North Am J Sports Phys Ther NAJSPT.* 2009;4(2):92-99.
154. Grindstaff TL, Dolan N, Morton SK. Ankle dorsiflexion range of motion influences Lateral Step Down Test scores in individuals with chronic ankle instability. *Phys Ther Sport Off J Assoc Chrt Physiother Sports Med.* 2017;23:75-81. doi:10.1016/j.ptsp.2016.07.008.
155. Donovan L, Miklovic TM, Feger MA. Step-down task identifies differences in ankle biomechanics across functional activities. *Int J Sports Med.* 2018;39(11):846-852. doi:10.1055/a-0637-2126.
156. Lima YL, Ferreira VMLM, de Paula Lima PO, Bezerra MA, de Oliveira RR, Almeida GPL. The association of ankle dorsiflexion and dynamic knee valgus: A systematic review and meta-analysis. *Phys Ther Sport.* 2018;29:61-69. doi:10.1016/j.ptsp.2017.07.003.
157. Padua DA, Marshall SW, Boling MC, Thigpen CA, Garrett WE, Beutler AI. The Landing Error Scoring System (LESS) is a valid and reliable clinical assessment tool of jump-landing biomechanics: The JUMP-ACL Study. *Am J Sports Med.* 2009;37(10):1996-2002. doi:10.1177/0363546509343200.
158. Bandura A. Self-efficacy: Toward a unifying theory of behavioral change. *Psychol Rev.* 1977;84(2):191-215. doi:10.1037/0033-295X.84.2.191.
159. The road to resilience. <http://www.apa.org>. <http://www.apa.org/helpcenter/road-resilience.aspx>. Accessed September 13, 2018.
160. Briet JP, Houwert RM, Hageman MGJS, Hietbrink F, Ring DC, Verleisdonk EJJM. Factors associated with pain intensity and physical limitations after lateral ankle sprains. *Injury.* 2016;47(11):2565-2569. doi:10.1016/j.injury.2016.09.016.
161. Connolly FR, Aitken LM, Tower M. An integrative review of self-efficacy and patient recovery post acute injury. *J Adv Nurs.* 2014;70(4):714-728. doi:10.1111/jan.12237.
162. Shivarathre DG, Howard N, Krishna S, Cowan C, Platt SR. Psychological factors and personality traits associated with patients in chronic foot and ankle pain. *Foot Ankle Int.* 2014;35(11):1103-1107. doi:10.1177/1071100714550648.
163. McCann RS, Gribble PA. Resilience and self-efficacy: a theory-based model of chronic ankle instability. *Int J Athl Ther Train.* 2016;21(3):32-37. doi:10.1123/ijatt.2015-0032.
164. Milne M, Hall C, Forwell L. Self-efficacy, imagery use, and adherence to rehabilitation by injured athletes. *J Sport Rehabil.* 2005;14(2):150-167. doi:10.1123/jsr.14.2.150.
165. Hsu C-J, Meierbacholt A, George SZ, Chmielewski TL. Fear of reinjury in athletes. *Sports Health.* 2016;9(2):162-167. doi:10.1177/1941738116666813.
166. Podlog L, Banham SM, Wadey R, Hannon JC. Psychological readiness to return to competitive sport following injury: A Qualitative Study. *Sport Psychol.* 2015;29(1):1-14. doi:10.1123/tsp.2014-0063.
167. Podlog L, Eklund RC. The psychosocial aspects of a return to sport following serious injury: A review of the literature from a self-determination perspective. *Psychol Sport Exerc.* 2007;8(4):535-566. doi:10.1016/j.psychsport.2006.07.008.
168. Glazer DD. Development and Preliminary Validation of the Injury-Psychological Readiness to Return to Sport (I-PRRS) Scale. *J Athl Train.* 2009;44(2):185-189.
169. Weerasekara I, Osmotherly P, Snodgrass S, Marquez J, de Zoete R, Rivett DA. Clinical benefits of joint mobilization on ankle sprains: a systematic review and meta-analysis. *Arch Phys Med Rehabil.* 2018;99(7):1395-1412.e5. doi:10.1016/j.apmr.2017.07.019.
170. Powden CJ, Hoch JM, Hoch MC. Rehabilitation and improvement of health-related quality-of-life detriments in individuals with chronic ankle instability:

- a meta-analysis. *J Athl Train.* 2017;52(8):753-765. doi:10.4085/1062-6050-52.5.01.
171. McKeon PO, Wikstrom EA. Sensory-targeted ankle rehabilitation strategies for chronic ankle instability. *Med Sci Sports Exerc.* 2016;48(5):776-784. doi:10.1249/MSS.00000000000000859.
 172. Terada M, Pietrosimone BG, Gribble PA. Therapeutic interventions for increasing ankle dorsiflexion after ankle sprain: a systematic review. *J Athl Train.* 2013;48(5):696-709. doi:10.4085/1062-6050-48.4.11.
 173. Kay AD, Husbands-Beasley J, Blazevich AJ. Effects of contract-relax, static stretching, and isometric contractions on muscle-tendon mechanics. *Med Sci Sports Exerc.* 2015;47(10):2181. doi:10.1249/MSS.0000000000000632.
 174. Tsikopoulos K, Mavridis D, Georgiannos D, Cain MS. Efficacy of non-surgical interventions on dynamic balance in patients with ankle instability: A network meta-analysis. *J Sci Med Sport.* 2018;21(9):873-879. doi:10.1016/j.jsams.2018.01.017.
 175. Loudon JK, Santos MJ, Franks L, Wen Liu. The effectiveness of active exercise as an intervention for functional ankle instability. *Sports Med.* 2008;38(7):553-563.
 176. Kosik KB, McCann RS, Terada M, Gribble PA. Therapeutic interventions for improving self-reported function in patients with chronic ankle instability: a systematic review. *Br J Sports Med.* November 2016;bjspor-2016-096534. doi:10.1136/bjspor-2016-096534.
 177. Kim M-H, Kwon O-Y, Kim S-H, Jung D-Y. Comparison of muscle activities of abductor hallucis and adductor hallucis between the short foot and toe-spread-out exercises in subjects with mild hallux valgus. *J Back Musculoskelet Rehabil.* 2013;26(2):163-168.
 178. Gooding TM, Feger MA, Hart JM, Hertel J. Intrinsic foot muscle activation during specific exercises: A T2 Time Magnetic Resonance Imaging Study. *J Athl Train.* 2016;51(8):644-650. doi:10.4085/1062-6050-51.10.07.
 179. Fraser JJ, Hertel J. Effects of a 4-week intrinsic foot muscle exercise program on motor function: a preliminary randomized control trial. *J Sport Rehabil.* January 2018;1-32. doi:10.1123/jsr.2017-0150.
 180. Mignogna CA, Welsch LA, Hoch MC. The effects of short-foot exercises on postural control: a critically appraised topic. *Int J Athl Ther Train.* 2016;21(6):8-12. doi:10.1123/ijatt.2016-0049.
 181. de Vasconcelos GS, Cini A, Sbruzzi G, Lima CS. Effects of proprioceptive training on the incidence of ankle sprain in athletes: systematic review and meta-analysis. *Clin Rehabil.* 2018;32(12):1581-1590. doi:10.1177/0269215518788683.
 182. Bellows R, Wong CK. The effect of bracing and balance training on ankle sprain incidence among athletes: a systematic review with meta-analysis. *Int J Sports Phys Ther.* 2018;13(3):379-388.
 183. McKeon PO, Paolini G, Ingersoll CD, et al. Effects of balance training on gait parameters in patients with chronic ankle instability: a randomized controlled trial. *Clin Rehabil.* 2009;23(7):609-621. doi:10.1177/0269215509102954.
 184. Chinn L, Dicharry J, Hart JM, Saliba S, Wilder R, Hertel J. Gait kinematics after taping in participants with chronic ankle instability. *J Athl Train.* 2014;49(3):322-330. doi:10.4085/1062-6050-49.3.08.
 185. Yen SC, Folmar E, Friend KA, Wang YC, Chui KK. Effects of kinesiotaping and athletic taping on ankle kinematics during walking in individuals with chronic ankle instability: A pilot study. *Gait Posture.* 2018;66:118-123. doi:10.1016/j.gaitpost.2018.08.034.
 186. Donovan L, Feger MA, Hart JM, Saliba S, Park J, Hertel J. Effects of an auditory biofeedback device on plantar pressure in patients with chronic ankle instability. *Gait Posture.* 2016;44:29-36. doi:10.1016/j.gaitpost.2015.10.013.
 187. Feger MA, Hertel J. Surface electromyography and plantar pressure changes with novel gait training device in participants with chronic ankle instability. *Clin Biomech.* 2016;37:117-124. doi:10.1016/j.clinbiomech.2016.07.002.
 188. Feger MA, Hart JM, Saliba S, Abel MF, Hertel J. Gait training for chronic ankle instability improves neuromechanics during walking. *J Orthop Res.* 2018;36(1):515-524. doi:10.1002/jor.23639.
 189. Silva PB, Oliveira AS, Mrachacz-Kersting N, Kersting UG. Effects of wobble board training on single-leg landing neuromechanics. *Scand J Med Sci Sports.* 2018;28(3):972-982. doi:10.1111/sms.13027.
 190. Minoonejad H, Ardakani MK, Rajabi R, Wikstrom EA, Sharifnezhad A. Hop stabilization training improves neuromuscular control in collegiate basketball players with chronic ankle instability: A Randomized Controlled Trial. *J Sport Rehabil.* June 2018;1-25. doi:10.1123/jsr.2018-0103.
 191. Delahunt E, Cusack K, Wilson L, Doherty C. Joint mobilization acutely improves landing kinematics in chronic ankle instability. *Med Sci Sports Exerc.* 2013;45(3):514-519. doi:10.1249/MSS.0b013e3182746d0a.
 192. Yoshida T, Tanino Y, Suzuki T. Effect of exercise therapy combining electrical therapy and balance training on functional instability resulting from ankle sprain—focus on stability of jump landing. *J Phys Ther Sci.* 2015;27(10):3069-3071. doi:10.1589/jpts.27.3069.
 193. Ho YH, Lin CF, Chang CH, Wu HW. Effect of ankle kinesio taping on vertical jump with run-up and countermovement jump in athletes with ankle functional instability. *J Phys Ther Sci.* 2015;27(7):2087-2090. doi:10.1589/jpts.27.2087.

194. Mattacola CG, Dwyer MK. Rehabilitation of the ankle after acute sprain or chronic instability. *J Athl Train*. 2002;37(4):413-429.
195. Hudson Z. Rehabilitation and return to play after foot and ankle injuries in athletes. *Sports Med Arthrosc Rev*. 2009;17(3):203-207. doi:10.1097/JSA.0b013e3181a5ce96.
196. Herring SA, Kibler WB, Putukian M. The team physician and the return-to-play decision: a consensus statement-2012 update. *Med Sci Sports Exerc*. 2012;44(12):2446-2448. doi:10.1249/MSS.0b013e3182750534.
197. Doherty C, Bleakley C, Delahunt E, Holden S. Treatment and prevention of acute and recurrent ankle sprain: an overview of systematic reviews with meta-analysis. *Br J Sports Med*. 2017;51(2):113-125. doi:10.1136/bjsports-2016-096178.
198. Bot SDM, Van Mechelen W. The effect of ankle bracing on athletic performance. *Sports Med*. 1999;27(3):171-178. doi:10.2165/00007256-199927030-00003.
199. Olmsted LC, Vela LI, Denegar CR, Hertel J. Prophylactic ankle taping and bracing: a numbers-needed-to-treat and cost-benefit analysis. *J Athl Train*. 2004;39(1):95-100.