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The Influence of Cognitive Loading on Landing Mechanics: A Systematic Review

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The Influence of Cognitive Loading on Landing Mechanics: A Systematic Review

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Purpose

- To evaluate current literature about the effects of cognitive loading on jump landing mechanics

Background

- There are approximately 200,000 ACL injuries in the US annually with a majority resulting from sport participation. Research consistently supports that most of these injuries are non-contact and during the rapid deceleration of the landing phase of a jump when the tibia experiences an increased shear force in relation to the femur, placing additional stress on the ACL. The external demands of a sport challenge the athletes' cognitive-perceptual skills and draws their attention away from landing with proper kinematics.

Methods

- Databases utilized in the search strategy included PubMed, SportDiscuss, and CINAHL. Two search strategies were used for each database. There were 65 total articles identified and an additional 15 articles were included via hand searching. Two researchers screened titles and abstracts for inclusion and exclusion criteria.
- Inclusion criteria for this study included adolescents and young adults, defined as 12-45 years old and an assessment of jump landing mechanics
- Exclusion criteria for this study included articles of the english language only, dated between 2010-2020, and excluded conference proceedings, dissertations, and case studies.
- 8 total articles met the inclusion and exclusion criteria.

Results: Study Characteristics

- Studies involved 2 Repeated Measures Designs, 1 Controlled Laboratory Study, 2 Observational Studies, and 3 Cross-sectional Studies. Each was assessed using the modified Downs & Black checklist and all were deemed as high quality. The studies excluded recent lower extremity injuries or surgeries with some putting emphasis on excluding prior ACL injury or surgery.
- Only one study incorporated a control group while the others took the average of trials for the participants.
- Participants ranged from 16 to 27 years of age across all studies with the majority being recreational athletes and some incorporating competitive athletes. 5 studies incorporated male and female participants, 2 used only females, and 1 used only males.

Results: Landing Tasks

Mache et al[13]
- Overhead bar
- Drop-landing trials
- Drop-jump trials
- Randomized decision making trials

Herman et al[16]
- Unanticipated jump-landing from 35cm box
- Second target

Dai et al[17]
- Jump-landing from 30cm box forward 50% of standing height
- Maximum vertical jump

DiCesare et al[18] and Almonroder et al[19]
- DVJ from 31cm box
- Maximum vertical jump to OH target

Kajiwara et al[20]
- SL drop landing from 30cm box onto markers

Mejane et al[21]
- Double-foot forward leap, SL landing, lateral cutting movements upon landing

Giesche et al[22]
- 70 countermovement jumps
- Randomized planned and unplanned SL landings

Results: Cognitive Tasks

Mache et al[13] and Herman et al[16]
- both signaled the participant second landing task milliseconds after the first jump

Dai et al[17]
- incorporated counting tasks

DiCesare et al[18]
- Used a virtual reality soccer specific task

Almonroeder et al[19]
- facilitated cognitive load by using a overhead goal and a decision-making goal

Kajiwara et al[20]
- added a stroop task of landing on target indicated on a color display

Mejane et al[21]
- had the participants identify a sphere upon landing

Gieshe et al[22]
- provided a cue on which leg the participant had to land on 120ms after take-off

Results: Outcomes Assessed

Reflective markers, force plates, and video systems assessed:
- Knee kinetics and kinematics in the sagittal and frontal planes
- Ground reaction forces
- Jump height
- Hip and ankle kinematics
- Lateral trunk movement
- Stability and recovery during single-leg stance

Results: Significant Findings

- Studies found decreased hip and knee flexion and increased ground reaction force leading to stiffer landings.
- There was increased knee abduction and tibial internal rotation which showed similar movements to those common in ACL injuries.
- Researchers also found decreased jump time with another article finding increased flight time due to compensations in the participant to be able to complete their task.

Discussion

- The effects of cognitive loading on landing mechanics overall increases the likelihood of an ACL injury and decreases performance based upon the findings in this systematic review.
- Significant findings are supported by previous research. Two in vivo studies, Taylor et al. and Utturkar et al., found that there is an increased strain or elongation of the ACL with lesser knee flexion angles upon loading. This increased strain increases the anterior shear force of the tibia in comparison to the femur.
- Current prevention training and RTS protocols fail to represent the perceptual demands of game-like scenarios. RTS protocols are primarily focused on the fundamentals of movement quality and neuromuscular training, failing to incorporate cognitive loading. Incorporation of dual tasks into RTS protocols may enhance neurocognition and reaction times of athletes to improve lower extremity biomechanics and reduce ACL injury risk.

Conclusion

-This systematic review demonstrates that landing mechanics are altered with the addition of cognitive loading.
-Ongoing analysis of dual-task cognitive loading when implementing a RTS protocol to decrease the risk of ACL injury may be warranted.

Limitations

- There is a high degree of variability between the dual tasks the participants were performing. This can also be considered a strength since these tasks can more readily be implemented into a clinical setting.
- Five studies did not calculate the sample size which limits the validity of the results.
- There is limited evidence on dual task and landing mechanics specifically, which is an indication for future research.

Clinical Relevance

- Clinical research should focus on the usefulness of incorporating dual task training into injury prevention programs, return to sport protocols, and for athletes experiencing lower extremity biomechanical dysfunction. This training will improve landing mechanics and decrease risk of ACL injury during sport-specific tasks.

References

1. Griffin LY, Albohm MJ, Arendt EA, et al. Understanding and preventing noncontact anterior cruciate ligament injuries: a review of the Hunt Valley II Meeting. January 2005. *Am J Sports Med.* 2006;34:1512–32. doi: 10.1177/0363546506286866.
2. Siegel M, Barber-Westin S. Arthroscopic-assisted outpatient anterior cruciate ligament reconstruction using the semitendinosus and gracilis tendons. *Arthroscopy.* 1998;14(3):268-277. doi:10.1016/s0749-8063(98)70142-2.
3. Feller JA, Webster KE. A randomized comparison of patellar tendon and hamstring tendon anterior cruciate ligament reconstruction. *Am J Sports Med.* 2003;31(4):564-573. doi:10.1177/03635465030310041501.
4. Paterno MV, Rauh MJ, Schmitt LC, Ford KR, Hewett TE. Incidence of second ACL injuries 2 years after primary ACL reconstruction and return to Sport. *Am J Sports Med.* 2014;42(7):1567-1573. doi:10.1177/0363546514530088.)
5. Gornitzky AL, Lott A, Yellin JL, et al. Sport-specific yearly risk and incidence of anterior cruciate ligament tears in high school athletes. *Am J Sports Med.* 2016;44(10):2716-2723. doi:10.1177/0363546515617742.
6. Swanik CB. Brains and sprains: The brain's role in noncontact anterior cruciate ligament injuries. *J Athl Train.* 2015;50(10):1100–1102. doi:10.4085/1062-6050-50.10.08.
7. Myklebust G. Return to play guidelines after anterior cruciate ligament surgery. *Br J Sports Med.* 2005;39(3):127-131. doi:10.1136/bjsm.2004.010900.
8. Almonroeder TG, Garcia E, Kurt M. The effects of anticipation on the mechanics of the knee during single-leg cutting tasks: A systematic review. *Int J Sports Phys Ther.* 2015;10(7):918–928. doi: 10.1016/j.knee.2018.10.017.
9. Welling W, Benjaminse A, Seil R, Lemmink K, Gokeler A. Altered movement during single leg hop test after ACL reconstruction: implications to incorporate 2-D video movement analysis for hop tests. *Knee Surg Sports Traumatol Arthrosc.* 2018;26(10):3012-3019. doi:10.1007/s00167-018-4893-7.
10. Myer GD, Ford KR, Hewett TE. Tuck jump assessment for reducing anterior cruciate ligament injury risk. *Athl Ther Today.* 2008;13(5):39-44. doi:10.1123/att.13.5.39.
11. Bolgia LA, Keskula DR. Reliability of lower extremity functional performance tests. *J Orthop Sports Phys Ther.* 1997; 26(3): 138-142. doi:10.2519/jospt.1997.26.3.138.
12. Brown LA, Hall EE, Ketcham CJ, et al. Turn characteristics during gait differ with and without a cognitive demand among college athletes. *J Sport Rehabil.* 2019:1-20. doi: 10.1123/jsr.2018-0129.
13. Fleddermann MT, Zentgraf K. Tapping the full potential? Jumping performance in game-like situations. *Front Psychol.* 2018:9:1375. doi: 10.3389/fpsyg.2018.01375.
14. Mache MA, Hoffman MA, Hannigan K, Golden GM, Pavol MJ. Effects of decision making on landing mechanics as a function of task and sex. *Clin Biomech.* 2012;28(1):104-109.
15. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med.* 6(7): e1000097. doi:10.1371/journal.pmed1000097
16. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Commun H.* 1998;52(6):377-384. doi:10.1136/jech.52.6.377.
17. Mache MA, Hoffman MA, Hannigan K, et al. Effects of decision making on landing mechanics as a function of task and sex. *Clin Biomech (Bristol).* 2012;28(1):104-109.(2012).
18. Herman DC, Barth JT. Drop-jump landing varies with baseline neurocognition: implications for anterior cruciate ligament injury risk and prevention. *Am J Sports Med.* 2016;44(9):2347-2353.
19. Dai B, Cook RF, Meyer EA, et al. The effect of a secondary cognitive task on landing mechanics and jump performance. *Sports Biomech.* 2018;17(2):192-205. doi:10.1080/14763141.2016.1265579
20. DiCesare CA, Kiefer AW, Bonnette S, Myer GD. High-Risk Lower-Extremity Biomechanics Evaluated in Simulated Soccer-Specific Virtual Environments [published online ahead of print, 2019 Jun 13]. *J Sport Rehabil.* 2019;1-7. doi:10.1123/jsr.2018-0237
21. Almonroeder TG, Kernozek T, Cobb S, Slavens B, Wang J, Huddleston W. Cognitive demands influence lower extremity mechanics during a drop vertical jump task in female athletes. *J Orthop Sports Phys Ther.* 2018;48(5):381-387. doi:10.2519/jospt.2018.7739.
22. Kajiwara M, Kanamori A, Kadone H, et al. Knee biomechanics changes under dual task during single-leg drop landing. *J Exp Orthop.* 2019;6(1):5. doi:10.1186/s40634-019-0170-z
23. Mejane J, Faubert J, Romeas T, Labbe DR. The combined impact of a perceptual-cognitive task and neuromuscular fatigue on knee biomechanics during landing. *Knee.* 2019;26(1):52-60. doi:10.1016/j.knee.2018.10.017
24. Giesche F, Wilke J, Engeroff T, et al. Are biomechanical stability deficits during unplanned single-leg landings related to specific markers of cognitive function?. *J Sci Med Sport.* 2020;23(1):82-88. doi:10.1016/j.jsams.2019.09.003
25. Taylor KA, Terry ME, Utturkar GM, et al. Measurement of in vivo anterior cruciate ligament strain during dynamic jump landing. *J Biomech.* 2011;44(3):365-371. doi:10.1016/j.jbiomech.2010.10.028
26. Dai B, Mao D, EW, et al. Anterior cruciate ligament injuries in soccer: Loading mechanisms, risk factors, and prevention programs. *J Sport Health Sci.* 2014;3(4):299-306. doi: 10.1016/j.jshs.2014.06.002.
27. Utturkar GM, Irribarra LA, Taylor KA, et al. The effects of a valgus collapse knee position on in vivo ACL elongation. *Ann Biomed Eng.* 2013;41(1):123-130. doi:10.1007/s10439-012-0629-x.
28. Webster KE, Hewett TE. Meta-analysis of meta-analyses of anterior cruciate ligament injury reduction training programs. *J Orthop Res.* 2018;36(10):2696-2708. doi:10.1002/jor.24043
29. Davies GJ, McCarty E, Provencher M, Manske RC. ACL return to sport guidelines and criteria. *Curr Rev Musculoskelet Med.* 2017;10(3):307-314. doi:10.1007/s12178-017-9420-9.