

OPTIMAL MOVEMENT FOR LOWER EXTREMITY INJURY PREVENTION; HOW TO CREATE AN OPTIMAL LEARNING ENVIRONMENT FOR YOUTH SOCCER GIRLS

Eline M. Nijmeijer¹, Marije T. Elferink-Gemser¹, Bert Otten¹, and Anne Benjaminse^{1,2}

Department of Human Movement Sciences, University Medical Center Groningen, University of Groningen, The Netherlands¹

School of Sport Studies, Hanze University Groningen, The Netherlands²

For lower extremity injury prevention, it is crucial to decrease external loads to the joints in sport-specific situations. The purpose of this study was to examine how landing kinetics and psychological factors (i.e., motivation) change during a four-week laboratory training program. Ten talented soccer girls practiced three sport-specific tasks and received expert video instruction. Increased fun and competence in week 3 compared to week 1 was observed. No significant changes of effort and joint load (a discrete number to describe combined external frontal and transverse plane knee and ankle moments) were found. Results are promising and innovative as this is the first study testing the entire OPTIMAL model including retention and linking biomechanics with perceived motivation. More research is planned on additional instructions and feedback that may enhance the motor learning curve.

KEYWORDS: injury prevention, observational learning, joint load, motor learning, expert modelling

INTRODUCTION: Despite intensive effort, researchers and sports professionals have not been able yet to effectively reduce the injury incidence in the long term, after more than two decades of effort. Traditional lower extremity injury prevention programs seem effective in the short-term but have not decreased long-term injury incidence (Agel et al., 2016). Current injury prevention programs mainly address the physical part of injury prevention. However, an examination of psychological factors on injury prevention is highly needed (Benjaminse et al., 2015). This is because, according to the OPTIMAL model of motor learning, optimal learning takes place when acknowledging three elements; motivation by 1) autonomy and 2) enhanced expectancies, and 3) implicit learning (IL) (e.g., stimulated with an external focus of attention (EF)). These components contribute to an increased focus on the goal and improve motor skill acquisition (Wulf & Lewthwaite, 2016). In contrast, an internal focus of attention (IF) is frequently used by many coaches (Porter et al., 2010). The FIFA 11+ is a currently prescribed prevention program and consists of running, strength, plyometric and balance tasks, that should be performed in a specific order. IF instructions such as “keep your pelvis stable” are prescribed and no built-up of tasks is embedded (FIFA Medical Assessment and Research Centre, 2009). Around 30% of soccer coaches and physical therapists reported current use of the program to some degree. Solely, 50% found the program soccer-specific and 22% believed that the program contained adequate progression and variation. This may explain the low motivation rates of the players (O’Brien & Finch, 2016). To sum, the FIFA 11+ uses 1) less autonomy, 2) less enhanced expectancies and 3) no EF instructions.

Fortunately, optimistic prospects could be sketched as previous research has shown beneficial effects of the OPTIMAL theory on motor performance and learning. First, autonomy in terms of choosing the timing of feedback, is shown to positively affect motor skill learning by initiating more active involvement of the athlete (Benjaminse et al., 2015). Second, enhanced expectancies may enhance feelings of competence and self-efficacy (Chiviakowsky et al., 2012). Third, in addition to EF, IL can also be triggered by showing video demonstrations to athletes and asking them to imitate the movement pattern. This seems to be a powerful opportunity to enhance motor learning through self-exploration and -organization (Correia et al., 2019), especially when observation is combined with physical practice (Welling et al., 2016). Enhanced learning has been shown when

adopting these three factors together relative to combinations of two factors (Wulf et al., 2017). Using these principles of motor learning strategies can thus enhance skill acquisition required for sports, as movements become more efficient and automatized (Wulf & Lewthwaite, 2016). This can be translated to safer movement patterns and reducing the risk of injuries (Benjaminse et al., 2018; Welling et al., 2016). For injury prevention it is crucial to decrease external forces applied to the lower extremity in sport-specific situations (Benjaminse et al., 2015). An ACL injury mechanism mostly involves a relatively extended knee, knee abduction motion and tibial external rotation (Koga et al., 2010). Ankle sprain injuries occur due to an ankle inversion and internal rotation force while the ankle is in plantar flexion (Malanga & Ramirez - Del Toro, 2008). These external moments can be described as load at the joint. Smaller knee abduction/adduction and internal rotation moments reduce the risk of an ACL injury (Dempsey et al., 2007). Smaller internal rotation and inversion moments of the ankle reduce the risk of an ankle sprain (De Asla et al., 2009). Both can be linked to a more optimal (i.e., lower) knee and ankle joint load, respectively. To date, the effect of IL, autonomy and enhanced expectancies on movement biomechanics over a longer period is not known yet. Also, to optimize injury prevention programs an examination of psychological factors is needed. Therefore, the aim of this study is to examine landing kinetics and psychological factors (perceived motivation: fun, effort and competence) change over time.

METHODS: Ten talented soccer girls (age 15.3 ± 1.2 y, height 168.1 ± 5.0 cm, mass 75.2 ± 6.9 kg) participated in this study. Expert videos (frontal and sagittal plane) of the tasks were obtained before the experimental study to provide video instruction to the subjects. Three slightly better peers of the same team with different height and mass were selected by coaches and deemed to have excellent motor skills to serve as expert. The videos of each task were selected based on the landing technique, following the same method as previously used (Welling et al, 2016).

Each subject practiced three sport-specific tasks (each ten trials) for four weeks (T1-4; training phase). Furthermore, a baseline, immediate post and retention test (a basic variation of the task) were performed (testing phase; T0, T5, T6). The three tasks included unanticipated cutting, single and double leg jumping and landing. Motivation was stimulated by adding autonomy (e.g., choosing the order of the tasks) and enhanced expectancies (e.g., the tasks were built up during the weeks using an increase of visual and physical load). For example, passing balls to targets and increasing parkour length were added in week 3 to increase sport-specificity. All tasks were performed with a buddy to increase enjoyment and motivation during the training.

After a static calibration, general instruction by the investigator and familiarization with the task, subjects watched a video of an expert (matched by height and sex) performing the task. To stimulate IL, subjects were instructed to imitate the expert to the best of their ability. This 'whole-body approach' enhances being embedded in the task (embodied cognition) and turns out to be an effective method to promote motor learning (Benjaminse et al., 2015). During the training phase, subjects watched the same video after the fifth trial.

The Vicon Plug-in-Gait lower body model (Vicon Motion Systems, INC., Centennial, CO) was used and five additional trunk markers on the sternum, clavicle, C7, T10 and right scapula were attached. Kinematic and kinetic data were captured using a 200 Hz eight camera motion analysis system (Vicon Motion Systems, INC., Centennial, CO, USA), Vicon Nexus Software (version 2.10 Motions Systems, INC., Centennial, CO, USA) and two 1000 Hz Bertec force plates (Bertec Corporation Columbus, OH, USA). The statements of the psychological questionnaire were 'I enjoyed doing this task' (fun), 'I think I am pretty good at this task' (competence) and 'I did my best during this task' (effort) (Centre for Self-Determination Theory, n.d.). Subjects rated these statements on a Likert scale, ranging from 1 ("strongly disagree") to 7 ("strongly agree"), during the training phase. Primary kinetic variables were frontal and transverse plane moments of knee and ankle. A customized MATLAB script 9.6 (The MathWorks Inc., Natick, MA, USA) was used to compute variables of the tested leg(s). Knee and ankle loads were determined for all timepoints of the whole stand phase by using formula 1 and 2 for each trial. As many injuries happen due to

high external joint forces in the frontal (y-axis) and transverse (z-axis) plane, the peak value of each joint was used to calculate the total joint load (JL) during initial contact by using formula 3.

$$\text{Knee load} = \sqrt{\text{kneemoment}(y - \text{axis})^2 + \text{kneemoment}(z - \text{axis})^2} \quad (1)$$

$$\text{Ankle load} = \sqrt{\text{anklemoment}(y - \text{axis})^2 + \text{anklemoment}(z - \text{axis})^2} \quad (2)$$

$$\text{Total joint load (JL)} = \sqrt[10]{(\text{kneeloadleft}^{10} + \text{ankleloadleft}^{10} + \text{kneeloadright}^{10} + \text{ankleloadright}^{10})} \quad (3)$$

A to the tenth exponentiation was used to apply a winners-takes-it-all principle that is still continuous to give more value to the highest contributing factor. The JLs of the dominant leg only were used for single leg tasks. As enhanced motor learning goes together with lower JL, the average of the three lowest JLs per session per task was used for the analyses. To determine differences in landing kinetics, a repeated measures multivariate analysis of variance (RM-MANOVA) for time effects was used to analyse the JL during testing phase (T0, T5 and T6). Fun, effort and competence scores and JL during the training phase (T1-T4) were analysed by a RM-MANOVA. Bonferroni post-hoc tests were used, when appropriate. The significance level for all tests was set a priori to 0.05. Statistical analyses were performed using SPSS (version 27.0.0; IBM Corp, Armonk, NY).

RESULTS: Fun ($p = .001$) and competence ($p < .001$) significantly changed over time. Post-hoc tests showed that fun at T3 (6.0 ± 0.9) was significantly greater than at T1 (4.8 ± 1.1) ($p = .012$) and T4 (5.3 ± 1.3) ($p = .001$). Competence was significantly greater at T2 (4.9 ± 1.3) ($p = .024$), T3 (5.3 ± 1.1) ($p = .047$) and T4 (5.1 ± 1.1) ($p = .003$) compared to T1 (4.1 ± 1.3). No significant differences for effort ($p = .408$) and JL (testing phase $p = .177$, training phase $p = .567$) were found, see Figure 1.

DISCUSSION: This is the first study examining the entire OPTIMAL model in relation to lower extremity injury prevention and linking biomechanical and the accompanying psychological constructs of a training program over time. First, increased fun at T3 compared to T1 and T4 was found, which may be explained by the built-up of tasks (e.g., increase of parkour length at T3). However, the increased sport-specificity from T3 to T4 does not reflect the increased fun at T3 compared to T4. Possibly, subjects found the transition from T3 to T4 disappointing because the transition from T2 to T3 was relatively large. Second, effort was considerably high during the entire training phase (range 6.1-6.3), which indicates that subjects were willing to practice. Lastly, perceived competence was significantly higher at T2, T3 and T4 than at T1. The JL was lower at T4 (0.61 ± 0.23) compared to T1 (0.65 ± 0.22) although no significant differences were found. Only watching an expert video did not result in significant decrease of JL. Thus, additional instructions or feedback (e.g., through self-modeling) may be necessary to optimize the learning curve and decrease external loads on the joints (Oñate et al., 2005). The JL is a relatively easy but unique way to give a single number to the multiplanar load in vulnerable planes placed at joint(s). No cut-off points regarding movements that may place the subjects at risk for an ankle or knee injury are available yet, although the closer to zero, the better (Dempsey et al., 2007). The tasks were built up using visual, coordinative, and physical load. By doing so, several disadvantages of the Fifa 11+ program such as less progression, non-specificity and low motivation were tackled (O'Brien & Finch, 2016). Coaches are advised to add variation, progression, and sport-specificity to the training program to enhance motivation rates. As no control group was included, the changes cannot be linked directly to the intervention. However, the results are preliminary and more results are on their way.

CONCLUSION: Perceived competence and fun were higher in the third week compared to the first week. Small, non-significant decreases in JL were found during training phase. This implies that additional instructions or feedback may be needed to decrease the loads. Results are promising and innovative in a sense that is the first study testing the entire OPTIMAL model including retention and linking biomechanics with perceived motivation. Further research is

planned to examine the effects of combined modelling from an expert and subjects themselves and additional instructions which may enhance the effects of observational learning.

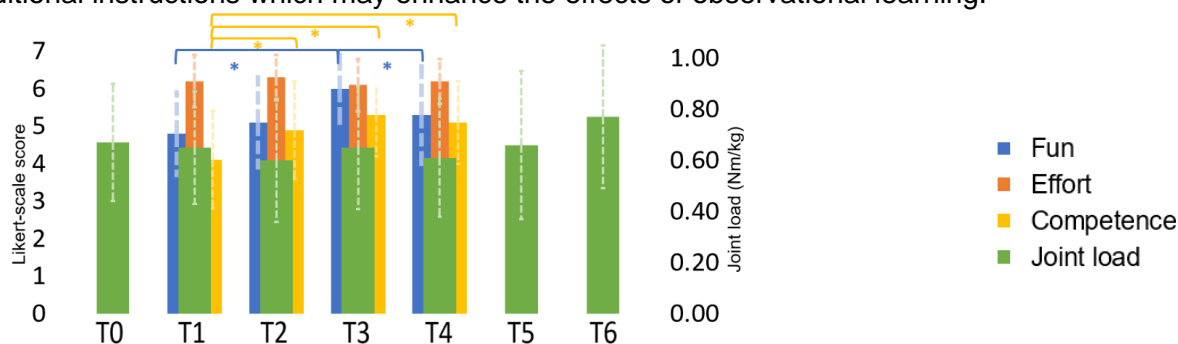


Figure 1 Means (std) of psychological variables and joint load over time (* indicates significance)

REFERENCES

- Agel, J., Rockwood, T., & Klossner, D. (2016). Collegiate ACL Injury Rates Across 15 Sports: National Collegiate Athletic Association Injury Surveillance System Data Update (2004-2005 Through 2012-2013). *Clin J Sport Med*, 26(6), 518–523.
- Benjaminse, A., Gokeler, A., Dowling, A.V., Faigenbaum, A., Ford, K.R., Hewett, T.E., . . . Myer, G.D. (2015). Optimization of the Anterior Cruciate Ligament Injury Prevention Paradigm: Novel Feedback Techniques to Enhance Motor Learning and Reduce Injury Risk. *J Orthop Sport Phys Ther*, 45(3), 170–182.
- Benjaminse, A., Welling, W., Otten, B., & Gokeler, A. (2018). Transfer of improved movement technique after receiving verbal external focus and video instruction. *Knee Surgery, Sport Traumatol Arthrosc*, 26(3), 955–962.
- Centre for Self-Determination Theory. (n.d.). Intrinsic Motivation Theory. <https://selfdeterminationtheory.org/intrinsic-motivation-inventory/>
- Correia V, Carvalho J, Araújo D, Pereira E, Davids K. Principles of nonlinear pedagogy in sport practice. *Phys Educ Sport Pedagog*. 2019;24(2):117-132.
- Chiviacowsky, S., Wulf, G., & Lewthwaite, R. (2012). Self-controlled learning: The importance of protecting perceptions of competence. *Front Psychol*, 3(NOV), 1–8.
- De Asla, R. J., Kozánek, M., Wan, L., Rubash, H. E., & Li, G. (2009). Function of anterior talofibular and calcaneofibular ligaments during in-vivo motion of the ankle joint complex. *J Orthop Surg Res*, 4(1), 1–6.
- Dempsey, A. R., Lloyd, D. G., Elliott, B. C., Steele, J. R., Munro, B. J., & Russo, K. A. (2007). The effect of technique change on knee loads during sidestep cutting. *Med Sci Sports Exerc*, 39(10), 1765–1773
- FIFA Medical Assessment and Research Centre. (2009). *Fifa11+manual*.
- Koga, H., Nakamae, A., Shima, Y., Iwasa, J., Myklebust, G., Engebretsen, L., . . . Krosshaug, T. (2010). Mechanisms for noncontact anterior cruciate ligament injuries: Knee joint kinematics in 10 injury situations from female team handball and basketball. *Am J Sports Med*, 38(11), 2218–2225.
- Malanga, G. A., & Ramirez - Del Toro, J.A. (2008). Common Injuries of the Foot and Ankle in the Child and Adolescent Athlete. *Phys Med Rehabil Clin N Am*, 19(2), 347–371.
- O'Brien, J., & Finch, C.F. (2016). Injury prevention exercise programmes in professional youth soccer: understanding the perceptions of programme deliverers. *BMJ Open Sport Exerc Med*, 2(1), e000075.
- Oñate, J. A., Guskiewicz, K. M., Marshall, S. W., Giuliani, C., Yu, B., & Garrett, W. E. (2005). Instruction of Jump-Landing Technique Using Videotape Feedback Altering Lower Extremity Motion Patterns. *Am J Sports Med*, 33(6), 831–842.
- Porter, J., Wu, W., & Partridge, J. (2010). Focus of Attention and Verbal Instructions: Strategies of Elite Track and Field Coaches and Athletes. *Sport Sci Rev*, 19(3–4), 77–89.
- Welling, W., Benjaminse, A., Gokeler, A., & Otten, B. (2016). Enhanced retention of drop vertical jump landing technique: A randomized controlled trial. *Hum Mov Sci*, 45, 84–95.
- Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. *Psychon Bull Rev*, 23(5), 1382–1414.
- Wulf, G., Lewthwaite, R., Cardozo, P., & Chiviacowsky, S. (2017). Triple play: Additive contributions of enhanced expectancies, autonomy support, and external attentional focus to motor learning. *Q J Exp Psychol*, 0(0), 1–9.