International Journal of Martial Arts

Evaluation of a Novel ACL Injury Prevention Technique: Can Martial Arts Fall Training (Break-falling and Rolling) Alter the Lower Extremity At-Risk Biomechanics in Soccer Athletes

Karen M. Myrick DNP APRN[a,b], John Edward Franklin Zobian[a], Conor Kasabo[a], Kyoshi Darin Reisler[c], Sensei Michael Golden[d], Richard Feinn[b], PhD, Juan C. Garbalosa, PT, Ph.D[e]

a. University of Saint Joseph , School of Interdisciplinary Health and Sciences, West Hartford, Connecticut.
b. Quinnipiac University School of Medicine, Hamden, Connecticut.
c. Plus One Defense Systems, West Hartford, Connecticut.
d. Custom Neruo Solutions, Connecticut.
e. Quinnipiac University School of Health Sciences, Hamden Connecticut.

Received: 2019. 09. 07: **Accepted: 2019**. 09. 30: **Published online: 2019.** 11. 27

Abstract

Background: Interventions have not reduced the incidence of ACL tears. The majority of ACL injuries occur during noncontact episodes, often when athletes land from a jump or stop to change direction. We proposed that by introducing martial arts fall training (break-falling and rolling), the neuropathways of athletes will be trained to recognize and avoid at risk postures by having an alternative response. **Objective**: The aim was to compare lower extremity biomechanics in soccer athletes with fall training compared to those without. **Subjects**: 5 youth athletes between the ages of 9 and 16 years old who were members of a youth premier soccer club were recruited. **Methods**: Subjects continued usual soccer training. The intervention group completed a twice weekly 10-week training program taught by a karate and aikido expert. At baseline and after the program, subjects underwent a biomechanical evaluation. **Results**: A significant decrease in knee flexion in the sagittal plane at initial contact was demonstrated pre and post-intervention (-4.802 degrees, P <0.001). There was also a significant decrease in knee flexion in the sagittal plane at heel strike 33ms (-7.384 degrees, P<0.001). **Conclusion**: A statistically significant change in body mechanics when comparing pre and post-break falling intervention was discovered.

Key words: Martial arts, break falling, ACL, injury prevention

I. Introduction

In the United States alone, it is estimated that approximately 100,000-250,000 individuals suffer an ACL injury each year, with the majority of these injuries occurring in athletes between the ages of 15-25 years of age (Hewett, et al, 2016). As a result of these injuries, nearly 350,000 reconstructions are performed annually making it the largest single orthopedic problem in orthopedic sports medicine (Nessler, et al, 2017). These devastating injuries are associated with a significant loss of playing time, a lengthy and often painful rehabilitation and psychological effects. The financial burden associated with an ACL injury is high, with the average lifetime cost per injury totaling between $38,121 to $88,538 depending on if ACL reconstruction is performed (Mather, et al 2013). In addition, it is estimated that the annual cost of diagnosis, treatment and rehabilitation of ACL injuries in the United States would be between $2.78 billion and $4.24 billion (Mather, et al, 2013). Besides the short-term and financial burdens, long-term health complications such as an increased risk of meniscal tears and the development of osteoarthritis are a major concern for individuals with ACL injuries regardless of whether ACL reconstruction was performed (Mather, et al, 2013). In women 12 years post ACL tear, Lohmander et al, found that roughly 50% of individuals had radiographic evidence of osteoarthritis with approximately 75% of those women acknowledging that their knee issues decreased quality of life(Lohmander, 2004). Both the long-term physical consequences and high economic cost associated with ACL injuries emphasize the importance of the development of effective preventative strategies.

A large number of ACL injuries (60% for women, 41% for men) occur during noncontact episodes (Agnel, et al, 2016). These injuries typically involve changes of direction or cutting maneuvers, deceleration, or landing tasks that are often associated with high external knee joint loads(Chochrane, 2007). Dynamic stabilization of the knee joint via the neuromuscular control system is a critical component in maintaining the structural integrity of the knee (Renstrom, 2008). In addition, because the knee does not act in isolation, trunk, core and upper body mechanics have also been shown to influence knee biomechanics (Bakker, 2016; Hashemi, 2010; Renstrom, 2008).

Various martial arts like judo, aikido, and jiu-jitsu employ similar techniques to avoid injury. The point of one such technique called break-falling is to disperse or decrease the force of the fall by dispersing the energy of a fall over the greatest surface area possible, so as to decrease the specific impact point and decrease the risk of injury. This involves utilizing body mechanics to properly go from an upright position into the fall and also uses the extremities to express energy away from the core of the body and out into the ground, striking the ground with the martial artist's hand, forearm, and/or feet before they land. This is meant to decelerate their fall and orient them to avoid injury. Athletes playing sports on soft surfaces like grass could easily use these techniques. A break-falling program incorporating proprioceptive training could encourage athletes to decrease knee joint loads by increasing their kinesthetic awareness of where their joints are positioned and train them to have another option in reacting to these risky maneuvers.

Martial arts falling techniques have already been utilized in studies for the sake of lowering hip fracture rates in the elderly. Two studies using subjects with martial arts backgrounds found reduction in force of impact on the hip with martial arts falling techniques compared with a 'block' technique (blocking the ground with an arm, a natural falling response) (van der Zjdien, 2012; Groen, 2008). A study conducted over the course of 14 years in Kingston, Ontario found that among all types of martial arts injuries leading to emergency room visits, the most common causes were throws, falls, and jumps. 21% led to fractures and 12% led to a strain or sprain. The most common location of these injuries were lower limb (41%) (McPerson & Pickett, 2010). Other non-combative sports have similar risks of fall and jump-related injuries. The techniques used by expert martial artists to avoid lower limb injury may translate to other sports.

II. Methodology

All subjects continued their usual soccer training. The intervention group completed a twice weekly 10-week training program in addition to their usual training, taught by a karate and aikido expert at the level of 3rd degree black belt and also a black belt in aikido (training regimen enclosed in Appendix A). At baseline and after the 10 week program is completed, all subjects underwent a biomechanical evaluation that measured hip and knee movement/position in frontal, transverse, and sagittal planes at 4 different time points during a drop fall (initial contact, heel strike 33 milliseconds, maximum knee valgus, and maximum knee flexion). To minimize the risk of muscle strain/soreness, subjects were afforded a warm up period consisting of lower extremity stretching and jogging on a treadmill for 5 minutes prior to testing. Prior to obtaining angular displacement data the marker trajectories was filtered with a 4thorder, zero lag, Butterworth filter with a 10 Hz cutoff frequency. The lower and lower extremities, trunk and pelvis was modeled as a 12-segment rigid body system with 11, 3 degree of freedom joints interspersed between the segments. Using this model and the filtered trajectory data, the three dimensional angular displacements of the trunk and right and left hip, knee, and ankle joints was determined using an Euler decomposition method (Z,Y,X). Using the filtered data, the above kinematic model, and filtered trajectory data the joint reaction and moment data was derived using a commercially available software package (KinTools, Motion Analysis Corp., Santa Barbara, CA). For each subject the mean of peak angular values of 3 trials for each limb was obtained and used for statistical analysis.

The subjects consisted of: 9 y/o female, weight 75lb, height 4'8.5"; 17 y/o male, weight 143lb, height 5'10"; 11y/o female, weight 66lb, height 4'7"; 14 y/o male, weight 112lb, height 5'5". The inclusion criteria for the study were that the subjects: be free of injury, have no prior knee ligament surgeries, have no prior break-falling training, and have no known adhesive tape allergy.

1. Data Analysis

A multivariate multilevel linear mixed model was used to test if there was a change in the kinematic outcomes from baseline to end of program. Movement in the sagittal, frontal, and transverse planes of both the hip and knee (6 outcomes) were analyzed simultaneously for the four different time points. The intercepts for each outcome were treated as random and allowed to covary at the level of the subject and trials nested within subject. The multivariate multilevel is able to account for the correlation among kinematics outcomes and reduce the number of models that need to be run. Analyses were conducted in SPSS v24 and the alpha level for statistical significance was set at 0.05.

III . Results

Figure 1 shows the mean kinematic measures during initial contact. A statistically significant change in the sagittal plane of the knee was identified. There was a reduction from baseline to post of 4.8 degrees ($p<.001$). There was no statistically significant change in the other two planes of the knee or hip. Figure 2 shows kinematic measures during heel strike. Similar to initial contact, significant change occurred in the sagittal plane of the knee where there was a lowering of 7.4 degrees ($p<.001$). Figure 3 shows the kinematic measures during maximum knee valgus and figure during maximum knee flexion. Neither of these two time points showed a significant change in any of the six outcomes.

Figure 1: Mean (±SEM) angular degree at Initial Contact

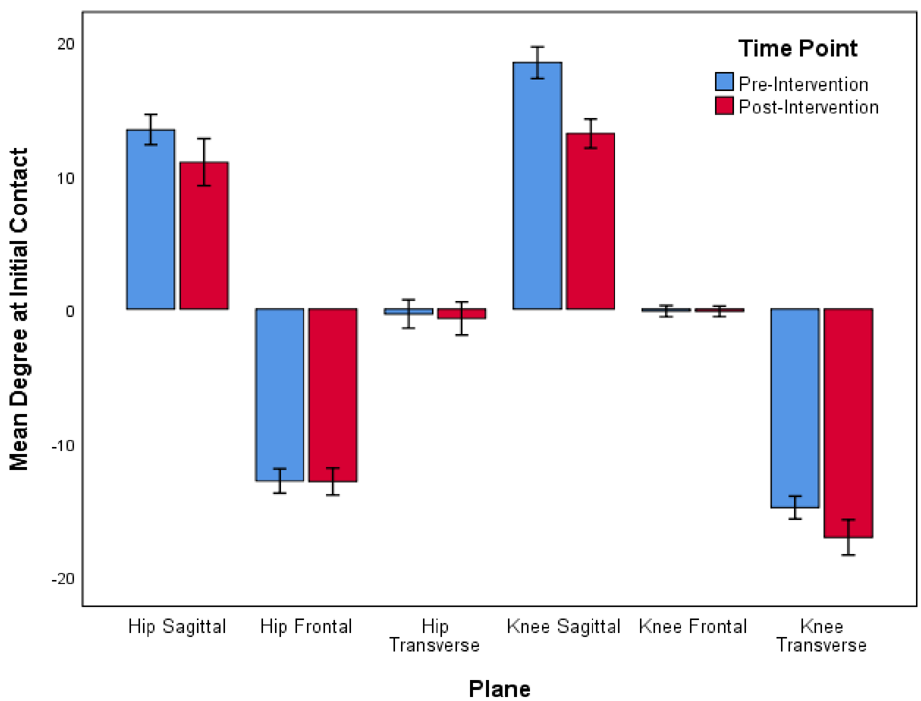


Figure 2: Mean (±SEM) angular degree at Heel Strike

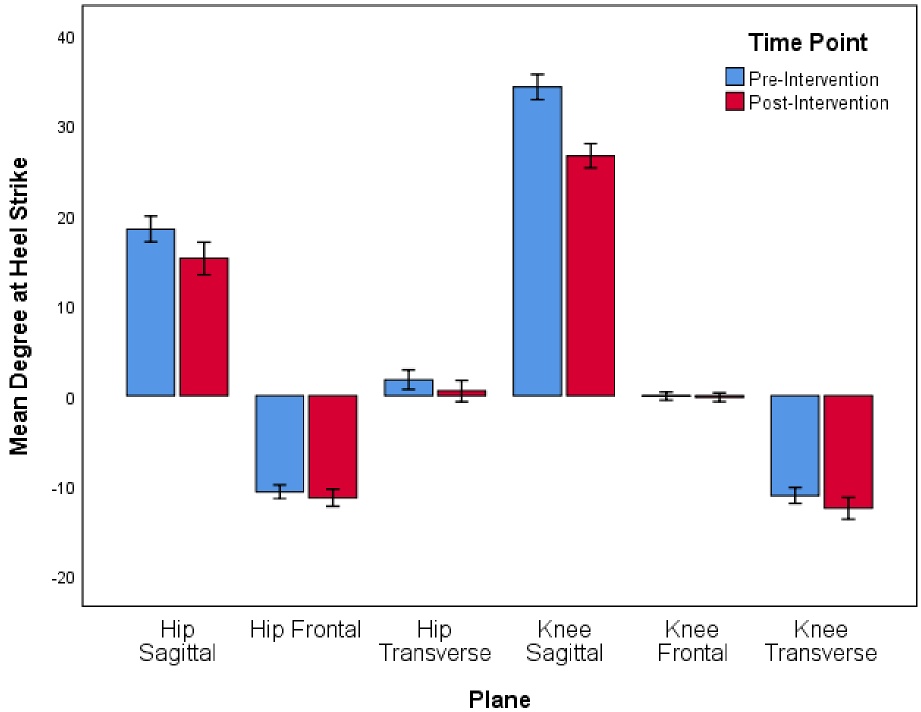


Figure 3: Mean (±SEM) maximum angular degree during Knee Valgus

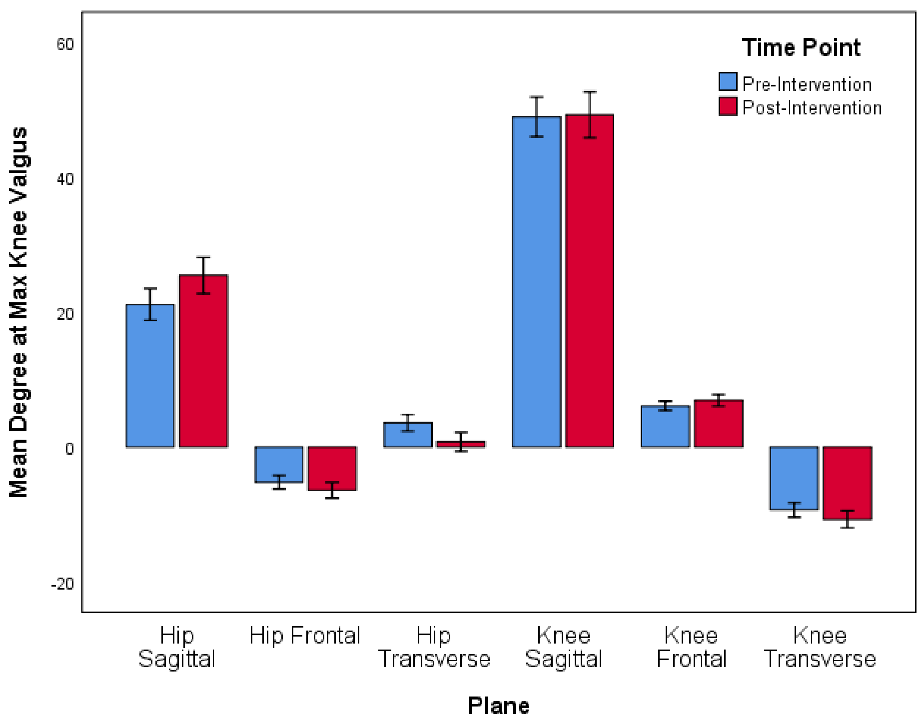
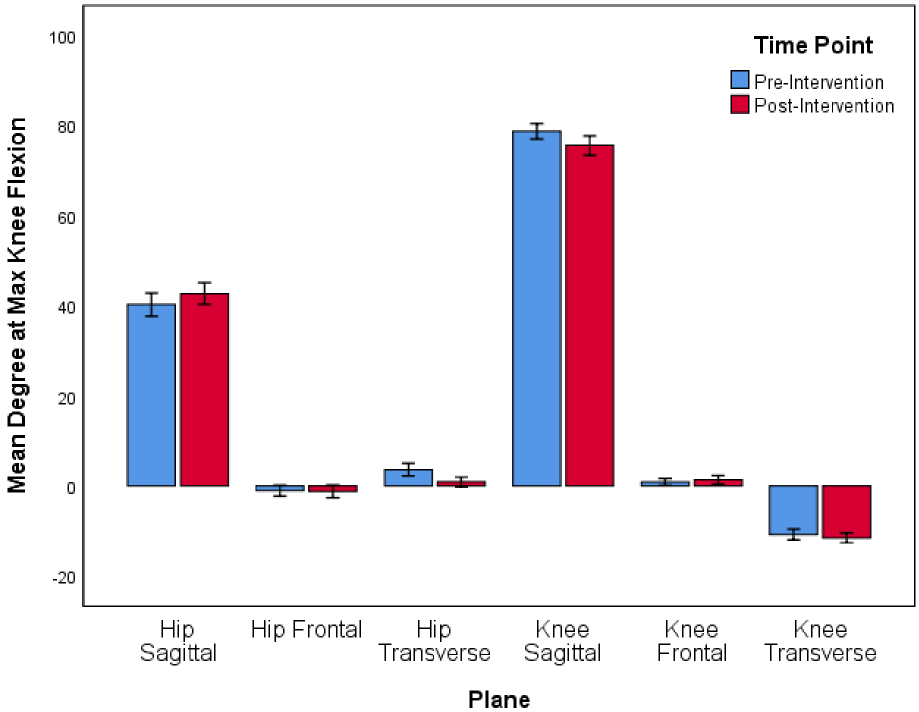


Figure 4: Mean (±SEM) maximum angular degree Knee Flexion



IV. Discussion

There are only a few studies to date that have used martial arts break-falling techniques or proprioceptive training derived from martial arts, and none that have studied the possibility of their application to ACL injury prevention as far as we know. There were several reasons for using this novel approach other than the fact that previous attempts to decrease ACL injury rates thus far have not made a significant impact in their national incidence. These martial arts are no strangers to non-contact lower body injuries(McPherson & Pickett, 2010), yet their generations old injury prevention techniques have not been adequately explored. Also, approaching ACL injury prevention with a technique like break-falling gives athletes a conscious choice to land safely in various situations.

A statistically significant change in the sagittal plane of the knee occurred after the 10-week intervention. There was also a change in how the subjects were landing before max flexion which is the main subject of our study. It is possible that the proprioceptive training these subjects underwent influenced their landing by giving them more degrees of knee flexion to absorb the impact of the landing as well as a longer span of time in which the subjects are in contact with the ground at all. Less of an abrupt deceleration of vertical motion may lead to longer time to max ACL strain and perhaps decreased overall ACL strain.

The literature has shown relationships between sagittal plane hip, trunk, and knee flexion on landing with ACL strain parameters(Zouhita, 2009). Specifically, knee mechanics have been found to be associated with ACL strain rate while both knee and hip mechanics have been found to correlate with ACL strain magnitude (Bakker, 2016). The hip extension knee flexion paradox described by Hashemi et al notes the importance of the hip and knees flexing on the sagittal plane at compatible velocities during landings to avoid overloading the ACL with ground reaction forces(Hashimi, 2010). While our data did not show a significant change in hip flexion, the changes in sagittal knee flexion could represent a more honed motion to avoid unnecessary strain. This theory includes other aspects that affect the ACL load such as the speed of quadricep and hamstring muscle activation, medial tibial and posterior tibial slopes, and ground reaction forces on a near fully extended knee. Future studies could examine muscle activation speeds to look for post-intervention changes. It would also be useful to examine trunk positioning changes in subsequent studies since there have been findings of decreased ACL strain models with forward trunk positioning versus upright trunk positioning (Shimokochi, 2016).

One of the weaknesses of this study is the limited sample size. Future trials will attempt to have larger numbers of participants, preferably within the same gender and age group. Groups may be obtained from the same soccer clubs at first but variations between soccer clubs, genders, and age groups are potential directions for study. Another weakness of this study is the short time frame. Tracking kinematic data in these athletes over the span of years would allow us to observe whether there is long-term change in their landings. This would be more aligned with the study's goal since ACL injuries typically occur in later age groups than the ones we are currently working with. Not having surface electromyograph data to observe quadricep and hamstring muscle activation is a limiting factor as well, considering their importance in the strain the ACL bears. Of course, not having a measurable way to quantify actual ACL strain during testing is a limitation that has forced us to examine our data by comparing kinematic changes to findings from other literature. This could be worked around by using computer simulated models to indirectly quantify the strain.

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), 26*(6), 518-523.

Bakker, R., Tomescu, S., Brenneman, E., Hangalur, G., Laing, A., & Chandrashekar, N. (2016). Effect of sagittal plane mechanics on ACL strain during jump landing. *Journal of Orthopedic Surgery, 34*(9), 1636-44. doi: 10.1002/jor.23164.

Chochrane, J. L., & Lloyd, D. G. (2007). Characteristics of anterior cruciate ligament injuries in Australian football. *Journal of Science and Medicine in Sports, 10*(2), 96-104.

Groen, B. E., Weedersteyn, V., & Duysens. (2008). The relation between hip impact velocity and hip impact force differs between sideways fall techniques. *Journal of Electromyography and Kinesiology, 18* (2), 228-234. doi.org/10.1016/j.jelekin.2007.06.002

Hashemi, J., Breighner, R., Chandrashekar, N., Hardy, D., Chaudhari, A. M., Shultz, S. J., Slauterbeck, J. R., & Beynnon, B. D. (2010). Hip extension, knee flexion paradox: a new mechanism for non-contact ACL injury. *Journal of Biomechanics, 44* (4), 577-585. doi.org/10.1016/j.jbiomech.2010.11.013.

Hewett, T. E., Myer, G. D., Ford, K. R, Paterno, M. V., & Quatman, C. E. (2016). Mechanisms, Prediction, and Prevention of ACL Injuries: Cut Risk With Three Sharpened and Validated Tools. *Journal or Orthopedic Research, 34*(11), 1843-1855. 10.1002/jor.23414

Lohmander, L. S., Ostenberg, A., Englund, & M., Roos, H. (2004). High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury. *Arthritis And Amp: Rheumatism, 50*(10).

Mather, R. C., Koening, L., Mininder, S. K., Dall, T. M., Gallo, P., Scott, D. J., Bach, B. R., Spindler, K. P. (2013). Societal and Economic Impact of Anterior Cruciate Ligament Tears. *The Journal of Bone and Joint Surgery, 95*(19), 1751-1759. 10.2106/JBJS.L.01705

McPherson, M., Pickett, W. (2010). Characteristics of martial art injuries in a defined Canadian population: a descriptive epidemiological study. *BMC Public Health. 795*van der Zjden, AM., Groen, B. E., Tanck, E., Niemhuis, B., Verdonschot, N., & Weedesteyn, V. (2012). Can martial arts techniques reduce fall severity? An *in vivo* study of femoral loading configurations in sideways falls. *Journal of Biomechanics, 45*(9), 1650-1655.

Nessler, T., Denney, & Sampley, J. (2017). ACL Injury Prevention: What Does Research Tell Us? *Current Reviews in Musculoskeletal Medicine, 10*(3), 281-288. 10.1007/s12178-017-9416-5

Renstrom, P., Ljungqvist, A., Arendt, E., Beynnon, B., Fukubayashi, T., Garrett, W., Georgoulis, T., Hewett, T. E., Johnson, R., Krosshaug, T., Mandelbaum, B., Micheli, L., Myklebust, G., Roos, E., Roos, H., Schamasch, P., Shultz, S., Werner, S., Wojtys, E., & Engebretsen, L. (2008). Non-contact ACL injuries in female athletes: an international Olympic committee current concepts statement. *British Journal of Sports Medicine, 42*(6), 394-412. oi: 10.1136/bjsm.2008.048934.

Shimokochi, Y., Ambegaonkar, J. P., & Myer, E. G. (2016). Changing Sagittal-Plane Landing Styles to Modulate Impact and Tibiofemoral Force Magnitude and Directions Relative to the Tibia. *Journal of Athletic Training, 51*(9).

Zouita, B. M, Zouita, S., Dziri, C., & Salah, B. (2009). Single-leg assessment of postural stability and knee functional outcome two years after anterio r cruciate ligament reconstruction. *Annals of Physical Rehabilitation Medicine, 52*(6), 475-84.