# The effect of neuromuscular training with AposTherapy system in recreational female athletes with a high risk for a non-contact Anterior Cruciate Ligament injury

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Injury to the anterior cruciate ligament (ACL) is considered one of the most debilitating knee injuries which could occur in any young athlete. ACL injuries have short and long-term morbidity consequences, with all the negative impact in the individual wellbeing and health-system. Mitigation of the risk factors (e.g., knee valgus) through training are key in reducing the risk of an ACL injury. However, the majority of neuromuscular training programs require a time-intensive commitment and have a considerable level of complexity and intensity, thus reducing compliance to the programs AposTherapy is a unstable foot-worn biomechanical device which aims to alter alignment and enhance neuromuscular control but has the advantage as a simpler intervention. The purpose of this study was to investigate the effect of implementing an unstable footwear device, AposTherapy system, on lower limb biomechanics in recreational female athletes The study identified a significant reduction in knee valgus angle in the AposTherapy group. Utilising foot-worn biomechanical interventions may be a different method for mitigating risks of ACL injury.

**KEYWORDS:** ACL injury, female athletes, Neuromuscular Training

**INTRODUCTION**: Injury to the anterior cruciate ligament **(**ACL) is considered one of the most debilitating knee injuries which could happen to any young athlete (Alentorn-Geli, 2009). Young females involved in jumping, landing and pivoting sports have been documented to have a 4-6-time greater potential of sustaining a non-contact ACL (NCACL) injury during sport participation in comparison to their male counterpart. Various biomechanical risk factors for ACL injury been identified with knee valgus been postulated as one of the primary predictors for ACL injury in high risk active population (Koga et al., 2010; Hewett et al., 2005). Thus, mitigating the risk by reducing knee valgus is a target for training programs. However, a recent report by Norcross et al. (2017) does raise caution with this finding as Hewett et al used non-normalised moments and when normalised moments were used, no significant difference was found. The nature of DVJ tasks used by Hewett et al and others makes it difficult to discriminate between two lower limbs as it is a bilateral task, whereas, most ACL injuries occurs during single limb activities (Herrington et al., 2017).

Many neuromuscular training (NMT) prevention programs have been introduced with the aim to reduce ACL injury risk (Sugimoto et al., 2015). However, the disparity between positive laboratory results demonstrating NMT programs and the actual effects on injury outcomes among high-risk female athlete's population suggests a missing link between current published research and clinical applications of a prevention intervention programs (Sugimoto et al., 2015). The majority of NMT programs require a large time commitment and have a considerable level of complexity and intensity. This has appeared to deter athletes and reduce their compliance rates (Sugimoto et al., 2012). This highlights the need for a simpler yet effective intervention to be developed.

AposTherapy (APOS) is an unstable foot-worn biomechanical device which aims to alter alignment in the lower limb whilst also targeting neuromuscular control. Evidence for the treatment is established in osteoarthritis, although no study has examined whether this system can alter knee valgus in individuals at a risk of a NCACL injury. The purpose of this study was to determine the effect of incorporating APOS alone or in combination with an exercise programme on dynamic knee valgus in a group of young recreational female athletes. The study hypothesis was that the introduction of perturbation training with alignment re-

adjustment by using APOS would reduce knee valgus angle and moment compared to the control group.

**METHODS**: This was a pilot parallel group randomized controlled trial (Pilot RCT) study. 32 young adult recreational female athletes (age=26.3±4.36 years, Height=165.7±3.5cm, Mass=64.4±4.3kg). All participants provided informed consent, and the study was approved by Research Ethics Committee at the University of Salford.

**2D VIDEO ASSESSMENT**: Individuals who agreed to take part in the study were initially assessed using 2D analysis to assess the frontal plane projection angle (FPPA) of their non-dominant knee while performing a Single leg squat (SLS) task. The SLS task was considered most appropriate for assessing athletes who are at higher risk of NCACL injury as it showed high level of correlation with other high demanding single legged sports movements such as single leg landing, running and cutting (Alenezi et al., 2014). In order to be eligible for the study, the individuals must have a knee valgus angle >8° on their non-dominant knee which was considered higher than the normative knee valgus angles reported (Mendonça et al., 2011; Herrington et al., 2014). The dominant leg was defined as the leg that the participant used to kick a ball.

**APOSTHERAPY CALIBRATION**: The APOS comprises of two modular elements attached onto each footwear platform (Haim et al., 2008). The elements are attached under the forefoot and hind foot regions of foot platform using two mounting rails which allows for flexible positioning of each element (Haim et al., 2008). The exact protocol for the calibration is governed by intellectual property rights of the company and thus for confidentiality reasons this cannot be contained in this article. However, the postulated mechanism of the APOS for reducing the knee valgus loads on the knee joint was influenced with the direction the elements where configuration in particular the once under the forefoot at medial-lateral direction. The manipulation of the element towards the lateral or medial direction, showed the ability to alter the frontal plane loads at the knee joint (Haim et al., 2008). The calibration was subjectively performed with aim reduce knee valgus alignment of non-dominant knee with the aid of 2D video analysis. All participants had their APOS specifically calibrated by the same senior technician (AposTherapy, UK) (Figure 1) and were required to attend the laboratory for the baseline data collection session soon after these were calibrated.

**Figure 1: Show the calibration process of the participants.**

The participants were divided into three study groups, Group 1: walking without APOS (W gp), Group 2: Walking + exercise with APOS (WE gp) and Group 3: usual training without APOS (Cont gp). The walking study group used APOS only with no additional exercise, 2) The walking and exercise used APOS with the addition of 15 minutes' exercise ,3) The control group did not use APOS and continue their usual training regime with no changes. The individuals were required to wear the device for a minimum of one hour per day during typical walking activities in the home. Everyone attended the gait laboratory twice at baseline and following a six-week intervention period. 3D motion and force plate data of the lower limb kinematics and kinetic variables were measured during the Single leg squat (SLS) and Single

leg landing (SLL).

**RESULTS**: The walking group knee valgus angle (KVA) during the SLL task showed a significant reduction from baseline after 6 weeks APOS intervention with a moderate effect size d=0.53 and was significantly reduced in comparison to the control group. In regarding the walking and exercise group they showed significant difference when compared with control group. In addition, significant changes in the hip adduction moment (HDM) during SLS and SLL tasks from baseline and after 6 weeks APOS intervention with effect size 2.28 and 0.41, respectively.

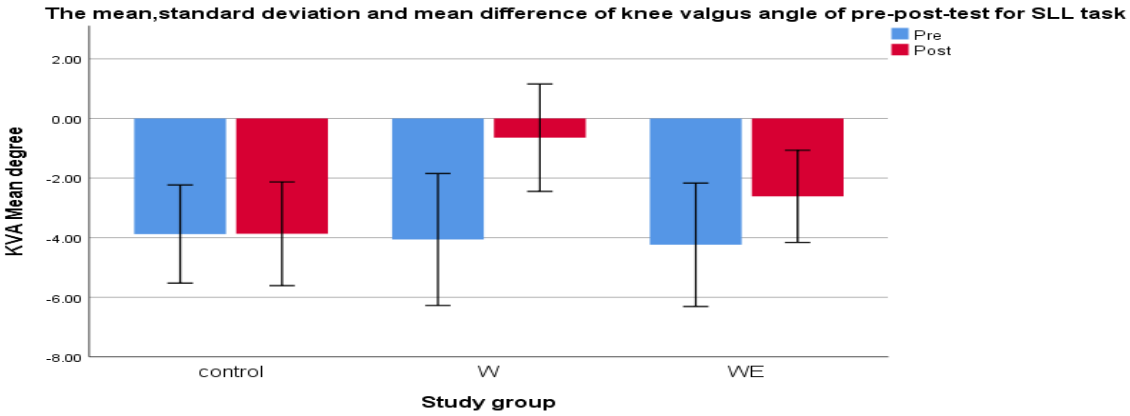


**Figure 3: The mean, standard deviation (SD) and the mean difference (Mean diff.) of the knee valgus angle (KVA) of pre- and post-test for SLL task. Y –axis KVA (degrees) and X-axis Study groups.**

**DISCUSSION:** The APOS showed a significant reduction in knee valgus in the walking only group during the SLL task (d=0.53). The mean difference was 3.42°, which may be considered clinically significant as it also was also greater than the pre-assessed standard of error of measurement of 2.5° (Ortiz, et al., 2007). When looking at the other secondary outcomes, participants in the walking and exercise group showed improvements in the frontal plane hip joint variables, a significant reduction in hip adduction moment was observed during the performance of SLL and SLS functional tasks with a large effect size of d=2.28 and d=0.41, respectively. This improvement in the frontal plane at the hip joint level in participants in the walking and exercise group may be attributed to the nature of the study intervention, with the added exercise elements improving the hip abductor muscle activation pattern and strength that could be related to the incorporation of multiple squatting to a high level of difficulty.

Different unstable footwear designs have demonstrated that they could generate the biomechanical manipulation commonly employed for this purpose by acting as an interface between the ground and foot (Farzadi et al., 2017). The unstable footwear may manipulate sensory feedback information originating from the plantar surface of the foot generating those stimuli (Khoury et al., 2015). The concept behind these designs is to introduce a controlled destabilisation which would challenge lower limb joint dynamic stability and balance control (Farzadi et al., 2017). This alteration in lower limb muscle recruitment pattern may allow users to develop adequate motor control to protect their lower extremity joints from potentially hazardous loads during functional activities (Farzadi et al., 2017).

The outcomes of the walking group in the current study may suggest it's possible to adapted a low impact intervention with just using APOS while walking during daily activities. This may be attributed to APOS is designed to enforce a biomechanical effect on neuromuscular control by its ability to simultaneously introduce perturbation through the creation of controlled micro-instability, which may challenge the dynamic stability of the lower limbs while modifying the chain of joints to its optimal alignment (Khoury et al., 2015). The convex shape of the elements puts participants in a state of perturbation by having the participant walk with a device every day thereby considered to induce neuromuscular adaption towards the desired neuromuscular

gait pattern (Bar-Ziv et al., 2013). The study intervention adopted using APOS during walking and not during other sport movements for two main reason: Mainly for health and safety as it's an unstable footwear. The other reason was for the propose of providing simple low impact intervention with a minimum interference with athlete's daily schedule. The flexibility of using the APOS can encourage its use as a more time efficient intervention component yet may deliver the required neuromuscular control enhancement effect.

**CONCLUSION**: The time demand and complexity can be daunting for athletes and coaches implementing NMT programs. The study outcomes in this study have showed promising effects as a result of incorporating APOS intervention during walking alone. A significant reduction in knee valgus angle was seen and may present a time efficient and effective ACL injury mitigation intervention, which would be easy to incorporate around the busy schedule of high-risk female athlete's population.

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