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Neuromuscular Training Outcomes of an ACL Injury Prevention Program for Rural Adolescent Female Athletes

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Abstract

Purpose: There is considerable evidence that young females are at an increased risk for incurring an ACL injury. Additionally, patients in rural areas experience disparities in access to health care and worse post-operative outcomes after ACL reconstruction compared with their suburban counterparts. Evidence suggests that neuromuscular training (NMT) is an effective means of reducing ACL injuries through improvements in rate of force development, neuromuscular activation, and force absorption during landing tasks. Limited research exists examining the feasibility and outcomes of NMT programs in rural adolescent populations. The purpose of this study was to examine jump performance outcomes of rural secondary school-aged females who participated in the ACL Strong® injury prevention program. **Method:** Twenty female basketball athletes attending a rural secondary school participated in this quasi-experimental study. All participants were provided access to the ACL Strong program on their mobile devices. Before and after the intervention, Kinvent Delta Force Plates® were used to measure jump height and impulse during a vertical jump task. Paired-samples t-tests were used to compare pre- and post-intervention outcomes. **Results:** Paired samples t-tests revealed a significant increase in jump height from pre-test to post-test ($p = 0.002$). There was also a significant improvement from pre-test to post-test impulse deficit between limbs ($p < 0.001$). **Conclusions:** Participation in a six-week neuromuscular training program resulted in significant improvements in jump performance and limb symmetry among rural adolescent female athletes. These findings support the implementation of a mobile app ACL injury prevention programs in a rural school setting.

Keywords

ACL, Intervention, Rural Health, Neuromuscular Training

1. Introduction

There is considerable evidence that young females are at an increased risk for incurring an anterior cruciate ligament (ACL) injury [1]. The ACL is one of the four primary ligaments responsible for stabilizing the knee joint. According to National High School Sports-Surveillance Studies, the knee is the third most commonly injured body site in organized U.S. high school sports [2]. Approximately 250,000 ACL ruptures occur annually, and the majority of individuals intending to return to sport undergo ACL reconstruction [3] [4]. Female high school athletes experience an approximately 1.6-fold greater rate of ACL tears per athletic exposure compared with males [5]. Sports with the highest risk among females include soccer, basketball, and lacrosse.

ACL injuries frequently occur during non-contact tasks such as landing from a jump or rapid changes in direction [6]. Multiple intrinsic and extrinsic factors contribute to ACL injury risk, including anatomical structure, hormonal influences, and biomechanical movement patterns [7]. It is well known that elevated ground reaction force due to lack of force absorption in the lower extremity may increase ACL injury risk [6]. While many studies focus on landing, the acceleration and takeoff phase of the vertical jump has also been correlated with risk of ACL injury [8].

Impulse is indicative of time dependent compensatory strategies during initial loading in the knee and can be measured with a commercial force plate [9]. Impulse has a high between and within day reliability in counter movement jump performance [10]. Concentric impulse and concentric force were already shown to be strong predictors of ACL injury risk [11]. New insights may be gained from examining side to side differences in impulse. Impulse is indicative of rapid shift from eccentric to concentric phases and a shift in control from the upper to lower leg movement and power. Asymmetry of coordination between the two legs during this phase could create a valgus force that exposes vulnerability in the ACL. Reinjury studies have shown that side to side differences in laxity indicate increased risk of reinjury [12]. Also, ACL injury has a lasting effect on the asymmetry of the concentric phase impulse during counter movement jumps [9].

Up to 25% of young athletes experience a secondary ACL injury within one year of returning to sport [13]. These risks may be mitigated through neuromuscular training programs emphasizing strength, balance, and proper landing mechanics [14]. Access to care differs between rural and urban populations, with rural patients experiencing delays in diagnosis, treatment, and rehabilitation, as well as worse postoperative outcomes following ACL reconstruction [15] [16]. Rural schools are often geographically isolated and face shortages of specialized healthcare providers, contributing to disparities in injury prevention and management [16] [17].

Neuromuscular training (NMT) programs have demonstrated effectiveness in reducing ACL injury risk and improving neuromuscular coordination in dynamic movements [18] [19]. However, implementation of such programs in rural settings remains limited due to resource constraints and reduced access to trained professionals such as athletic trainers.

ACL strong is a knee strengthening program delivered through a mobile app [20].

ACL strong is a commercially available intervention program to help athletes strengthen their knee and prevent ACL injury at home. The intervention is delivered through a mobile app and athletes can complete the program independently by performing 15 - 20 minutes of exercise, three times a week for six weeks. The program cost is approximately $200 and was funded by a grant from a local hospital system. By completing the program, athletes have the potential to reduce their ACL injury risk in the absence of an athletic trainer.

The purpose of this study was to examine jump performance outcomes among rural secondary school-aged female athletes participating in the ACL Strong® injury prevention program. It was hypothesized that participation in the program would result in improved jump performance and impulse symmetry.

2. Methods

2.1. Participants

Twenty one secondary school rural female basketball athletes ages 15 - 18 years of age were recruited in this study. Participants were excluded if they reported symptoms of joint injury or disease; neurologic impartment; history of hip, knee, or ankle (lower extremity) injury; balance or vestibular disorders; use of any form of prophylactic walking aid or device. Participants were recruited from two different communities in Arkansas. Both schools are located in an area considered Rural fringe by the National Center for Education Statistics [21]. Neither school has access to a full-time athletic trainer. Institutional Review Board (IRB) approval was granted by XX University and parental consent was given.

Each participant was asked to complete a short biographical data sheet that encompassed questions concerning their gender, age, height (cm), weight (kg), past surgical procedures (orthopedic) and physical activity levels (PAL) per week. All participants were fully capable of flexion and extension of both knee joints through a full range of motion. As a screen tool for participation, each volunteer was asked to perform a straight leg raise (SLR) and 10 consecutive single-leg hops. All participants reported "no pain" and were within 75% strength for bilateral comparison on manual muscle testing of gluteus minimus and medius muscle.

2.2. Experimental Procedures

A pretest was implemented for each participant before the intervention. Each participant was given 1-warm up jump. Participants were asked to perform three trials of a counter movement jump with a 10 second rest in between trials. The jumps were performed on the Kinvent Delta Force Plates® with each limb associated with a separate force plate. Participants were asked to place their hands on their hips during each jump. To eliminate footwear issues, hops were performed barefoot. Jump height (cm) and Left and Right impulse (kg*s) were calculated by the Kinvent Physio App and recorded for each trial. Total impulse was calculated as the area under the curve of force and time from movement initiation until take off [22]. It is reported as the percentage of the impulse on each of the left and right plates. Impulse deficit was calculated as the percentage difference between the impulse on the left and right plates.

$$Impulse_{deficit\%} = \frac{Right - Left}{Right}$$

Each participant was given a subscription to the ACL Strong® program for the intervention. Athletes completed 15 - 20 minute workouts, three times a week for 6 weeks through their mobile app that focused on building knee strength [20]. Completion of the program was verified by checking logins on the ACL strong website. At the end of 6-weeks, a post-test was completed using the same parameters and conditions as the pre-test. The same assessor was present for both the pre and post-test.

2.3. Statistical Analysis

This study employed a quantitative quasi-experimental pre-test/post-test design. Mean and standard deviations were computed by trial and then averaged by time (pre/post) for impulse deficit and jump height. A paired t-test was used to compare the pre-test and post-test results for each variable. Cohen's d is reported as an estimate of the effect size. All analyses were performed using SPSS statistical software (version 22.0; IBM Corp, Armonk, NY) and an alpha level of 0.05 was set a priori.

3. Results

20 participants completed the study with a mean age of 15.54 ± 0.44 years. One participant was excluded for having had a previous ACL injury. The remaining participants reported no impairments.

All assumptions were met and data was found to be normal. The paired samples t-test revealed a significant difference in jump height pre-test and jump post-test ($t(19) = -3.22$, $p = 0.002$, $d = -0.72$). Jump height increased from pre-test to post test. There was a significant difference in pre-test deficit and post-test deficit ($t(19) = 3.73$, $p < 0.001$, $d = 0.83$). The deficit decreased from pre-test to post-test (**Table 1**).

Table 1. Pre and post-intervention jump performance and impulse deficit.

Variable	Pre-test (mean ± SD)	Post-test (mean ± SD)	*p*	95% confidence intervals	
Jump height (cm)	12.55 ± 5.92	15.45 ± 7.48	0.002	−4.78	−1.01
Impulse deficit (%)	11.27 ± 8.23	7.64 ± 5.47	<0.001	1.59	5.67

4. Discussion

The current study assessed the benefits of the ACL Strong intervention in a small group of female adolescent athletes from rural school districts. The results revealed a statistically significant improvement in jump height and impulse deficit following the intervention. These results are in line with previous research states there is a substantial beneficial effect of ACL injury prevention programs, with a risk reduction of approximately 75% in female athletes [18] [19].

The study's results are promising as a potential solution for improving access to ACL interventions in rural settings. Rural areas often lack specialized sports medicine facilities or athletic trainers who can address ACL injury prevention [16]. The ACL Strong program shows potential in bridging these gaps, because it is delivered via a mobile app and performed in the home, thus reducing barriers related to transportation and access to facilities and equipment.

Home-based programs have their own challenges compared to interventions delivered in a physiotherapy or athletic training clinic. Compliance with home-based programs may be impacted by boredom and time management, but are typically not affected by a need for adequate space or technology constraints [23]. In studies of home rehabilitation adherence, high self-motivation is the highest predictor of success [24]. Social support is also identified as a strong indicator of compliance with home based physio programs [24] [25]. Therefore, education on the benefits of the program and accountability with regular check ins from coaches would be vital to ensure the intervention is successful.

Some limitations should be acknowledged when interpreting these results. The small sample size limits generalizability but the large effect size suggests that the outcome would be the same if replicated with a larger sample. The absence of a control group precludes causal inference. Additionally, limb dominance, sport exposure, and compliance with the training program were not formally quantified, which may have influenced observed outcomes. The use of jump performance and impulse measures as surrogate indicators of injury risk, while supported by prior research [9]-[12], does not directly reflect ACL injury incidence. Future studies should incorporate larger samples, and direct injury tracking to further validate these results.

Despite these limitations, the present study contributes novel evidence supporting the potential benefits of the ACL Strong intervention. The program has the potential to produce benefit female, and rural populations by improving jump performance from their home without the need to travel to or pay for private services. in rural secondary schools. Identifying funding sources, such as health institutions to cover the cost of the subscription would be key to successful implementation.

5. Conclusion

The results indicated that both jump height and impulse deficit improved after completion of the 6 week ACL strong program. Future research should aim to include a larger sample size of athletes and a control group from rural communities to confirm these findings. This study is particularly important as it demonstrates the benefits of implementing a mobile app ACL prevention program in a rural setting on jump performance of female basketball athletes.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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