Feasibility and Efficacy of Delivering a Mobile-Application-Based Neuromuscular Training Program to High School Athletes: Adherence, Agility, and Single Leg Squat Kinematics

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INTRODUCTION: Non-contact lower extremity injuries are common and debilitating in the adolescent athlete population, frequently occurring during high-risk maneuvers such as cutting, jumping, and directional changes. Such injuries can lead to long-term joint dysfunction, cessation of sport participation, and early-onset osteoarthritis. Prior literature has implicated poor neuromuscular control—specifically increased dynamic knee valgus and impaired hip control—as a key modifiable risk factor for injury [1]. To mitigate these deficits, neuromuscular training (NMT) has demonstrated efficacy for reducing lower extremity injury incidence and improving lower extremity biomechanics [2]. However, implementation in high school athletic programs remains limited due to lack of access to trained professionals. Mobile-based NMT programs offer a potential solution, but little is known about their feasibility and efficacy. To address this gap, we conducted a 6-week pilot study, delivering an NMT intervention to high school athletes via a mobile application. Our objectives were (1) to assess recruitment, retention, and adherence rates, (2) to evaluate preliminary efficacy via an agility test and single leg squat (SLS) test, and (3) to assess whether greater adherence was related to greater improvement in outcomes. We hypothesized that the intervention would be feasible, and that athletes with higher adherence would exhibit greater magnitudes of improvement in agility and SLS mechanics than athletes with lower adherence.

METHODS: With IRB approval, we recruited high school athletes (ages 14-18) from Westchester County, NY to participate in a 6-week, mobile-application-based NMT program that was downloaded onto each participant's personal smartphone and consisted of 24 unique 7-minute sessions. Exercises emphasized bodyweight training targeting landing mechanics, trunk control, balance, and posterior chain engagement, with progressive difficulty. Pre/post intervention assessments included (1) an agility T test and (2) a video-recorded SLS test from sagittal and coronal planes. Sagittal plane analysis captured peak knee and hip flexion angles; coronal plane analysis assessed alignment of the knee, hips, and trunk. These subcomponent scores were combined into an 8-point composite movement quality score previously described by Di Paolo et al. [3]. Paired t-tests and effect sizes (Cohen's d) were computed in Stata (v.18) to evaluate pre-post changes in agility T test performance and Di Paolo SLS composite and subcomponent scores. Participants were arranged by adherence into high (≥12 sessions) and low (<12 sessions) groups to determine if any relationship existed between adherence and outcome measures.

RESULTS: Of the 28 athletes approached, 19 enrolled (68% recruitment) and 14 completed post-testing. One was excluded from analysis for completing zero NMT sessions, yielding a final analytic cohort of 13 participants (74% retention). Adherence ranged from 4 to 25 sessions; 9/13 (69%) participants completed ≥6 sessions and 6/13 (46%) completed ≥12 sessions. Participants demonstrated large, significant improvements in agility T test times following the intervention (mean Δ = -0.60s, d = 1.30, $p < 0.001$). Improvements in agility were similar between the high adherence (n = 6) and low adherence (n = 7) groups. Across the full cohort, small improvements were observed in the composite Di Paolo SLS score (mean Δ = 0.45, d = 0.29) with moderate improvements in frontal plane hip (mean Δ = 0.309, d = 0.39) and trunk (mean Δ = 0.17, d = 0.35) control subcomponents; however, none of these changes reached statistical significance ($p > 0.05$). When stratified by adherence, the high adherence group showed much larger improvements in the composite Di Paolo score (mean Δ = 0.98, d = 0.82) than the low adherence group (mean Δ = -0.005, d = 0.002), though these changes did not reach statistical significance ($p > 0.05$). Furthermore, large, significant improvements in the frontal plane hip control scores (mean Δ = 0.63, d = 1.14, $p = 0.038$) were observed in the high adherence group, while non-significant, negligible changes across all subcomponent categories ($p > 0.05$) were observed in the low adherence group.

DISCUSSION: This pilot study demonstrated that a mobile-application-based NMT intervention can be successfully implemented in high school athletes and that agility may be enhanced following training. Furthermore, SLS kinematics—particularly those representing frontal plane control of the hips and pelvis—may also be improved following training, especially in those who complete a greater number of sessions. We observed a 74% retention rate, with nearly half (46%) of participants completing ≥12 sessions, a threshold selected to reflect an average of two sessions per week. These rates of retention and adherence are consistent with those reported in previous studies of tech-based physical activity interventions [4]. The large improvements in agility T test performance (d = 1.30) observed throughout our full cohort suggest that the intervention may enhance explosiveness and change of direction. Additionally, high adherence was associated with a statistically significant improvement in frontal plane hip control and a large, though non-significant, improvement in the composite Di Paolo score, suggesting that greater adherence may be associated with better SLS mechanics. These preliminary findings support the potential of mobile NMT programs to improve movement quality when performed consistently.

SIGNIFICANCE: This study demonstrates the potential of a mobile-application-based NMT intervention to induce improvements in agility in adolescent athletes. Additionally, high participant adherence was associated with an improved ability by athletes to keep their hips level in the frontal plane, suggesting that mobile-application-based NMT interventions may improve movement patterns associated with lower extremity injury risk in adolescent athletes.

REFERENCES: [1] Read 2016 Sports Med. [2] Petushek 2019 AJSM [3] Di Paolo 2024 The Knee [4] Christiansen 2021 Arthritis Care Res (Hoboken)

Figure 1: Pre-to-post-intervention outcomes demonstrating changes in agility. Agility T test times demonstrated a large improvement following the intervention, with a large effect size (d = 1.30, p = 0.0005).

Figure 2: Pre-to-post-intervention outcomes demonstrating changes in hip control. (A) Frontal plane hip control subcomponents from the Di Paolo single leg squat assessment showed large improvements in the high adherence group (≥12 sessions) (d = 1.42, p = 0.038). (B) In contrast, the low adherence group (<12 sessions) demonstrated negligible changes in hip control (d = 0.042).

Participant Characteristics	Mean (SD)
Age, y	15.8 (1.0)
Sex	
Male	11
Female	2
Ethnicity	
African-American	1
Caucasian	9
Hispanic/Latino	1
Biracial	2
Years of sport participation	10.0 (2.7)
Pre-Intervention Biometric Data	
Height, in	69.6 (3.8)
Weight, lbs	151.8 (28.1)
Post-Intervention Biometric Data	
Height, in	69.8 (3.8)
Weight, lbs	151.0 (28.7)

Table 1: Participant Characteristics for individuals who completed both pre- and post-intervention testing and engaged in the intervention (n=13). Age was recorded before the intervention as was years of sport participation.