

Paper 51. Effects of Platelet-Rich Plasma and Bone Marrow Aspirate on Knee Kinematics, Graft Elongation and Muscle Function after ACL Reconstruction: A Randomized Clinical Trial

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Objectives: Even with state-of-the-art surgical techniques and rehabilitation protocols, full recovery from ACL reconstruction (ACLR) can take 6 months to a year or longer before safe return to play (RTP). Orthobiologic injections of platelet-rich plasma (PRP) and bone marrow aspirate concentrate (BMAC) are used clinically with the goal of accelerating ACL graft healing and RTP; however, there is limited in vivo evidence of their effects on knee, graft and muscle function. This study aimed to evaluate the efficacy of PRP and BMAC for improving knee function and to identify biomechanical factors associated with functional recovery following ACL reconstruction.

Methods: Forty-three patients (22 females, age 29 ± 7 years) who underwent unilateral, anatomical bone-patellar tendon-bone ACL reconstruction were enrolled in an IRB-approved randomized clinical trial (IRB# 2019-13, NCT04205656). Participants were randomized into control, PRP or BMAC treatment groups, with orthobiologic injections administered at the time of surgery. All other surgical and rehabilitation protocols followed the standard of care. Comprehensive functional assessment was performed 6 and 12 months post-surgery using advanced imaging and biomechanical testing. Dynamic stereo x-ray (DSX) imaging (1ms pulsed exposures @ 90 kVp, 120mA) was acquired at 120 frames/second during standardized downhill running (10° decline, 2.5 m/s) on an instrumented dual-belt treadmill (Bertec), with acquisitions triggered just before foot-strike. High-resolution CT scans were registered to biplanar x-ray images to enable precise assessment of three-dimensional knee joint kinematics, reported using International Society of Biomechanics (ISB) standards. ACL elongation was calculated based on the dynamic distance between graft tunnel aperture centers, with the reference length determined from the knee posture in CT scans. DSX data was analyzed from 0-30% of stance phase, when the knee was unobstructed in both x-ray views. Isokinetic knee flexion/extension strength testing was performed using HUMAC dynamometry (600/s), with asymmetries calculated as peak torque and total work differences between intact and reconstructed limbs. Statistical Parametric Mapping (SPM) was employed to perform ANOVA assessing treatment group differences in the temporal patterns of ground reaction forces, knee kinematics, and ACL graft strain. Pearson correlation coefficients quantified relationships between muscle strength and kinematic asymmetries across all participants at both time points.

Results: The downhill running assessments were completed by 24 study participants at 6 months and 28 at 12 months post-ACLR. At 6 months post-surgery, PRP and BMAC treatment groups demonstrated significantly smaller side-to-side asymmetries in knee extension strength peak torque than controls. During dynamic loading, treatment groups exhibited increased ground reaction forces (GRF; 13-50% stance phase) and elevated ACL strain (3-30% stance phase) on the reconstructed side compared to controls (Figure 1), indicating enhanced loading capacity and accelerated functional recovery. There were no significant differences in GRF or ACL strain

between the PRP and BMAC groups. These treatment group differences largely resolved by 12 months, with only minor differences in ground reaction forces (75-95% stance phase) and no significant differences in muscle strength or ACL strain between groups. Kinematic analysis revealed substantial asymmetries at 6 months across all groups, with average differences of -11° flexion, +2mm anterior translation, and -8° internal rotation between reconstructed and intact knees (Figure 2). Concurrent strength deficits showed extension peak torque asymmetries of -31% and flexion asymmetries of -9% in the reconstructed limb. No significant correlations were observed between muscle strength and knee kinematics at 6 months, suggesting multifactorial influences on early recovery, including pain and tissue healing. By 12 months post-ACLR, kinematic asymmetries decreased to -8° flexion, +1mm anterior translation, and -5° internal rotation, while strength asymmetries improved to -19% extension and -6% flexion. Critically, strong correlations emerged between knee extension strength asymmetry and both flexion angle ($R=0.6$, $p=0.001$) and anterior tibial translation ($R=-0.6$, $p=0.001$), demonstrating direct relationships between quadriceps weakness and altered knee mechanics. No correlation was observed with rotational asymmetry ($R=-0.08$, $p=0.7$) or between flexion strength and kinematic parameters.

Conclusions: Orthobiologic interventions with PRP and BMAC significantly accelerate functional recovery following ACL reconstruction, demonstrating improved muscle strength and enhanced loading capacity 6 months post-surgery. The emergence of strong correlations between quadriceps strength deficits and kinematic asymmetries at 12 months highlights the critical importance of addressing muscle weakness in rehabilitation protocols. The relationship between extension strength asymmetry and anterior tibial translation reflects quadriceps force application through the patellar tendon, while correlations with flexion angle emphasize the role of the quadriceps for load acceptance during running. These findings suggest that combining orthobiologic treatments with targeted strength training may optimize dynamic knee function, potentially reducing reinjury risk and post-traumatic osteoarthritis development.

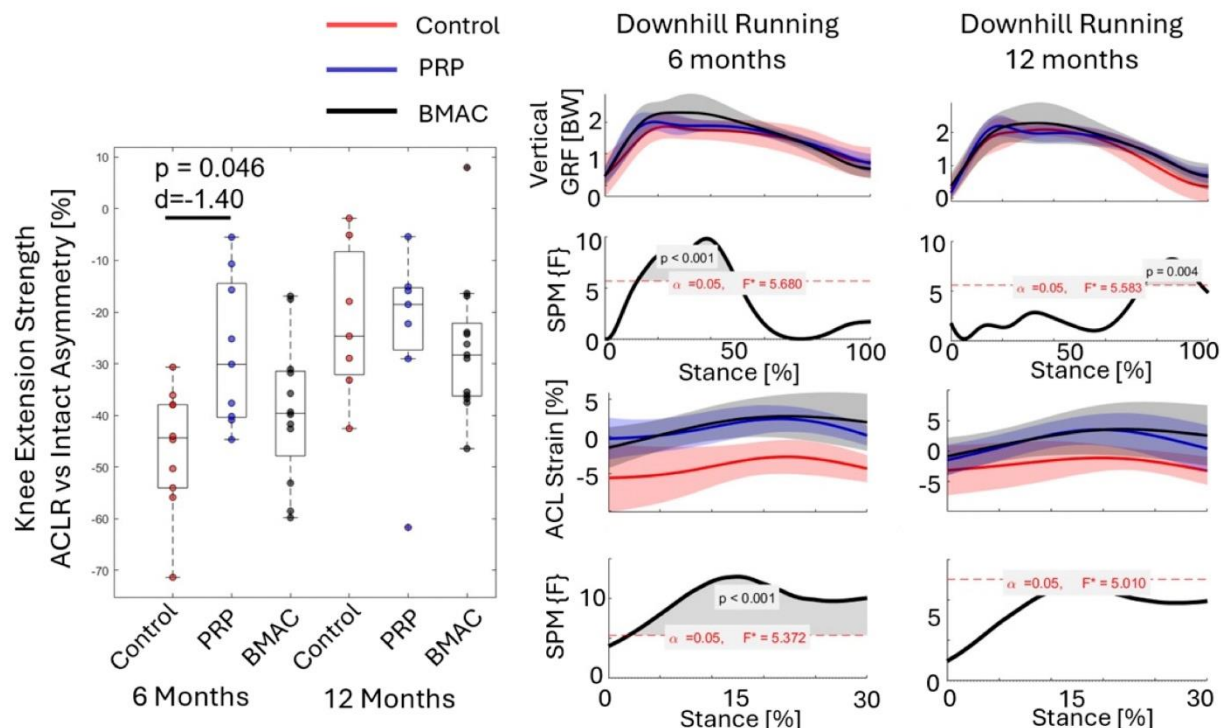


Figure 1 – (Left) The PRP and BMAC groups showed improved strength in the ACLR limb compared to the control at 6 months. (Right) Compared to the control, the PRP and BMAC groups showed increased ground reaction forces on the ACLR limb and strain in the ACLR graft during downhill running at 6 months indicating an accelerated recovery of function.

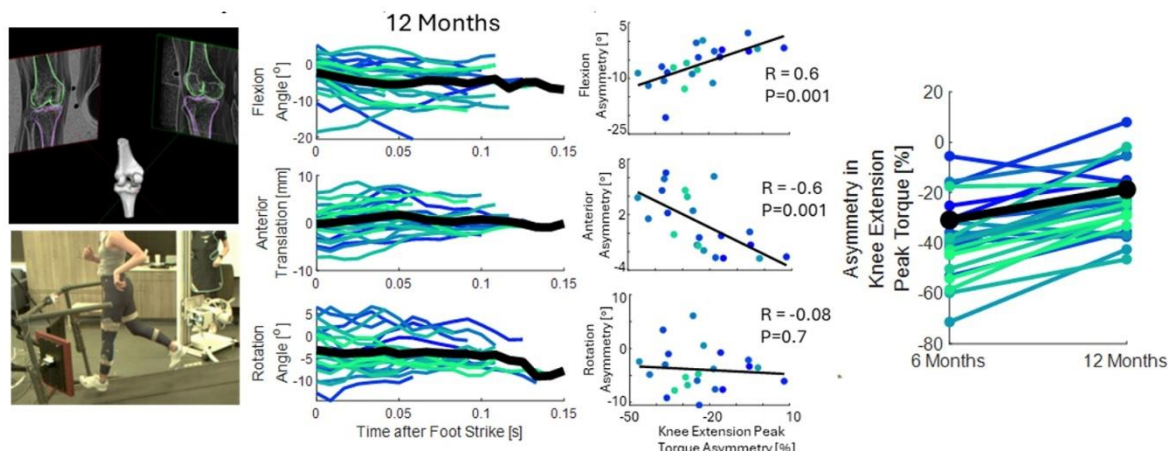


Figure 2: Left, bottom – Subject running on inclined instrumented treadmill in the DSX system. Left, top – Tracking of tibiofemoral kinematics from biplane x-rays and CT. Center – The kinematic asymmetries (ACLR knee minus contralateral, uninjured knee) for 6- and 12-month post-surgery are lines (color-coded for each group), and the average of all participants is plotted as a dark black line. Center-Right – Significant correlations were found between asymmetries in knee extension torque and both knee flexion and anterior translation at 6 months, but these asymmetries decreased from six to twelve months.