Part 4.1 Performance Monitoring Flag System Justification

In Part 4, we developed a performance monitoring flagging system (`part4_flags.py`) to identify athletes who may require additional attention based on trends in their neuromuscular performance, external workload, and strength asymmetry data. This system uses the same five metrics selected earlier; Jump Height (Hawkins), Peak Propulsive Power (Hawkins), Total Distance (Kinexon), Accumulated Acceleration Load (Kinexon), and MaxForce Left/Right (Vald), to produce meaningful indicators of athlete readiness, fatigue, undertraining, and potential injury risk. Because prior research frequently analyzes these systems in isolation, an integrated flagging approach helps operationalize real-world monitoring needs and addresses the gap identified in our literature review.

The first category of flags, inactivity, identifies athletes who have not completed any testing in the last 30 days. Consistent monitoring is essential in high-performance settings, where weekly CMJ testing, daily GPS load tracking, and periodic strength assessments form the foundation of longitudinal analysis. Extended gaps in testing may reflect injury recovery, inconsistent data collection, or reduced training participation. Flagging inactivity ensures that missing data is recognized and that staff can reestablish regular monitoring practices (Gabbett, 2016). The second flagging category, performance decline, detects short-term neuromuscular reductions by comparing an athlete's most recent CMJ test to their three-test rolling mean. An athlete is flagged if the most recent value drops more than 10% below this individualized baseline. This method aligns with research demonstrating that CMJ metrics, particularly Jump High and Peak Propulsive Power, are sensitive indicators of neuromuscular fatigue and mechanical load, often decreasing following periods of elevated training stress or insufficient recovery (Gathercole et al., 2015). Using a rolling average rather than a fixed baseline accounts for individual variability and enhances early detection of meaningful performance changes.The third flagging category, team norm deviations, identifies athletes whose values fall ±2 standard deviations from the team mean for a given metric. This threshold is a widely accepted statistical cutoff for identifying outliers and helps contextualize an athlete's performance relative to peers performing similar training. Deviation in workload (Total Distance, Accel Load Accum), CMJ performance, or strength output may indicate differences in role, training load execution, conditioning status, or reintegration from injury. Finally, the system evaluates interlimb asymmetry using MaxForce Left/Right and flags athletes exceeding a 10% difference. Thresholds in this range are commonly associated with elevated injury risk and compensatory movement strategies (Croisier et al., 2008). While asymmetry alone does not indicate dysfunction, it provides a useful prompt for further assessment.

All flagged results are consolidated into a single output file, `part4_flagged_athletes.csv`, offering a clear, practical summary of athlete status. This integrated system reflects modern sports performance monitoring practices and supports early identification of meaningful changes in athlete readiness.