Jumping Towards Best-Practice: Recommendations for Effective Use of Force Plate Testing in the NBA

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Introduction

The use of force platforms, otherwise known as force plates, as a central tool in screening, profiling, monitoring, and rehabilitating elite athletes has become prevalent among the majority of teams in the NBA. Force plate testing becomes especially useful in leagues like the NBA with irregular and congested competitive schedules as a tool to evaluate athlete readiness, via standardized movements intended to reliably evaluate neuromuscular status in lieu of sports-specific movements. Where injury risk stratification, physical development, and fatigue monitoring are all areas which support staff wish to draw frequent and detailed insights, force plates offer a versatile, fast, and simple solution. They also offer superior individualization to and less invasiveness than measures of external and internal load, respectively. In the NBA, where the Collective Bargaining Agreement (CBA) does not presently require athletes to comply with performance testing or other technological prescriptions of the support staff, the culture, communication, and administration of testing protocols are at least as important as the science and techniques themselves. In this brief commentary, we summarize best-practice concepts to deliver effective use of force plates within an NBA environment.

Concepts and Purpose

Sports Science sometimes forgets the first word of our field, as to the author's best knowledge, nobody has been termed merely a "fitness scientist". Information provided, and therefore protocols completed by support staff must always bear in mind the context of the sport itself. For example, when evaluating if an athlete is fit to compete on any given day, although injury risk stratification may be the primary consideration, so too should the notion that an athlete at a below-normal status may still add significantly more value than their available replacement. Coaching staff receive an enormous amount of information from a variety of sources daily, and it is natural for any given member of staff to subconsciously bias towards justifying their existence with an over-interventionalist approach. Regardless of how much useful insight is drawn from force plate testing, it is essential for practitioners to bear in mind the Iceberg Principle when considering what should influence within and across-staff decisions and what might be essential to bring to coaching staff (1). Within that there is a natural balance of making information available and reports submitted, driving recommendations, and the frequency of each. Finally, a fundamental task of any scientist—and we are all scientists—is the appreciation and accounting for how little we can be sure of: accommodate the pace at which we accrue knowledge about the relationships between force plate values, injury risk, and actual sporting performances (2–4). As with any piece of technology or monitoring technique, outputs merely guide our actions, as this is only one piece of the performance puzzle (5).

Protocols

The majority of force plate testing in most elite sports, including basketball, centers around the Countermovement Jump (CMJ). The CMJ is the most detailed test with the simplest setup and generally has the best athlete compliance, as well as the greatest literature base alongside the Isometric Mid-Thigh Pull (IMTP)(6,7). Therefore, much of the following will elaborate on the use of the CMJ and it's data insights while other test types are within context centered around or alongside CMJ. Testing frequency and schedule will naturally revolve around travel; some teams are fortunate enough to have portable force plates and appropriate athlete engagement to use them on the road. This may improve CMJ frequency, although set up, flooring, and typically smaller landing surfaces must be considered. This should be logistically accommodated with landing-surface inserts or soft add-on frames, especially for taller and more powerful athletes who may find it more challenging to land on a small surface. Communication, trust, familiarization, sufficient space and portable landing-areas are all of value.

Screening and Profiling. As in most sports, practitioners in Basketball are naturally inclined to collect as much information, in as many different ways as possible, during offseason and preseason periods. CMJ should serve as the test upon which all other results are compared and the most strategies inferred. When deeper analysis is required and feasible, Single Leg Jumps (SLJ or SL-CMJ) provide limb-specific information. SLJs often reveal different insights than bilateral CMJ asymmetries and serve as important benchmarks for if, or when, an athlete finds themselves in a lower-limb rehabilitation scenario (8). Squat Jumps (SJ) offer concentric-only information and valuable comparison with the eccentric components of the CMJ. There is a significant tangential and anecdotal basis for the Eccentric Utilization Ratio (EUR), comparing SJ and CMJ performances, as an indicator of patellar tendon health (9–11), key in basketball (12,13).

IMTP details zero-velocity maximal force application and therefore serves as a marker of overall strength development. Drop Jumps (DJ) have significant familiarization requirements and lower reliability than other tests. However, they provide uniquely valuable information about amortization and, simply, how effectively an athlete can jump after a landing. Whether rebounding a shot or finishing a scoring move after a crossover step, this type of action happens frequently in basketball so the test has utility. Finally, the Land And Hold (LAH) test provides crucial, isolated information on jump-landing and can identify limb-specific stability issues which may correspond to injury risk. A variety of repeated-hop tests can be adminis-

tered, and practitioners are encouraged to develop protocols around these which maximize effective time and energy demands involved. They may have significant relevance in basketball where repeated jumping is a featured action.

A battery consisting most or all of the above tests is recommended at regular intervals through the offseason as well as at the start and finish of preseason. Partial protocols of two to three of the above tests besides the CMJ should be administered at more regular—perhaps monthly—intervals throughout the competitive season, with the aim of no fewer than six data collections from each test across a calendar year. While such regular testing might ideally coincide with training cycles, more realistic are natural moments in the schedule such as long homestands, multiple days off, training camps, and the All-Star break. Comprehensive mid-season evaluations can bring each athlete into dialogue with support staff and stakeholders to assess progress on prescribed goals and flag any potential injuries or negative deviations. While whole-team or small-group test administration may in some ways be ideal, another approach is to communicate a several-day window in which players are asked to report for testing, so that it may be performed at a time of their choosing. While athletes may be reluctant towards frequent testing for a variety of reasons, practitioners should make the most of the available data while striving to move from minimal to moderate to optimal testing frequencies as described in Table 1.

Programming. Information derived from force plate testing batteries must be promptly and effectively put to use if athletes and coaches alike are to value force plates. Medical and Performance staff should review data together to create collaborative, deliberate plans and ensure coherence across all programming for each athlete's health and performance (14). Benchmarks and Key Performance Indicators (KPI) should be addressed against the individual, group, and arbitrary contexts. Staff can establish stratified intended benchmarks, from their experiences as well as consultations. Athletes should be compared within the group data and in the context of both individual areas of strengths and weaknesses as well as their own changes over time. From the CMJ, output-type metrics such as Jump Height, Reactive Strength Index, Impulse, and Peak Power, as well as Eccentric Rates of Force Development and Concentric Rates of Power Development are all useful when comparing and contrasting athletes and tracking progress throughout training programs (15).

Monitoring. As with any information, determinations of meaningful change must include concepts of signal vs noise (16). In the NBA, where athletes who possess extraordinary neuromuscular capabilities are frequently fatigued, this becomes paramount. Frequent monitoring using CMJs has become standard across the league, where there are few easily available or widely accepted uses of in-house readiness evaluation. While some athletes may be more enthusiastic about frequent testing than others, multiple tests per week are feasible and near-daily testing is not uncommon. As the science and culture around force plate testing continue to develop, organizations can build clearer concepts of "normal" outputs on different amounts of rest. While in regularly scheduled sports with weekly or twice weekly competitions, matchday, matchday minus-one, and similar standardized information is both practical and valuable, professional basketball does not offer such opportunities for simple sports science. High schedule density with frequent time-zone travel creates a need to examine trends macroscopically and within the context of how rested athletes are at the time of test in order to at least somewhat standardize data (17,18). Ultimately, practitioners in the NBA may be less focused on developing outstanding jumpers than on retaining existing qualities over 82 games and intervening when necessary.

Over all test-cases, athletes can be categorized across the competitive season as follows: Stable pattern, a slow decline, an improvement, or high variance with multiple evolutions. Generally, athletes may follow a standard pattern throughout their career, meaning support staff can normalize and model trajectories for periods of soreness, elevated injury risk or opportunities for increased training load (19,20). Whether with output, mechanical, or asymmetry variables, it is generally noteworthy when stable athletes demonstrate high variability, or else highly variable athletes exhibiting consistent patterns. This highlights the value of frequent testing to provide time-course data. When practitioners can examine an athlete's daily, weekly, or monthly trends in relation to the entire season or calendar year, insights are powerful.

RSImod and Eccentric Duration provide both reliable and sensitive jump performance and strategy data. For athletes performing multiple tests per week, dependent on the metric involved, one standard-deviation away from the mean on three consecutive tests can be considered noteworthy and is on its own cause for further investigation. Where only one or two tests show abnormal results, it is suggested to compare with subjective indicators, other available markers, and staff reporting. Among athletes who test once per week or less frequently, reliable readiness monitoring is improbable, and practitioners are encouraged to focus on use of data for assessing and tracking KPIs as detailed in the previous section. While more advanced statistical modelling can and should be applied in pursuit of coherence across different variables and different data types, force plate testing is an example where with the roster sizes of NBA teams it is feasible and even advised to look at each individual data point for selected variables (21–24).

Timing of testing may be a topic of greatest variability and potential for enhancement. While ecological validity should always be pursued, the reality of the NBA schedule is that tests will be performed whenever feasible. Interestingly, gamedays appear to be one of the most consistent opportunities due to their set rhythms and schedules, at least within the day itself pending travel. Tests can typically be performed 90-20 minutes before tip-off, once athletes are generally warmed up yet not too close to game time for it to be a distraction. At this time, game day test results are not considered a sensible in-situ report as lineup decisions have already been made based upon multitudes of other information, so unless safety is an immediate concern, game day tests serve to provide consistent contextual information and may be of more immediate use when playing on consecutive days or planning an upcoming rest day.

Rehabilitation. Perhaps the biggest advocacy for healthy, non-fatigued baseline data collected throughout the offseason and preseason is the context it provides under the circumstances of an injury (25,26). Medical staff must be provided with markers towards which they can rehabilitate athletes in order to objectively declare them ready to return to competition. All information generated by force plate testing is of use in these processes following lower-body injuries, with several additional dynamics. When performing the CMJ, athletes will frequently not display meaningful asymmetries during early and middle stages of longer-term rehabilitation for the simple reason that they are not yet jumping fast enough: Eccentric Peak Velocity should be monitored closely, with asymmetry data only remarked upon once this has returned to normal values.

Table 1. Schedules for intermittent administration of multiple-test force plate protocols. Example: IMTP, SJ, DJ, LAH, SL-CMJ.

Minimal	Moderate	Optimal
Start Offseason	Start Offseason	Start Offseason
End Offseason/Start Preseason	End Offseason/Start Preseason	End Offseason/Start Preseason
End Preseason	End Preseason	End Preseason
Midseason	Midseason	Midseason
	Post All-Star Break	Pre All-Star Break
	Start Playoffs (TBD)	Post All-Star Break
		∼Game 70 or Start Playoffs (TBD)
		Start Playoffs or Mid Playoffs (TBD)

Table 2. Variables used and their practical applications. Program placement and best uses of each described throughout the text.

Metric	Test	Definition	Unit	Practical Application
RSI-modified (RSImod)	CMJ or SLJ	Jump Height : Contraction Time	m/s	Robust comprehensive indicator of jump performance inclusive of JH, ED, EPV. The first sightline in all-purpose monitoring.
Eccentric Utilization Ratio (EUR)	CMJ + SLJ	Jump Height CMJ : Jump Height SJ	Ratio	Reliance on or relationship with the Stretch Shortening Cycle (SSC). High utility for clarifying training needs.
Peak Vertical Force (PVF)	IMTP	Maximal Isometric Force Produced	N or N/kg	Absolute strength at zero velocity and more reliable than force outputs at velocities. Non-jumping NMP evaluation. Sensitive to training age and Long Term Athletic Development.
Time to Stabilization (TTS)	LAH	Ability to stabilize mass upon landing	s	Measure of dynamic stability: Isolated landing, limb-specific risk stratification. Crucial in back and lower-limb rehabilitation.
Reactive Strength Index (RSI)	DJ	Flight Time : Contraction Time	Ratio	Overall proficiency assessment when tasked with landing prior to jumping, illustrates elastic components while highlighting lower-limb health status.
Jump Height (JH)	CMJ or SLJ	Vertical displacement between takeoff and landing phases	cm	Output somewhat representative of athletic ability, provides context for practitioner and simplified motivation for athlete.
Countermovement Depth (CM Depth)	CMJ or SLJ	Negative vertical displacement from initiation of descent through the end of eccentric phase	cm	Easily visualized physical representation of the eccentric phase.
Eccentric Deceleration RFD (EDRFD)	CMJ or SLJ	Rate of Force Development calculated over the Eccentric Deceleration Phase	N/s or N/s/kg	Output somewhat representative of athletic ability, provides context for practitioner and simplified motivation for athlete.
Eccentric Duration (ED)	CMJ or SLJ	Elapsed time from start of movement until zero velocity	ms	Highly sensitive indicator of readiness, embedded within RSImod.
Eccentric Peak Velocity (EPV)	CMJ or SLJ	Maximum negative velocity realized during the eccentric phase (typically at the start of eccentric deceleration phase)	m/s	Start of decelerative phase, explanatory context in conjunction with ED & RSImod. Recommend remove tests < 1.2 m/s.
Force at Zero Velocity (FZV)	CMJ or SLJ	The total force at the instant of zero velocity prior to takeoff	N or N/kg	The ability to produce force at or near end range in the countermovement.
Concentric Rate of Power Development (CRPD)	CMJ or SLJ	The rate of power development from start of concentric phase to instant of peak power	W/s	The accelerative component of jumping. High velocities and variable force outputs in the concentric phase make this a KPI.

CMJ = countermovement jump; SLJ = single leg jump; SJ = squat jump; DJ = drop jump; LAH = land and hold.

Subsequently, Peak Landing Force Asymmetry and Eccentric Rate of Force Development Asymmetry are both likely to return to normal far later than output-style variables such as Jump Height, Impulse, and Peak Power. It is recommended that those markers of bilteral asymmetry be considered essential criteria in clearing athletes to return to competition. Additionally, the Land and Hold test and Single Leg CMJs have great utility in rehabilitation, especially after traumatic injury such as bone fractures and ligament ruptures (27).

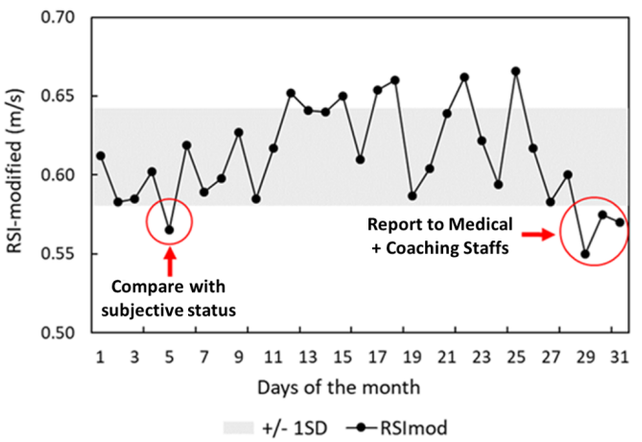

Fig. 1. Time-course of force plate tests showing course of action from one and multiple abnormal results.

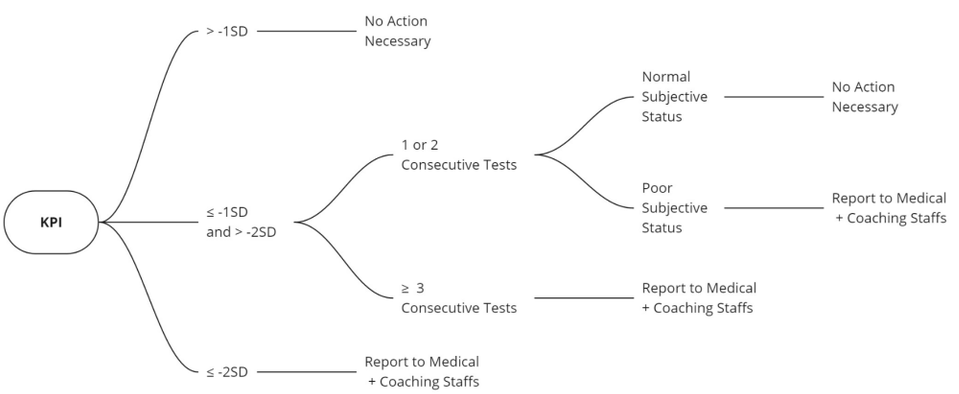

Fig. 2. Decision-tree of response to abnormal force plate results.

Communication and Culture

Executive and Coaching. As with any communication to someone in an area of different expertise from one's own, concise and simple speech is essential. Terminology should be standardized across support staff, with common terms such as "strength", "power", and "asymmetry" used in lieu of detailed neuromuscular metric jargon. Most of the time, coaching and executive staff simply wish to understand if the support staff perceive an athlete to be "up" or "down" or else "ready" or "at-risk" (28,29). A layered approach with concise communications as supported by tactfully available reports is most likely to be successful at gaining buy-in and understanding. Executive staff may be most interested in force plate data during the recruiting process (i.e. Draft & Free Agency) and this period should be valued as an opportunity to both deepen databases comparing and contrasting athletes and to demonstrate the role of neuromuscular evaluation as a part of the high-performance program.

Support Staff. Force plate data, like any information collected by support staff, should be considered a shared domain with value and utility for all. Just as a doctor would remark reported knee pain or a nutritionist might update on a hydration intervention, neuromuscular performance data derived from force plate testing must enter organizational culture as an integrated part of the program for all support staff in order to be most effective. It is observed that some teams find force plates only to be used and discussed by medical staff, others strength and conditioning staff, and still others only sports science and analytics staff. Regular reports in language relative to or at least understandable by each department should be circulated and discussed (30). At least as much as any other measurable in the daily high-performance environment, force plate data provides an opportunity for support staff to discuss matters together and it is up to each member of staff to see how insights might benefit their colleagues and collective athlete welfare

Athletes. Utility and efficacy of force plates is only possible with athlete buy in. Regardless of how simple and non-invasive the tests are, they still involve asking the athlete to expend time and energy while putting their data—and possible personnel decisions—in the hands of support staff. This is not to be treated lightly. Regular conversations, private or in small groups, is encouraged to develop understanding of test results and how they are being used. Force plate insights can provide both justification for strength and conditioning programs as well as evidence of their effectiveness to encourage further training. They can also demonstrate injury rehabilitation progress, crucial for psychological status during challenging times.

Accommodation of sport-specific preferences can significantly enhance athlete buy-in. For example, as basketball is a jumping sport, athletes are more likely to prefer frequent jump testing to isometric testing. There may be converse examples where athletes are averse to additional landing loads and may prefer isometric tests. Furthermore, the constrained arms of a CMJ can be disorienting or frustrating to athletes used to having freedom of movement in their sport. While it is undeniable that the method validity is incomparable, a common protocol is to allow athletes to perform one jump at the end of each testing session with their arms free, and the data quietly discarded

Regular discussion which maximizes engagement is essential to compliance. Communication of where each athlete stands among KPIs and benchmarks can motivate athletes to understand their development and participate in regular monitoring. Creating competitive testing environments can drive both compliance and performances. Leaderboard displays generate discussions and enhance the athlete-staff dynamic. As with executives, describing variables in simple terms and relating them to teammates or competitors can add meaning. After recommending a minimum of three times per week, asking an athlete how many times they might be willing to test puts impetus on the individual to drive their own performance. Involving athletes in their development process is essential to program success. Agents may enter into data ownership dynamics and practitioners can benefit from accommodating this as the CBA is likely to evolve around this space (28,31,32). Making testing information available to an athlete and his advisors, while not without risk, can enhance buy-in. Finally, accommodating day to day variability and gently seeking out what is possible rather than what is optimal will build patience and trust.

Conclusion

Much of the above advice could apply to any sport, especially one involving fixture congestion or significant travel. NBA basketball features an extremely demanding schedule which produces a high amount of risk and a naturally lower emphasis on non-basketball activities such as weight training or jump testing. Integration of force plates for neuromuscular profiling, monitoring, and rehabilitation are probably essential in an environment where more invasive testing is improbable, but especially in a sport which places high emphasis on jumping and other powerful outputs. Practitioners are encouraged to drive a culture of sharing and communication while acknowledging the place of force plate testing within the larger picture of a program and its mission. Timing of testing and interventions, interpretations and actioning of feedback, and thematic references to basketball can all contribute to this.

In a sport, league, and moment in sports science development where technology does not provide a particularly clear picture regarding athlete load, evaluating load-response and in general neuromuscular status can be of great use (33). Presently, privacy outside of team activities is topical, and detailed assessments which can be performed in-house and provide information on status regardless of cause is incredibly valuable (34,35). The considerations and protocols detailed in this paper can be used to administer effective and valued force plate tests as a fundamental part of high-performance programs in the NBA. We hope that these solutions provide opportunities for growth and to further best practices in the league and elite sport globally.

Practical Applications

- Wherein NBA athletes are extremely athletic and may be averse to invasive testing, force plate analysis provides reliable opportunities to profile and screen prospective and current athletes.
- Frequent in-season force plate testing is a feasible and highly useful method of monitoring neuromuscular readiness and tracking athletic development.
- Multiple test options provide objectivity during injury rehabilitation processes and can bring performance and medical staffs together around athlete welfare.
- Communication, clear explanations, clean reporting, and cohesive benchmarking and protocols are all crucial towards integrating and emphasizing force plate use in NBA environments.

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Authorship

JS wrote the paper, DB provided the intellectual content and figures, DL edited the paper and added ideas.

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