Jump Height

Jump height measures the maximum vertical displacement of the center of mass and is a critical assessment of lower-body neuromuscular power and explosive performance, central to sports such as basketball and volleyball (Eythorsdottir et al., 2024; Sanders et al., 2024). Values of jump height vary by gender and sport type. The average jump height for a normal male ranges around 0.4–0.5 m, while for a normal female it is about 0.3–0.4 m. For athletes, male values increase to 0.6–0.7 m and female athletes average between 0.5–0.6 m (Kons et al., 2018). Jump height is important for athletic performance because it reflects an athlete's ability to generate rapid, high-force movements essential for jumping, sprinting, and changing direction. Existing research highlights a strong correlation between vertical jump height and lower-body propulsive power, which underpins performance in both linear speed and agility tests (Kons et al., 2018).

Accurate and standardized jump height calculation methods are necessary, as discrepancies among measurement techniques can affect data interpretation and athlete monitoring (Kozinc & Pleša, 2022). Furthermore, longitudinal monitoring reveals significant positional differences in jump loads and force-velocity profiles, especially in sports like volleyball where different positions show varied neuromuscular fatigue and training demands (Sanders et al., 2024).

Limited research has been conducted on jump height measures in specific sports and populations, such as female athletes and youth players. The association between jump height and injury risk is also more complicated than it appears—higher jump height alone isn't the problem; instead, limb asymmetries in jump height, strength, or movement mechanics, as well as worse total leap capacity, have been associated to increased injury risk. It is yet unclear how fatigue-related decreases in jump performance contribute to injury risk. Comparing jump height and force velocity parameters across teams and positions is a viable approach to developing more personalized fatigue management and injury prevention measures.

Peak Propulsive Force

Peak Propulsive Force (PPF) is the maximum forward-directed force produced during push-off in self-initiated walking, indicating when one actively propels themselves ahead (Hsiao et al., 2016a). Unlike overall ground reaction force measurements, which include braking and non-propulsive components, PPF isolates the true propulsive force responsible for moving the body forward during walking tasks at a specified pace (Hsiao et al., 2016a; Hsiao et al., 2016b).

PPF is an essential measure of functional mobility because it indicates propulsion efficiency, making it one of the most important factors to consider in gait functionality and rehabilitation (Hsiao et al., 2016b). Older people frequently have decreased PPF due to age-related plantarflexor inefficiencies, although techniques like real-time feedback training have been demonstrated to enhance propulsive capacity and walking performance (Franz et al., 2014).

While much study has focused on the value of PPF in clinical and elderly populations, recent studies have broadened its scope to include muscle activation patterns and propulsion efficiency (Tomaz et al., 2024). Future objectives include investigating its significance in overall mobility outcomes and injury prevention, notably through propulsion-focused training regimens in gait rehabilitation.

Total Distance

Total distance measures the cumulative ground an athlete covers during a training session or competition (Mujika, 2017; McKay et al., 2025; Kupperman et al., 2020). It quantifies overall external workload, reflecting the volume of physical activity and providing a foundational measure for assessing the metabolic and aerobic demands placed on the athlete. This metric is vital for athletic performance as it aids in planning and periodizing training loads, ensuring athletes build endurance while minimizing risks of overtraining and injury. Accurate monitoring of total distance enables coaches to tailor workloads for optimal performance outcomes and recovery (Mujika, 2017). Normal or elite values of total distance vary significantly by sport and position. For example, elite soccer players may cover distances ranging from 7 to 13 kilometers per match, depending on their tactical role and fitness level. Due to sport-specific movement demands, these values differ substantially across disciplines, necessitating contextual interpretation (McKay et al., 2025).

Research on total distance remains limited in certain sports, particularly those with varying movement patterns like combat sports or intermittent play sports beyond the mainstream team sports. Additionally, while total distance is commonly reported, its integration with intensity metrics such as accelerations, decelerations, and high-speed running remains an area ripe for further exploration (Kupperman et al., 2020). Unexplored relationships include the detailed connection between total distance and injury risk. While large increases in total distance can contribute to injury likelihood, especially without appropriate progression, granular studies distinguishing how total distance combined with intensity markers affects tissue loading and injury are sparse (Kupperman et al., 2020). Comparing total distance across teams and positions offers novel insights. Variability in distance covered by position within a team reflects differing physical demands, which can inform position-specific training and injury prevention strategies. Cross-team comparisons might also reveal how tactical styles influence workload, enabling tailored performance and recovery plans (McKay et al., 2025; Mujika, 2017).

Accumulated Acceleration Load

Accumulated Acceleration Load (AAL) is the overall neuromuscular stress that an athlete feels by adding instantaneous accelerations across the X, Y, and Z axes, capturing quick speed changes, collisions, landings, and direction shifts (Freitas et al., 2025). These high-impact, eccentric, and quasi-isometric actions—such as deceleration, cutting, and jump landings—are substantially associated with fatigue, tissue strain, and injury risk (Svilar et al., 2018). Because AAL is stated in system-specific arbitrary units, it is best suited for monitoring inside an athlete or team rather than cross-team comparisons. Basketball research suggests that AAL is responsive to contextual intensity, with collegiate athletes exhibiting much higher values when competing against professional-level opponents (Freitas et al., 2025).

Studies in basketball, handball, and other indoor sports regularly verify accelerometer-derived load measures as useful markers of mechanical stress and neuromuscular demands (Luteberget & Spencer, 2017; Svilar et al., 2018). AAL captures the accumulated "wear and tear" of quick accelerations and decelerations that typical distance metrics miss, making it useful for workload management and injury risk monitoring. When combined with internal load metrics such as session RPE, it provides a more comprehensive view of training stress, athlete preparation, and recovery requirements (Boyd et al., 2011; Fox et al., 2019; Kinexon Sports, 2024).

Left/Right Max Force

The Limb Symmetry Index (LSI), calculated as (stronger limb - weaker limb) ÷ stronger limb × 100%, measures inter-limb deficits in a unilateral isometric assessment. The maximal force is the most voluntary force that each limb is capable of producing. These are significant measurements because unilateral maximum force is highly related to sprint acceleration, jump performance, direction change ability, and overall injury avoidance (Freitas et al., 2025). According to Parkinson et al. (2021), asymmetries greater than ~10-15% increase the risk of injury and reduce performance. The LSI of ≥90% is often used to determine clearance for return to sport (Freitas et al., 2025). Ongoing analysis for normative data across genders, sports, and competitive levels is underway, as well as how inequalities impact performance (Sanders et al., 2024).

New research indicates that measuring recovery only on similar strength between limbs can make someone appear more recovered than they are. Wellsandt et al. (2017) found that measures of limb symmetry index (LSI) frequently underestimated quadriceps performance after ACL reconstruction and predicted re-injury risk. Kotsifaki et al. (2022) found that while athletes were approximately 97% symmetrical in horizontal hop distance, they were consistently asymmetrical in single-leg vertical jump performance (83%) and drop-jump performance (77%), indicating overall force and joint-work deficits. These findings highlight that, while maximal force and LSI are relevant and accurate, a more complete assessment of inter-limb balance should incorporate other biomechanical variables such as rate of force development, vertical-jump asymmetries, and/or joint moments, or biomechanical burden.

Research Gaps and Questions

- Accumulated Acceleration Load research can advance by exploring threshold values linked directly to overuse injuries and fatigue across different sports and gender.

- Max force research would benefit from expanded normative databases across competitive levels and sports, including pediatric and female populations.
- Investigating interaction effects between LSI, force output, and neuromuscular fatigue or recovery would advance injury prevention.
- Novel approaches could compare accumulated acceleration load and force asymmetries across positions within teams to optimize individual workload prescriptions.

Main Research Queston: How does gender influence injury risk in basketball players with high asymmetry and training loads?

References

Bradley, B. A. (2011). Correlation of Significant Duration with Amplitude and Cumulative Intensity Measures and Its Use in Ground Motion Selection. Journal of Earthquake Engineering, 15(6), 809–832. https://doi.org/10.1080/13632469.2011.557140

Boyd, L. J., Ball, K., & Aughey, R. J. (2011). Quantifying external load in team sport athletes: Accelerometer-based player load. *International Journal of Sports Physiology and Performance*, 6(3), 311-322. https://doi.org/10.1123/ijspp.6.3.311

Eythorsdottir, I., Øyvind Gløersen, Rice, H., Amelie Werkhausen, Gertjan Ettema, Fredrik Mentzoni, Solberg, P., Lindberg, K., & Paulsen, G. (2024). The battle of the equations: A systematic review of jump height calculations using force platforms. *Sports Medicine*, *54*. https://doi.org/10.1007/s40279-024-02098-x

Fort-Vanmeerhaeghe, A., Milà-Villarroel, R., Pujol-Marzo, M., Arboix-Alió, J., & Bishop, C. (2022). Higher Vertical Jumping Asymmetries and Lower Physical Performance are Indicators of Increased Injury Incidence in Youth Team-Sport Athletes. *Journal of strength and conditioning research*, *36*(8), 2204–2211. https://doi.org/10.1519/JSC.0000000000003828

Fox, J. L., Stanton, R., Sargent, C., O'Grady, C. J., & Scanlan, A. T. (2019). The Impact of Contextual Factors on Game Demands in Starting, Semiprofessional, Male Basketball Players. *International journal of sports physiology and performance*, *15*(4), 450–456. https://doi.org/10.1123/ijspp.2019-0203

Franz, J. R., Maletis, M., & Kram, R. (2014). *Real-time feedback enhances forward propulsion during walking in older adults.* Clinical Biomechanics, 29(1), 68–74. https://doi.org/10.1016/j.clinbiomech.2013.10.018

Freitas J, Moreira A, Carvalho J, Conceição F, Estriga L. Understanding Acceleration-Based Load Metrics: From Concepts to Implementation. Sensors. 2025; 25(9):2764. https://doi.org/10.3390/s2509276

Freitas, T. T., et al. (2025). Neuromuscular load and injury risk in basketball: A focus on accumulated acceleration load and limb symmetry. *Journal of Sports Science and Medicine.*

Gathercole, Rob J.; Sporer, Ben C.; Stellingwerff, Trent; Sleivert, Gord G.. Comparison of the Capacity of Different Jump and Sprint Field Tests to Detect Neuromuscular Fatigue. Journal of Strength and Conditioning Research 29(9):p 2522-2531, September 2015. | DOI: 10.1519/JSC.0000000000000912

Hsiao, H., Zabielski, T. M., Jr, Palmer, J. A., Higginson, J. S., & Binder-Macleod, S. A. (2016a). *Evaluating propulsion measurements that reflect changes in walking speed among* *individuals poststroke.* Journal of Biomechanics, 49(16), 4107–4112. https://doi.org/10.1016/j.jbiomech.2016.10.003

Hsiao, H., Knarr, B. A., Pohlig, R. T., Higginson, J. S., & Binder-Macleod, S. A. (2016b). *Mechanisms used to increase peak propulsive force after 12 weeks of gait training in people poststroke.* Journal of Biomechanics, 49(3), 388–395. https://doi.org/10.1016/j.jbiomech.2015.12.040

Kinexon Sports. (2024, August 19). Acceleration improves athletic performance. https://kinexon-sports.com/blog/athletic-performance-why-track-acceleration

Kons, R. L., Ache-Dias, J., Detanico, D., Barth, J., & Dal Pupo, J. (2018). Is Vertical Jump Height an Indicator of Athletes' Power Output in Different Sport Modalities? *Journal of Strength and Conditioning Research*, *32*(3), 708–715. https://doi.org/10.1519/jsc.0000000000001817

Kotsifaki, A., Van Rossom, S., Whiteley, R., Korakakis, V., Bahr, R., Sideris, V., & Jonkers, I. (2022). Single leg vertical jump performance identifies knee function deficits at return to sport after ACL reconstruction in male athletes. *British journal of sports medicine*, *56*(9), 490–498. https://doi.org/10.1136/bjsports-2021-104692

Kozinc, Ž., & Pleša, J. (2022). Discrepancy Among Different Methods for Vertical Jump Height Determination and Its Implications for Field-Based Testing: A Narrative Review. *Measurement in Physical Education and Exercise Science*, *27*(3), 1–9. https://doi.org/10.1080/1091367x.2022.2163398

Kupperman, N., & Hertel, J. (2020). Global Positioning System–Derived Workload Metrics and Injury Risk in Team-Based Field Sports: A Systematic Review. *Journal of Athletic Training*, *55*(9). https://doi.org/10.4085/1062-6050-473-19

Luteberget, L. S., & Spencer, M. (2017). High-Intensity Events in International Women's Team Handball Matches. *International journal of sports physiology and performance*, *12*(1), 56–61. https://doi.org/10.1123/ijspp.2015-0641

McKay, B., Mandorino, M., Lacome, M., Beanland, E., McLaren, S., & Green, J. (2025, October 22). *Overrated and underrated GPS metrics: The view of 6 experts - Sportsmith*. Sportsmith. https://www.sportsmith.co/articles/overrated-and-underrated-gps-metrics-the-view-of-6-experts/

Mujika, I. (2017). Quantification of Training and Competition Loads in Endurance Sports: Methods and Applications. *International Journal of Sports Physiology and Performance*, *12*(s2), S2-9S2-17. https://doi.org/10.1123/ijspp.2016-0403

Nuzzo, James L; Anning, Jonathan H; Scharfenberg, Jessica M. The Reliability of Three Devices Used for Measuring Vertical Jump Height. Journal of Strength and Conditioning Research 25(9):p 2580-2590, September 2011. | DOI: 10.1519/JSC.0b013e3181fee650

Parkinson, A. O., Apps, C. L., Morris, J. G., Barnett, C. T., & Lewis, M. G. C. (2021). The Calculation, Thresholds and Reporting of Inter-Limb Strength Asymmetry: A Systematic

Review. *Journal of sports science & medicine*, *20*(4), 594–617. https://doi.org/10.52082/jssm.2021.594

Sanders, G. J., Skodinski, S., Cabarkapa, D. V., Howard, M., Dimitrije Cabarkapa, & Peacock, C. A. (2024). Positional Differences in Jump Loads and Force and Velocity Metrics Throughout a 16‐Week Division I Volleyball Season. *Translational Sports Medicine*, *2024*(1). https://doi.org/10.1155/tsm2/5933923

Svilar, L., & Jukić, I. (2018). Load monitoring system in a top-level basketball team: Relationship between external and internal training load. *Kinesiology, 50*(1), 25–33. https://doi.org/10.26582/k.50.1.4

Tomaz, G. G., Souza, M. V. C., Carneiro, M. A. D. S., Lima, M. L., Assumpção, C. O., & Orsatti, F. L. (2024). *Propulsive forces and muscle activation during gait in premenopausal vs. postmenopausal midlife women.* Menopause, 31(3), 194–201. https://doi.org/10.1097/GME.0000000000002318

Wellsandt, E., Failla, M. J., & Snyder-Mackler, L. (2017). Limb Symmetry Indexes Can Overestimate Knee Function After Anterior Cruciate Ligament Injury. *The Journal of orthopaedic and sports physical therapy*, *47*(5), 334–338. https://doi.org/10.2519/jospt.2017.7285