



Performance Research Reviews

January 2026

Baseball

Are typical fastballs for a given throwing arm angle easier to hit? A game analysis of US Major League Baseball. International Journal of Sports Science & Coaching, Ahead of Print: 1-11, 2025.

Abstract - Fastballs with greater upward vertical break (“rise”) are believed to induce missed swings. However, batters may use learned associations between pitchers’ throwing arm angles and ball kinematics to predict the trajectory. Even with identical kinematics, batters may respond differently when ball kinematics deviate from expectations based on arm angle. We tested a hypothesis that fastballs typical for a given arm angle are easier to hit in Major League Baseball. We analyzed ball-tracking data from 297 pitchers throwing >150 fastballs swung at during the 2023–2024 seasons. Preliminary regression analysis showed that arm angle explained 67% of the variance in spin axis, so we used the residuals to define a deviation score, representing the atypicality of spin axis for each arm angle. Multiple regression analysis tested whether the variance in Whiff% (missed swings/total swings) was explained by the deviation score and covariates in each pitcher-batter handedness matchup. All variables together explained 41%–52% of the variance in Whiff% ($p < .001$). The quadratic terms of the deviation score were insignificant, rejecting our hypothesis. In same-side matchups, spin axis showed a positive association with Whiff% while the deviation score showed a negative association, indicating that pitchers whose fastballs had an axis more inclined toward horizontal had lower Whiff%, but those with an axis more inclined toward horizontal for a given arm angle achieved higher Whiff%. These findings suggest that in recent games, fastballs with an axis atypically inclined toward horizontal, potentially generating greater rise, induce more missed swings than fastballs merely having greater rise.

Changes in normalized shoulder strength and self-perceived function in healthy Division 1 baseball players over the course of a competitive season. International Journal of Sports Physical Therapy, 20(10): 1489-1501, 2025.

Background: Deficits in shoulder strength have been previously established as a risk factor associated with the development of time-loss shoulder and elbow injuries. However, limited data exists on normative shoulder strength



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changes in collegiate baseball athletes over the course of a competitive season. Hypothesis/Purpose: There were two purposes of this study: 1) to assess changes in shoulder strength over a competitive season, and 2) to assess self-perceived shoulder and elbow function changes over the course of a competitive season in healthy Division I collegiate baseball players. It was hypothesized that shoulder strength would differ over a competitive season with no observed differences in Kerlan-Jobe Orthopaedic Clinic (KJOC) scores over time in healthy baseball athletes.

Study design: Prospective cohort.

Methods: Forty-nine uninjured NCAA baseball athletes were assessed for bilateral isometric shoulder strength (external [ER] and internal [IR] rotation and scaption [SCAP]) via handheld dynamometry at four time points: fall physicals, preseason, mid-season, and postseason. Additionally, athletes completed the KJOC score at each testing session. A 2x4 repeated measures multivariate analysis of variances was conducted to determine the effect of playing position and time on normalized shoulder strength and KJOC scores.

Results: There was a main effect of time on isometric shoulder strength ($p < 0.001$). There was no effect for position ($p = 0.88$), or interaction effect of position and time ($p = 0.643$). Pairwise comparisons demonstrated differences across time in dominant limb ER ($p = 0.01$) and SCAP ($p < 0.001$), and non-dominant limb ER ($p < 0.001$), IR ($p = 0.004$) and SCAP ($p < 0.001$). There were no differences over time for dominant limb IR ($p = 0.131$) or KJOC scores ($p = 0.154$).

Conclusion: Uninjured collegiate baseball players demonstrated changes in shoulder strength over time that exceeded minimal detectable change scores over the course of a competitive season for both limbs. The results of the present study offers shoulder strength values using a reliable and reproducible normalization method to evaluate shoulder strength in collegiate baseball athletes.

Consistency verification and interpretation of explainable AI for predicting annual home runs of professional baseball players from sensor data. Scientific Reports, 15: 32815, 2025.

Abstract - This study aimed to verify and interpret a model for predicting the number of home runs per year using sensor data from professional baseball players during batting practice. A machine learning model was constructed using Random Forest from the bat kinematics and bat mass data of 41 professional baseball players collected by a bat-mounted sensor. Partial Dependence analysis and Feature Importance analysis by SHAP (SHapley Additive exPlanations) were used to explain the model's predictions. The predictive model showed that the bat speed, bat mass, and rotational acceleration are particularly important. The results indicated that a bat speed of 33.3 m/s and rotational acceleration

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exceeding 157 m/s² exhibited a trend toward a rapid increase in the number of predicted home runs per year. The mass of the bat suggests that an optimum value exists at 0.91 kg. These results suggest that batters who are expected to hit a large number of home runs each year increase the acceleration at the beginning of their swing to produce high bat speed in a short period of time and achieve bat speeds of 33.3 m/s or more with a bat that is somewhat heavier.

Early rate of force development and maximal strength at different positions of the Athletic Shoulder Test in baseball players. Sports, 13: 300, 2025.

Background/objectives: Peak force (PF) reflects maximal strength, while early rate of force development (RFD; 0-100 ms) indicates explosive neuromuscular output. The Athletic Shoulder (ASH) test is gaining popularity in overhead athlete profiling, but its use for assessing explosive strength in various shoulder positions is underexplored. This study compared PF and RFD at shoulder abductions of 180° (ASH-I), 135° (ASH-Y), and 90° (ASH-T) in baseball players.

Methods: Seventeen male athletes (age 22.7 ± 4.2 years; height 186.3 ± 7.3 cm; body mass 83.9 ± 10.1 kg) performed isometric ASH tests with the dominant arm. PF, PF relative to body mass (PF/BM), and early RFD were analyzed.

Results: ASH I showed 25% significantly higher PF (182 ± 41 N), PF/BM (2.15 ± 0.39 N/kg), and 40% higher RFD (545 N/s) than ASH Y or T (all $p < 0.001$), which did not differ significantly. PF showed excellent reliability (ICC = 0.86-0.93); RFD showed moderate-to-good reliability (ICC = 0.75-0.81). Smallest worthwhile changes were ~5% for PF and ~15% for RFD.

Conclusions: Maximal isometric shoulder strength and explosiveness were highest at 180° abduction in baseball athletes, with no significant difference between 135° and 90°. PF demonstrated excellent reliability, while early RFD showed moderate to good reliability and higher variability, highlighting the need for repeated measures. These findings provide specific position reference values and support the inclusion of multiple abduction angles in shoulder strength assessment to detect neuromuscular deficits and monitor training adaptations in baseball athletes.



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Basketball

Difference in change of direction performance between college basketball players with high and low change of direction deficit, shuffle, and jump asymmetry. International Journal of Performance Analysis in Sport, Ahead of Print: 1-16, 2025.

Abstract - This study aimed to (1) assess inter-limb asymmetry in shuffle, change of direction deficit (CODD), single-leg jump performance among college basketball players, and (2) compare change of direction speed between high and low asymmetry groups. Thirty-six players (16 males, 20 females) completed single-leg countermovement jump, lateral jump, CODD, and 5-m shuffle tests. Asymmetry was calculated using the following formula: $(\text{dominant} - \text{non-dominant}) / \text{dominant} \times 100\%$. The participants were median-split into high-asymmetry ($n = 18$) and low-asymmetry ($n = 18$) groups based on the calculated asymmetry scores. Change of direction performance was evaluated using the T-test, Lane test, and Run-Shuffle-Run (RSR) test. The inter-limb asymmetry score ranged from 2.77% to 15.16%. Grouping based on CODD asymmetry showed a significant difference in RSR performance ($p < 0.05$, $ES = 0.74$), while grouping based on shuffle asymmetry also revealed a significant difference in T-test performance ($p < 0.05$, $ES = 0.72$), indicating that inter-limb asymmetry of the CODD and shuffle have a significant negative impact on change of direction speed. Coaches should consider asymmetries in CODD and shuffle during movement assessments, as higher asymmetry significantly impairs performance in RSR and T-test.

Dynamometer resistance pad position influences knee strength and hamstring/quadriceps ratio in professional basketball players: Retrospective observational study. Applied Sciences, 15: 4000, 2025.

Abstract - Some knee strength measuring devices have an anterior cushioning area but relies on a belt for the posterior pad adjustment, creating an uneven force distribution. This study analyzed whether the distal pad position affects knee strength measurements. Eleven professional basketball players participated in this study, with a total of 22 knees evaluated. Knee flexion and extension dynamometric measurements were performed at different angular velocities: $30^\circ/\text{s}$, $120^\circ/\text{s}$, and $240^\circ/\text{s}$. For each angular velocity, two measurements were performed with varying positions of the measuring tool pad at the anterior and posterior aspects (AA and PA). The hamstring/quadriceps (H/Q) ratio was calculated by dividing the hamstring musculature's maximum peak strength by the quadricep musculature's maximum



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peak strength at each measurement. The knee work was extracted from the device after finishing the measurements. Significant differences were found between measurement positions in the knee flexion force at 30°/s ($p < 0.001$) and 120°/s ($p = 0.027$). No differences were found for the extension forces. As for the H/Q ratio, significant differences were found between positions at 30°/s ($p < 0.001$). Furthermore, significant differences between positions were found for the knee work at 120°/s ($p = 0.019$). These findings suggest that the positioning of the pad on the leg directly influences knee flexor strength measurements, which in turn impacts critical parameters, such as the H/Q ratio and knee work. Given the importance of these variables in injury prevention, particularly for conditions such as anterior cruciate ligament (ACL) injuries, ensuring precise and reliable measurement methods is essential. We recommend using the PA position because it increases knee flexion strength values, potentially leading to more accurate assessments of the muscle function and balance.

Game-related performance metrics differentiating winning and losing teams in the basketball Champions League. Journal of Physical Education, 36: e3647, 2025.

Abstracts - This study aimed to identify game-related performance variables that differentiate winning and losing teams in the Basketball Champions League and determine the most significant predictors of game outcomes. Data were collected from 175 games during the 2023-2024 season. The Mann-Whitney U test and logistic regression analysis were employed to evaluate the influence of offensive and defensive metrics on game outcomes. Significant differences were found in key metrics such as shooting percentages, points per game, and defensive rebounds, with winning teams consistently outperforming losing teams. Logistic regression identified steals and defensive rebounds as the strongest predictors of success. Steals increased the odds of victory by 59.6% and defensive rebounds by 48.8%, underscoring the critical role of defensive metrics. Conversely, two-point attempts negatively predicted winning odds, with each additional attempt reducing the likelihood of victory by 32.9%. The findings highlight the importance of efficient shot-making, effective defense, and offensive coordination in basketball performance. These results provide valuable insights for coaches and analysts seeking to enhance team performance and develop effective game strategies.



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Football

Closed kinetic chain upper extremity stability test reference values for NCAA American football. International Journal of Sports Physical Therapy, 20(9): 1338-1344, 2025.

Background: The Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) is a valid and reliable test commonly used during return to sport testing. While reference values have been determined for multiple sports, few have specifically considered National Collegiate Athletic Association (NCAA) American football players.

Purpose: To provide reference values on the CKCUEST for NCAA football players with considerations for position, history of upper extremity injury, year in school, and division of college football.

Study design: Cross-sectional study.

Methods: Eighty football players from three NCAA schools were recruited to participate in this study. Height, mass, position, year in school, and history of upper extremity injury were collected. Subjects completed three trials of the CKCUEST with their means recorded. Means were compared using ANOVA with post hoc Bonferroni tests. A T-test was used for a secondary comparison of mean touches of linemen versus all other positions. Pearson correlation coefficients assessed the relationship between number of touches and subject characteristics.

Results: Subjects were all males with a mean of 2.5 years in school (95% CI 2.18-2.85). Subjects of the study averaged 27.3 touches. There were no statistically significant performance differences between players from NCAA divisions, with/without injury history, years in school, or athlete demographics. Linebackers had significantly more touches compared to offensive linemen, 29.7 and 24.8 ($p < 0.03$), respectively. Additionally, linemen as a group (offensive and defensive) averaged 25.7 touches, which was significantly lower compared to all other positions combined (28.1 touches, $p < 0.01$). The minimal detectable change was 1.2 touches.

Conclusion: A reference value of 27 touches was found for the CKCUEST in NCAA football players. A change of at least two touches would indicate a measurable change. Position differences should play a role in clearance for return to sport; specifically, linemen may produce less touches than other non-lineman positions.

Level of evidence: Level 2c: Cross-sectional study.



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Down, set, record: Assessing warm-up structure and use of neuromuscular training exercises in Canadian adolescent tackle football. International Journal of Sports Science & Coaching, Ahead of Print: 1-11, 2025.

Abstract - Implementing injury prevention strategies is critical for coaches and sport organizations to promote player safety. Neuromuscular training (NMT) warm-up programs that involve aerobic, strength, agility, balance/coordination, and head-and-neck control exercises have demonstrated injury rate reductions of >35% across many adolescent sports. Tackle football (i.e., American football) has amongst the highest injury rates within youth sport and lacks examination of current warm-up structure and exercises. Our video-analysis study examined footage from 23 practice and game warm-ups (46 total) to document the duration and exercises completed for nine adolescent (males, ages 14–17) tackle football teams over a 9-week season within Calgary (Canada). We found that teams typically spent less than five minutes actively warming-up with most exercises being aerobic (51%) and dynamic stretching (29%), while <10% of exercises involved static stretching (6%) or NMT components of strength (9%), agility (3%), balance/coordination (1%), and head-and-neck control (1%). Warm-up length and use of NMT components were similar between games and practices, and over the season. Our findings demonstrate that NMT exercises are not being used in tackle football, which supports future implementation and evaluation of a tackle football-specific NMT program. We also provide coaches with a method for examining their team's warm-up structure.

Heavy hitters, light sleepers: Collision frequency and locomotor load on sleep architecture in professional Rugby Union players. European Journal of Sport Science, 25: e70052, 2025.

Abstract - To assess whether certain players are more vulnerable to post-match sleep disturbances by examining the relationship between match demands-collision frequency and locomotor load-and sleep in professional male rugby union players. A linear mixed-effects regression examined the relationship between match variables and sleep in 13 rugby players across three matches. Match variables included six physical demand variables derived from video analysis and GPS data (collision frequency, total distance, high-speed distance, sprint distance, acceleration load and fast acceleration count) and two contextual variables (location and kick-off time). Sleep variables collected via home-based polysomnography included total sleep time, sleep efficiency, sleep onset/offset, sleep onset latency, wake after sleep onset, number of awakenings and sleep stages (light, deep and rapid eye movement sleep [REM], evaluated both by proportion [%] and time [min]). Each match collision decreased total sleep time ($\beta = -4 \pm 1$ min and $p = 0.006$) and REM



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sleep (time: $\beta = -2 \pm 0$ min and $p < 0.001$; proportion: $\beta = -0.6 \pm 0.2\%$ and $p = 0.021$). Conversely, every 500 m increase in locomotor load (total distance) increased REM sleep (time: $\beta = +6 \pm 2$ min and $p = 0.014$; proportion: $\beta = +2.7 \pm 0.6\%$ and $p = 0.002$). Every 100 m increase in high-speed distance was associated with decreased REM sleep time ($\beta = -7 \pm 3$ min and $p = 0.020$). Match demands, including collision frequency and locomotor load, were associated with changes in post-match sleep architecture in professional rugby players, particularly REM sleep. Furthermore, greater number of collisions was associated with reduced sleep quantity. Practitioners can leverage GPS and video analysis data to tailor additional sleep strategies aimed at improving post-match sleep based on individual match demands.

Knee injury mechanism varies by injury category: Video analysis of multi-ligament knee injuries in the National Football League. Knee Surgery, Sports Traumatology, Arthroscopy, Ahead of Print: 1-8, 2025.

Purpose: This study aims to characterize the mechanism of multi-ligament knee injury (MLKI) sustained during a National Football League (NFL) game through video analysis.

Methods: A retrospective video analysis of official NFL game footage spanning 1997-2022 was performed. Players with MLKIs were identified from publicly available injury surveillance data. Player and game demographic information was collected. Athletes were categorized based on ligament injury patterns. Videos including MLKI were analyzed to categorize injuries based on non-contact, indirect or direct contact mechanisms and determine the hip, knee and ankle position at the time of injury. Differences across MLKI groups were identified by Fisher's exact test.

Results: Thirty-five MLKIs were identified. MLKIs most commonly occurred from direct contact to the limb (80%), with the second most common injury mechanism being indirect contact (14.3%). The most common MLKI was injury to the anterior cruciate ligament (ACL) and medial collateral ligament (MCL) (65%), while the second most common was the ACL and lateral collateral ligament (LCL) (15%). Direct contact MLKI most often resulted in a valgus and external rotational force about a flexed knee (58%). There were statistically significant differences when comparing the direction of contact, hip and knee position between injury MLKI groups. Combined ACL and MCL injury commonly occurs with knee flexion, valgus and external rotation. Combined ACL/posterior cruciate ligament (PCL) or ACL/LCL injuries occurred most commonly with varus and internal rotational forces on an extended knee. Multiligament injuries involving three ligaments occurred only from direct contact mechanisms.



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Conclusion: Various injury mechanisms and characteristics result in different types of MLKI in NFL athletes, though the vast majority of MLKIs occur from direct contact forces to the knee. Combined ACL and MCL injury occurred most frequently, resembling the mechanism and lower extremity position for isolated ACL injury, though it frequently occurs due to direct contact with the knee.

Level of evidence: Level IV.

Longitudinal changes in strength, power, speed, and body mass in American football players: Diminishing returns as training age increases. International Journal of Sports Science & Coaching, Ahead of Print: 1-13, 2025.

Abstract - The aims of this study were to: 1) detail the strength, power, speed, and body mass (i.e. physical qualities) of National Collegiate Athletic Association (NCAA) Division 1 American football players by playing position across a four-year collegiate career, and 2) quantify the rate of change in physical qualities as athletes progress through their eligibility period. 2628 observations from 512 NCAA Division 1 American football players were collected during a standardized testing battery that took place across a 15-year period. One-repetition maximum bench press and back squat, 40-yard sprint, vertical jump, standing broad jump, and body mass were analyzed. Year-on-year changes in physical characteristics by the entire cohort and positional groups were analyzed using linear mixed models with Cohen's effect size (ES) $\pm$ 95% confidence intervals (CI). Improvements in physical qualities occurred over the four years, although the largest changes were evident in the first year, with the improvements becoming less pronounced each year. For example, across the cohort, *large* effects in the bench press (ES $\pm$ 95%CI: 1.63 ± 0.18) and back squat (ES $\pm$ 95%CI: 1.62 ± 0.18) occurred in the first year but only *small* changes occurred between years 3 and 4 (ES $\pm$ 95%CI: 0.45 ± 0.16 and 0.26 ± 0.16 , respectively). Collectively, this study demonstrates the longitudinal changes in strength, power, speed, and body mass of collegiate Division 1 American football players across different positional groups. Furthermore, it shows that physical qualities improve throughout the four years, but the year-on-year change becomes smaller each year and therefore suggests physical qualities become harder to increase/improve.



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Gymnastics

Reliability of judging in Olympic breaking at the 2024 Paris games. Frontiers in Psychology, 16: 1593158, 2025.

Introduction: Although breakdancing was adopted as an Olympic sport at the 2024 Paris Olympics, difficulty of techniques and objective evaluation criteria for each technique were not clearly defined. The reliability of the evaluation system for breaking at the 2024 Olympics has not yet been analysed in the literature. This study reviews research on judging in other aesthetic sports and aims to evaluate the reliability of the scoring results for breakdancing at the 2024 Paris Olympics.

Methodology: The results of the 2024 Paris Olympics were extracted from the official Olympics website. The competition was conducted in a one-on-one battle format. Using a slide bar, the judges evaluated which dancer performed better in five categories: technique, vocabulary, originality, execution, and musicality. Absolute deviations from the final score for individual judges were calculated as measures of bias for validity analysis. The reliability of the evaluation was assessed using the intra-class correlation coefficients and Kendall's W.

Results: This study found that the reliability of the judges' scores was equivalent to that of DanceSport and hip-hop dance competitions and was considerably lower than that of artistic gymnastics competitions. Moreover, the originality category demonstrated good reliability, while the other four categories showed poor reliability. The judges were aware of the characteristics of breakdancing, where the winner was determined by the impressions and excitement of the audience, and this may have led to more reliable scoring in the artistic rather than in the technical category.

Discussion: These results will contribute to developing a more reliable evaluation system for hip-hop dance competitions.

Lower limb asymmetries in elite junior female vault gymnasts. Scientific Reports, 15: 43909, 2025.

Abstract - Due to long-term repetitive training of specific techniques, competitive vaulting gymnasts are prone to develop lower limb functional asymmetry. The symptom of lower limb functional asymmetry can seriously impair vaulting performance and is a major contributing factor to sports-related injuries. This study aimed to analyze the effect



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of key factors, including functional asymmetry in explosive power and balance ability among elite junior female vaulters, on run-up velocity and jumping ground reaction force. We conducted a series of assessments on twenty elite junior female vault specialists using the Noraxon MR3 wireless surface electromyography system, Kistler 3D force plates, and Tci-System infrared velocimetry. The assessments include countermovement jump (CMJ), Y-balance test (YBT), surface electromyography (sEMG), and vault trials. We employed paired-sample t-tests to analyze bilateral differences between dominant limb and non-dominant limb in jumping ground reaction force, balance, and muscle activation contributions. Pearson correlation analysis revealed the relationship between the bilateral asymmetry index (BAI) and vaulting run-up velocity or jumping ground reaction force. Segmented regression was employed to investigate the potential threshold effects of BAI on run-up velocity and jump ground reaction force. (1) We observed significant inter-limb differences in CMJ power production ($P < 0.05$), particularly in the vertical direction where the asymmetry index reached approximately 18.35%. (2) The YBT reach distance and center of pressure (COP) displacement both exhibited significant bilateral asymmetry ($P < 0.05$). The balance BAI were 3.25%, 3.04%, and 3.35% for the anterior (A), posteromedial (PM), and posterolateral (PL) directions. (3) The gluteus maximus showed significant inter-limb differences in muscle contribution rate ($P < 0.05$), while the rectus femoris, hamstrings, tibialis anterior, and gastrocnemius exhibited significant differences ($P < 0.01$). (4) The CMJ power asymmetry index exceeding 10.4% showed significant differences in jumping ground reaction force ($P < 0.05$), while exceeding 14.8% demonstrated significant differences in run-up velocity ($P < 0.05$). The YBT balance BAI showed no significant relationships with either jumping ground reaction force or run-up velocity ($P > 0.05$). Conclusion: Lower-limb power and balance asymmetries in elite junior female gymnasts exhibited measurable threshold ranges. Significant disparities exist in muscle contribution rates between dominant limb and non-dominant limb. The power asymmetry may influence vaulting run-up velocity and jumping ground reaction force beyond specific thresholds.

Golf

Associations between physical performance and golf shot data: A pilot study of touring professional female players. *Journal of Strength and Conditioning Research*, 39(6): 687-694, 2025.

Abstract - This study examined the relationship between a comprehensive physical testing battery and golf shot data in touring professional female golfers. Nineteen players (age: 31.00 ± 5.64 years; height: 170.84 ± 7.24 cm; body mass: 67.74 ± 9.16 kg; wingspan: 127.37 ± 14.21 cm) volunteered to take part in the study. Each player completed a dynamic warm-up before engaging in a 90-minute testing session, which gathered information on both physical capacity and golf



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shot data, all of which was collected at a single Ladies European Tour event. Golf shot data included clubhead speed, ball speed, carry distance, and smash factor, using a Trackman 4 launch monitor. Physical testing included anthropometry data, seated thoracic rotation, isometric mid-thigh pull (IMTP), isometric bench press, countermovement jump (CMJ), and seated medicine ball throws for distance. Pearson's r correlations showed the CMJ to have the strongest and most consistent associations with golf shot performance ($r = 0.51$ – 0.60). In addition, force at 100 ms during the IMTP also demonstrated large associations with carry distance ($r = 0.59$), further highlighting the significance of rapid force production in the lower body. Collectively, the findings demonstrate the importance of lower body ballistic force production for female golfers, providing important information for practitioners regarding the relevant physical capacities for testing and training.

The effects of a 10-week strength and conditioning intervention on physical capacity and golf shot performance in university male and female golfers. Journal of Strength and Conditioning Research, 40(1): e32-e40, 2025.

Abstract - The aim of the present study was to undertake a 10-week strength and conditioning training intervention and determine the effects on golf shot data and physical capacity in both high-level male and female university golfers. A total of 11 golfers (males = 6; females = 5) undertook a comprehensive testing battery preintervention and postintervention, consisting of golf shot data (with a driver), an isometric midthigh pull, isometric bench press, countermovement jump, seated medicine ball throw, and thoracic spine mobility. For the 10-week intervention, all players undertook 6 weeks of strength training twice per week, followed by 4 weeks of power training twice per week. No statistically significant differences were evident in the male group; however, large improvements (as defined by Hedges g effect size analysis) were observed for force at 100 milliseconds in the isometric bench press ($g = 1.13$), carry distance ($g = 0.98$), and ball speed ($g = 0.82$). In the female group, significant large improvements were evident in all isometric bench press metrics—force at 100 milliseconds ($g = 3.79$; $p < 0.05$), force at 200 milliseconds ($g = 3.04$; $p < 0.05$), and peak force ($g = 1.54$; $p < 0.05$), in addition to nonsignificant large increases in carry distance ($g = 0.84$). In summary, this intervention showed that large improvements in golf shot data can be made from undertaking strength and power training twice a week for 10 weeks, for both male and female players. Furthermore, and aligned with previous research in female golf, the importance of maximal and rapid force production in the upper body seems to be of particular importance for female golfers.



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Hockey

Recovery strategies in professional men's ice hockey: Balancing effectiveness, practicality, cost, and athlete compliance. Sport Performance & Science Reports, 272: 1-7, 2025.

Overview and Purpose

This review paper, authored by Cyril Besson and colleagues (published in 2025), examines recovery strategies in professional men's ice hockey. It addresses the sport's unique demands: high-intensity shifts, collisions, congested schedules (e.g., 50–80 games per season), extensive travel (especially in leagues like the NHL and KHL), and multifactorial fatigue (neuromuscular, metabolic, cognitive, and sleep/travel-related). The authors synthesize evidence from 77 studies (primarily from PubMed 2005–2025, with extrapolations from other team sports like soccer and rugby where hockey-specific data is limited). Strategies are evaluated across four key dimensions: **effectiveness** (physiological/psychological benefits), **practicality** (ease of implementation amid travel and schedules), **cost** (per player/season, from low <\$100 to high >\$5,000), and **athlete compliance** (adherence based on convenience and perception).

The goal is to provide a practical roadmap for sustaining performance, reducing injury risk, and managing fatigue across a season, including playoffs and international tournaments (summarized in Table 1, e.g., NHL: 82 regular-season games + playoffs ending mid-June with high cross-continental travel).

Key Fatigue Mechanisms

Fatigue in ice hockey stems from:

- **Metabolic/Neuromuscular:** Anaerobic glycolysis, phosphocreatine (PCr) depletion, glycogen loss, and pH changes during shifts, leading to reduced speed, power, and force late in games.
- **Hydration/Thermoregulation:** Sweat loss despite cool arenas, impairing performance if >2% body mass.
- **Cognitive/Psychological:** Impaired decision-making, reaction time, and focus from sleep disruption, circadian misalignment, and stress (e.g., late-night games, travel).
- **Recovery timelines:** PCr/metabolites clear in 24–48 hours; glycogen/neuromuscular recovery in 72 hours, but accumulates in back-to-backs or playoffs.



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Main Recovery Strategies and Appraisal

Strategies are categorized and rated in Table 2 (** = strong; * = moderate; * = limited evidence/impact). Prioritization is outlined in Table 3 (Core > Scalable > Targeted).

1. **Sleep and Travel Management** (** = effectiveness, ** = practicality, low cost, ** = compliance):
 - Most powerful for systemic restoration (hormonal, cognitive, neuromuscular).
 - Interventions: Hygiene education, naps, circadian tools (e.g., light therapy), monitoring (duration/efficiency).
 - Challenges: Disrupted by night games, arousal, and long-haul travel; prioritize naps and routines.
2. **Nutrition and Hydration** (** = effectiveness, ** = practicality, low cost, ** = compliance):
 - Carbohydrate-protein co-ingestion within 30–60 min post-game for glycogen resynthesis and repair.
 - Polyphenols/omega-3s for inflammation; fluids to prevent hypohydration.
 - Practical: Team catering, portable snacks; supports in-game performance (e.g., mouth-rinsing).
3. **Hydrotherapy/Thermal Interventions:**
 - Cold-water immersion (CWI, 11–15°C, 10–15 min): * effectiveness for soreness/inflammation reduction; * practicality (arena facilities); \$\$ cost; * compliance.
 - Heat/sauna (41–44°C, 30–45 min): * effectiveness for circulation/glycogen; * practicality; low cost.
 - Contrast baths: * effectiveness for swelling; * practicality; \$\$ cost.
 - Timing: Cool post-game for damage control; heat later for repair; avoid extreme cold if it delays sleep.
4. **Mechanical Interventions:**
 - Compression garments: * effectiveness (soreness relief); ** practicality (portable); \$ cost; ** compliance.
 - Pneumatic compression boots: * effectiveness (circulation); * practicality; \$\$ cost; * compliance.



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- Blood flow restriction (BFR): ** effectiveness (perfusion/torque); * practicality (needs supervision); \$\$ cost; ** compliance.
- Massage/self-myofascial release (foam rolling): ** effectiveness (flexibility/perception); *** practicality; \$/\$\$ cost; -* compliance.
- Active recovery (low-intensity cycling): ** effectiveness (metabolite clearance); *** practicality; \$ cost; ** compliance.

5. **Psychological/Cognitive Recovery** (** effectiveness, *** practicality, \$ cost, -* compliance):

- Mindfulness, breathing, relaxation, music/nature imagery for stress reduction and mental detachment.
- Scalable: Embed in routines (e.g., travel apps); underused but portable and inexpensive.

6. **Other/Emerging Modalities** (* effectiveness, * practicality, \$\$–\$\$\$ cost, -** compliance):

- Neuromuscular electrical stimulation, photobiomodulation, hyperbaric therapy, floatation: Limited evidence; best as adjuncts or individualized (e.g., injury recovery).
- Future: Personalized profiling (chronotype, movement patterns).

Monitoring for Individualization

- Combine subjective (fatigue/soreness/sleep scales) with objective metrics: Heart rate variability (autonomic status), countermovement jumps (neuromuscular readiness), groin squeezes/range-of-motion (injury risk), and tech like GPS/IMU for load tracking.
- Practical: Quick, sensitive tools to adjust strategies; avoid unreliable biochemical markers.

Discussion and Recommendations

- **Foundations First:** Sleep and nutrition are core (high impact, low barriers); complement with portable adjuncts (e.g., compression, foam rolling) for congested schedules.
- **Targeted Use:** Resource-heavy options (e.g., cryotherapy, BFR) for select players (high-load or injured) or off-days.
- Compliance drives success: Influenced by perception, culture, and autonomy (e.g., placebo effects in CWI).



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- Operational Focus: Embed in routines; multidisciplinary coordination (staff time > equipment cost).
- Prioritization (Table 3):
 - **Core:** Sleep, nutrition, compression, foam rolling (universal, travel-friendly).
 - **Scalable:** CWI, sauna, pneumatic boots, mindfulness, active recovery (team-efficient).
 - **Targeted:** Manual therapy, BFR, cryotherapy, emerging tech (individualized).
- Use magnitude-based inferences for decisions (e.g., meaningful changes like 3–5% jump improvement), not just p-values.

Limitations

- Limited hockey-specific studies; extrapolations from other sports.
- Focus on acute recovery; less on season-long accumulation.
- Undifferentiated for positions (e.g., goaltenders vs. skaters).
- Under-quantified compliance/cost/feasibility.

Conclusion and Practical Applications

Effective recovery prioritizes simplicity and consistency over high-tech solutions. Optimize sleep/nutrition as non-negotiables; use low-cost, portable tools for autonomy; reserve complex modalities sparingly. Integrate monitoring for personalization. This approach sustains performance, minimizes fatigue, and fits tight schedules/travel.

Bioelectrical Impedance Spectroscopy Measuring the Magnitude of Body Water Compartment Changes Pregame and Postgame in Collegiate Ice Hockey Players. Journal of Strength and Conditioning Research, 39(6): e769-e773, 2025.

Abstract - Bioelectrical impedance spectroscopy (BIS) is an accurate and feasible measure of hydration and compartment water, although its ability to detect meaningful changes in field settings is unknown. This study evaluated the typical changes in whole-body and segmental body compartment water before and after games in 25 male National



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Collegiate Athletic Association Division I ice hockey players using a SOZO BIS device. Measurements were taken the mornings of and the mornings after the first game of a two-game series across 9 home games. Absolute changes at the individual level were averaged for each game and across games to estimate typical changes in body water. Medium total body water loss (mean change [95% CI]: -0.63 L [-0.80 to -0.37]; percent change: 1.2%), large extracellular water loss (mean change [95% CI]: -0.56 L [-0.73 to -0.39]; percent change: 2.5%), and small leg intracellular water loss (mean change [95% CI]: -0.12 L [-0.23 to -0.01]; percent change: 1.1%) were still present in the morning after the game. These findings indicate that BIS is sensitive to small changes in whole-body and leg segment body water compartments at the group level in an ecologically valid sports setting, and the body water compartment losses observed in this study emphasize the importance of effective postgame rehydration strategies. Hypohydration is linked to meaningful end points in sport (e.g., exercise performance, heat illness, recovery), and the ability to noninvasively monitor whole-body and segmental compartment water with BIS may improve sport staff's ability to implement effective hydration and nutrition strategies for athletes.

Lacrosse/Field Hockey

Effect of World Lacrosse Sixes Match play on Neuromuscular Performance in International Men's Lacrosse Players. International Journal of Strength and Conditioning, 5(1): 1-16, 2025.

Sixes lacrosse is a new sport to be included in the 2028 Olympics, however there is limited understanding on the demands of Sixes lacrosse competition.

Purpose: To observe the effect of Sixes lacrosse on acute fatigue.

Methods: Eleven international male Sixes lacrosse players (24.82 ± 2.58 years, 180.17 ± 8.84 cm, 90.14 ± 7.63 kg) participated within the present study, playing in five competitive matches over three-days. Three countermovement jump (CMJ) trials were performed pre- and post-match.

Results: Very large ($d = 1.35$ [0.51-2.17]) decreases in system weight (SW), a moderate increase in jump height (JH) ($d = 0.67$ [-0.02-1.31]) and a moderate decrease in average relative braking force (ARBf) ($d = 0.68$ [-0.03-1.27]) were observed from pre-post one match. A moderate ($d = 0.76$ [0.07-1.42]) decrease in SW, with a small increase in average relative propulsive force (ARPF) ($d = 0.30$ [-0.31-0.90]) were observed from pre-post three matches. Very large increases in JH ($d = 1.69$ [0.73-2.61]) and time to take off ($d = 1.43$ [-0.40-2.45]) with a large increase in countermovement displacement ($d = 1.05$ [0.29-1.78]) and a large decrease in ARBF ($d = 0.84$ [0.13-1.52]), with no meaningful changes were



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observed for SW ($d = 0.03$ [-0.56-0.62]), or ARPf ($d = 0.04$ [-0.56-0.63]) observed from pre-post international tournament.

Conclusion: The results of this study have implications on recovery within Sixes lacrosse players during international tournaments. Moreover, the high levels of observed fatigue would likely require a period of restitution following international tournament.

Comparison of Game Data Between Halves and Quarters in Division I Women's Lacrosse. Journal of Science in Sport and Exercise, 7: 304-310, 2025.

Purpose: The purpose of this study was to compare in-game external load demands from the previous game format (two, 30-min halves) to the new format (four, 15-min quarters) in collegiate women's lacrosse.

Methods: External workload variables (total distance, high-intensity distance [HID], sprints, sprint distance, accelerations, and decelerations) were collected via microtechnology per minute of athlete ($n = 13$) playing time by half (H) for year one (Y1) and by quarter (Q) for year 2 (Y2).

Results: In H1, Y2 registered more distance (Y2: 179 ± 37 m/min, Y1: 69 ± 45 m/min), HID (Y2: 26.4 ± 9.8 m/min, Y1: 6.5 ± 5.0 m/min), accelerations (Y2: 3.2 ± 0.8 reps/min, Y1: 1.4 ± 0.9 reps/min), decelerations (Y2: 1.0 ± 0.3 reps/min, Y2: 0.4 ± 0.3 reps/min, all $P < 0.001$), sprints (Y2: 0.36 ± 0.25 reps/min, Y1: 0.07 ± 0.06 reps/min, $P = 0.006$) and sprint distance (Y2: 13.2 ± 8.7 m/min, Y1: 2.3 ± 2.0 m/min, $P = 0.004$). Y2 was greater in H2 for distance (Y2: 175 ± 24 m/min, Y1: 109 ± 28 m/min, $P < 0.001$), HID (Y2: 21.1 ± 0.6 m/min, Y1: 9.9 ± 3.3 m/min, $P < 0.001$), sprints (Y2: 0.29 ± 0.19 reps/min, Y1: 0.11 ± 0.04 reps/min, $P = 0.003$), accelerations (Y2: 2.8 ± 0.6 reps/min, Y1: 2.1 ± 0.5 reps/min, $P = 0.003$), decelerations (Y2: 0.9 ± 0.2 reps/min, Y1: 0.5 ± 0.1 reps/min, $P = 0.001$) and sprint distance (Y2: 10.6 ± 6.4 m/min, Y1: 3.7 ± 1.4 m/min, $P = 0.002$). Differences in whole game was found for sprints (Y2: 0.24 ± 0.3 reps/min, Y1: 0.11 ± 0.05 reps/min, $P = 0.009$).

Conclusion: The new competitive format presented a greater demand for players, with more high-intensity efforts and greater anaerobic demand. Coaches can use this information as key performance indicators to develop and alter training to focus on meeting higher-intensity game demands.



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Soccer

Systematic video analysis of ankle sprain injuries in elite male football (soccer): Injury mechanisms, situational patterns, biomechanics and neurocognitive errors study: A study of 140 consecutive players. Knee Surgery, Sports Traumatology Arthroscopy, 33: 4035-4049, 2025.

Purpose: To describe the mechanisms, situational patterns, biomechanics and neurocognitive errors related ankle sprain injuries of professional male football players during match play.

Methods: There were 166 consecutive ankle sprain injuries identified occurring during official matches in players of top European football leagues. One hundred and forty (84%) injury videos were analyzed for mechanism and situational pattern, with biomechanics on 20 players. Neurocognitive errors were investigated for all noncontact injuries. Three independent reviewers evaluated each video. Ankle sprain injury epidemiology-month, timing within the match and pitch location at the time of injury and time-loss according to sprain type was also documented.

Results: More injuries occurred in offensive ($n = 89$, 64%) than defensive ($n = 51$, 36%) situations ($p < 0.001$). Seventy (50%) direct contact, 42 (30%) indirect contact and 28 (20%) noncontact injuries were categorized. There were 67 (48%) inversion, 30 (21%) high ankle, 25 (17%) eversion, 6 with combination of high ankle and eversion (4%) and 12 (9%) unsure injuries. Four main situational patterns were described: (i) being tackled ($n = 59$, 42%); (ii) tackling/pressing ($n = 34$, 24%); (iii) landing from a jump ($n = 16$, 11%) and (iv) sliding ($n = 7$, 5%). Inversion injuries were associated with internal rotation, while high ankle injuries typically involved toe contact with the ground, slight plantar flexion and foot eversion. A neurocognitive error was documented 59% of noncontact injuries. A similar number of injuries occurred during the 1st ($n = 71$, 51%) and 2nd ($n = 69$, 49%) half ($p > 0.05$).

Discussion: Half of ankle sprain injuries occurred after direct contact, 3 in 10 after indirect contact and only 2 in 10 without contact. Injury prevention practices should consider mechanical perturbation, playing situation and neurocognitive factors when designing programs.

Level of evidence: Level IV.



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Influence of competitive match play on countermovement jump performance, lower-limb isometric strength, and self-reported subjective measures 40 hours post-match in professional soccer. Journal of Strength and Conditioning Research, Ahead of Print: 1-12, 2025.

Abstract - This study investigated the impact of competitive match play on countermovement jump (CMJ) performance, hamstrings and adductor isometric strength, and subjective self-reported measures 40 hours post-competitive match play in professional soccer players. Twenty-eight professional players completed baseline assessments during preseason. Assessment 40 hours post-match was limited to players who played ≥ 60 minutes, with players grouped into 2 categories based on minutes played: 60-89 minutes or 90-110 minutes. Baseline measures for subjective self-reported measures were collected 24 hours before each match. Across both groups, significant reductions ($p < 0.05$) were observed in all outcome, ratio, and driver metrics except for eccentric mean force. All strategy metrics significantly increased ($p < 0.05$). Minutes played and match demands were not significantly associated with CMJ performance ($\tau_b = -0.07$ to 0.16 and $\tau_b = -0.28$ to 0.00 , respectively). Prone isometric 0° showed nonsignificant reductions ($p > 0.05$) in both conditions with trivial to small effects. Significant reductions ($p < 0.05$) were observed for both conditions for the supine 90° hamstring test, however minutes played, and match demands were not significantly associated with a reduction in performance ($\tau_b = -0.04$ to -0.01 and $\tau_b = -0.27$ to 0.21). Short lever hip adduction results showed nonsignificant reductions ($p > 0.05$) in the 60-89 minutes group, but significant decreases ($p < 0.001$) were observed for the dominant limb, nondominant limb, and total score in the 90-110 minutes condition. However, minutes played and match demands were not significantly associated with reduction in adductor isometric strength ($\tau_b = 0.18$ - 0.22 and $\tau_b = -0.15$ to 0.11). Subjective measures revealed significant reductions in sleep quality ($p < 0.05$) and composite scores ($p < 0.001$), and significant increases in muscle soreness ($p < 0.001$) across both conditions. Mood was only significantly reduced ($p < 0.05$) in the 90-110 minutes condition. No significant associations were found between minutes played, match demand, and self-reported subjective scores ($\tau_b = -0.07$ to 0.05 and $\tau_b = -0.09$ to 0.00).



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Starters Experience Greater Weekly Match and Total Loads than Non-Starters in a Professional Female Soccer Team: An Exploratory Analysis Within the A-League Women's Australian Competition. Sensors, 25: 7290, 2025.

Abstract - Comprehensive weekly load data appears relatively absent in the literature for the professional female soccer population. This exploratory observational study quantified the weekly training, match, and total loads experienced in a professional soccer team and compared these loads according to player role. Data were collected over a full season from 22 players competing in the Australian national A-League Women's soccer competition. Internal (session-rating of perceived exertion load [session-RPE load]) and external load (total and relative values for total and high-speed running [HSR] distance) data were acquired during on-field training sessions and matches. Players were categorized as starters (started the match) or non-starters (used as a substitute in the match) within each week. Linear mixed models and effect size analyses were used to compare weekly loads between player roles. Weekly match and total load analyses revealed higher ($p < 0.001$, moderate-to-very large effects) duration, total distance, total HSR distance, and session-RPE load in starters than non-starters. In contrast, relative total and HSR distance in matches were higher ($p < 0.001$, moderate-to-large effects) in non-starters than in starters. These data provide an initial reference for the weekly loads in this competition, highlighting disparities between player roles that should be considered when developing training and preparation plans. Given the recruitment of a single team and small sample size, future research should extend upon this study to further strengthen the evidence base in this population.

Softball

Systematic review of clinical and performance outcome measures reported for softball pitchers. International Journal of Sports Medicine, Ahead of Print: 1-14, 2025.

Abstract - Fastpitch softball is popular among adolescent and collegiate female athletes. Softball pitchers are susceptible to overuse injuries, and clinical and performance outcome measures can be used to evaluate injury risk and readiness to return to play. Our purpose was to examine clinical and performance-related outcome measures in pitchers using a systematic review of the softball literature published since 1990. PubMed, Embase, CINAHL, and SPORTDiscus databases were searched using the term "softball" AND "pitching" OR "injuries". Inclusion criteria were studies reporting clinical or performance outcomes like strength, range of motion, anthropometrics, and patient-reported measures. A preliminary screening of studies was completed based on abstracts. Full-text articles were reviewed by two reviewers. Thirty-seven studies met all inclusion criteria. The risk of bias was low for all included studies. Studies reporting body composition ($n =$



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4), range of motion ($n = 10$), strength ($n=12$), functional testing ($n=4$), and patient-reported outcomes ($n=3$) were included in data extraction. There was a high degree of variability in outcome measures used to evaluate softball pitchers. Ten case studies were included in the discussion of results. Researchers would benefit from a standardized list and protocol for clinical and performance outcome measures used for softball pitchers. This systematic review identifies important gaps in the literature.

The association between selected lower extremity kinematic variables and fastpitch softball speed – A preliminary study. 43rd International Society of Biomechanics in Sports Conference, Doha, Qatar: November 2-6, 2025.

Abstract - This preliminary study aimed to examine the association between selected lower extremity kinematic variables and pitch speed in fastpitch softball. The kinematic variables were chosen for their practical applicability, allowing coaches and athletes to assess and enhance performance using accessible tools. Five collegiate female softball pitchers volunteered for the study. Using the OpenCap system, five strike pitches from each participant were analyzed. Due to the small sample size, Spearman's rho analysis was employed. Results indicated significant associations between ball speed and normalized stride length ($r^s = -0.46$, $p = .022$), and ball speed and normalized stride width ($r^s = 0.83$, $p < .001$). These findings suggest that specific lower extremity kinematic variables may influence pitch speed, warranting further investigation with a larger sample.

Swimming

Effects of Three Different Volumes of In-Water Warm-Up Protocols in Acute Physiologic Responses and 100 m Swimming Performance Across All Strokes. Journal of Strength and Conditioning Research, Ahead of Print: 1-7, 2025.

Abstract - This study examined the effects of 3 in-water warm-up (WU) protocols of varying volumes (600, 1,200, and 1,800 m) on acute physiologic responses and 100-m swimming performance across all strokes. Forty male national-level swimmers (21.0 ± 2.0 years) participated in a randomized crossover study, performing each WU protocol followed by a 100-m time trial in their respective strokes. Physiologic metrics, including blood lactate, temperature, heart rate, and rating of perceived exertion (RPE), were recorded. A repeated measures ANOVA was used to investigate the effects of the 3 protocols on physiologic and swimming performance across all the strokes. Results showed that the regular WU



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(1,200 m) led to significantly faster times in backstroke (65.56 ± 1.14 seconds vs 67.02 ± 1.20 seconds), breaststroke (70.73 ± 0.94 seconds vs 72.73 ± 0.94 seconds), and butterfly (58.64 ± 0.77 seconds vs 60.53 ± 0.86 seconds) than the long WU (1,800 m) ($p < 0.05$). For the butterfly, the short WU (600 m) also resulted in significantly better swimming performance than the long WU. No significant differences were observed in freestyle performance among the 3 WU protocols, nor were there differences in heart rate across all strokes ($p > 0.05$). Higher blood lactate and tympanic temperatures were observed after regular WU, while RPE was lowest after the short WU. This study emphasizes the importance of optimizing WU volumes based on stroke-specific demands in swimming. In addition, it also suggests practitioners to be cautious about using heart rate as a sole marker of WU effectiveness in swimming.

Impact of course length on swimming performance across age groups and swimming strokes. *Frontiers in Sports and Active Living*, 7: 1631870, 2025.

Introduction: Swimmers typically achieve faster times in the same distance events in short course (SC) than in long course (LC) due to the higher number of turns in SC; however, the influence of age and sex on performance differences between SC and LC events remains unclear.

Methods: This study aimed to examine the differences in the top 200 seasonal times between SC and LC in the 50, 100 and 200 m backstroke, breaststroke, butterfly, freestyle and individual medley events (200 and 400 m). Top 200 Spanish seasonal times of four age groups were considered for both sexes between two seasons. A three-way ANOVA with *post-hoc* analysis was performed to assess the impact of age, sex, and event type on the time differences between SC and LC.

Results: The results indicated that older swimmers showed greater differences between SC and LC times compared to other age groups in males and females ($p < 0.05$). In backstroke and breaststroke events, similar patterns were observed with higher differences between SC and LC compared to butterfly and freestyle, especially in 100 m and 200 m events ($p < 0.05$).

Discussion: These differences should be taken into consideration by coaches and swimmers when establishing differences in performance depending on the pool length.



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Tennis

To return forward or backward? That is the question: Analyzing and predicting return positioning in elite men's doubles tennis. International Journal of Sports Science & Coaching, Ahead of Print: 1-11, 2025.

Abstract - Return positioning is a critical yet understudied tactical element in elite men's doubles tennis. This study analyzed 21,881 Hawk-Eye tracked returns from 101 professional matches to identify distinct return depth patterns, compare associated serve characteristics, and develop predictive models. K-Means clustering revealed Short (approx. 11.1 m from net) and Deep (approx. 12.5 m) return clusters on both Deuce and Advantage sides. Deep return positions were significantly associated with higher serve speeds ($d > 1.02$), first serves ($V > 0.43$), and T-serves ($V > 0.30$), while short return positions correlated with lower speeds, second serves, and wide serves (all $p < 0.001$). Break point status was not significant. Classification and Regression Tree models, primarily using serve speed and type, predicted return depth with good accuracy (77–79%) and AUC (0.77–0.79). These findings demonstrate that elite players systematically adapt their return depth based on serve characteristics, likely to manage response time and angles considering the opposing net player. This provides novel empirical quantification of doubles return strategies, offering valuable insights for tactical training and performance analysis.

Effects of neuromuscular training on tennis players: A systematic review and meta-analysis. BMC Sports Science, Medicine and Rehabilitation, 17: 172, 2025.

Objective: To evaluate the effects of neuromuscular training (NT) on tennis performance metrics and determine the influence of age, training variables, and NT modalities.

Methods: This systematic review and meta-analysis involved a comprehensive search of PubMed, MEDLINE, Embase, Google Scholar, and Web of Science from inception to October 2024. Randomized controlled trials comparing neuromuscular training (NT) modalities-plyometric training (PT), resistance training (RT), and core stability training (CT)-with conventional training in tennis players were included, focusing on outcomes such as service velocity, service precision, agility, sprint performance, muscular strength, and power. Study quality was assessed with ROB2 tool, and evidence certainty graded through GRADE framework. Statistical synthesis was performed using R software (Version 4.4.1) with 'metafor' and 'gemtc' package, calculating Hedges' g effect sizes for outcomes.

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Results: Twenty-three studies involving 743 participants demonstrated that NT significantly improved service velocity (standardized mean difference [SMD] = 0.72; 95% CI, 0.47 to 0.99), agility (SMD = -0.64; 95% CI, -0.92 to -0.35), sprint performance (SMD = -0.33; 95% CI, -0.60 to -0.07), muscular strength (SMD = 0.57; 95% CI, 0.35 to 0.80), and power (SMD = 0.74; 95% CI, 0.41 to 1.08). However, no significant improvement was observed in service precision (SMD = 0.36; 95% CI, -0.13 to 0.86; $p = 0.1126$). Furthermore, age appeared to play a role, as players over 18 years showed greater gains in service velocity and power compared to their younger counterparts. Regarding training duration, interventions lasting over 12 weeks (> 24 sessions) did not provide additional benefits in agility and sprint performance. Interestingly, a training frequency of twice per week proved more effective than three times per week for improving sprint performance. When analyzing training modalities, PT emerged as the most effective for enhancing service velocity, sprint performance, and power. On the other hand, CT was found to be optimal for improving agility, while RT yielded the greatest gains in muscular strength.

Conclusion: NT effectively enhances key performance metrics in tennis players, with outcomes influenced by age, training variables, and NT modality. Coaches should tailor NT programs to the athlete's age and specific performance goals, emphasizing PT for explosive actions, CT for agility, and RT for strength.

Volleyball

Agreement between a motorized resistance device and traditional systems for sprint change-of-direction testing in female volleyball players. Journal of Strength and Conditioning Research, Ahead of Print: 1-8, 2025.

Abstract - The purpose of this study was to determine the agreement between a motorized sprint resistance device (MSRD) and timing gates and an inertial measurement unit (IMU), for assessing time to completion and peak velocity during linear and change-of-direction tasks in elite female volleyball players. Elite volleyball athletes ($n = 16$, 19.4 ± 1.5 years, 176.2 ± 10.6 cm, 71.5 ± 11.1 kg) performed the 18.29 m sprint and 5-10-5 drills while being simultaneously assessed using an MSRD, timing gates, and an IMU. Compared with timing gates for measuring sprint (3.09 ± 0.16 seconds) and 5-10-5 (5.08 ± 0.19 seconds) time, the MSRD showed significant ($p < 0.01$) mean differences (3.15 ± 0.17 seconds [$p < 0.01$, Cohen's $d = 0.49$, small]) and 5.16 ± 0.21 seconds [$p < 0.01$, Cohen's $d = 1.14$, moderate], respectively, but the correlations were very large to nearly perfect ($r = 0.97$ and 0.87 , respectively). Limits of agreement (LOA) for sprint time were -0.10 ± 0.10 seconds and for 5-10-5 time were 0.23 ± 0.24 seconds. For peak velocity, the mean values from MSRD and IMU for the sprint (4.62 ± 0.34 m·s⁻¹ and 4.72 ± 0.44 m·s⁻¹, respectively [$p = 0.78$]) and 5-10-5 drill (3.91 ± 0.47 m·s⁻¹ and 3.93 ± 0.50 m·s⁻¹, respectively [$p = 0.98$]) were not significantly different. The correlation between the



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peak velocity values was significant for the sprint ($r = 0.65$, $p < 0.01$), but not for 5-10-5 ($r = 0.25$, $p = 0.69$), with LOA values of $0.03 \pm 0.86 \text{ m}\cdot\text{s}^{-1}$ and $0.00 \pm 0.98 \text{ m}\cdot\text{s}^{-1}$, respectively. The MSRD seems to agree with timing gates for sprint and 5-10-5 time. However, the agreement with IMU for peak velocity is weaker.

Biomechanical improvements in performance and injury prevention in volleyball spikes: effects of a 4-week training program. Scientific Reports, Online Dec. 12, 2025.

Abstract - This study aimed to develop a 4-week volleyball-specific training program for the unique movement requirements of volleyball to enhance performance and reduce injury risk among adult players. Sixteen male participants were college players with at least 10 years of volleyball experience (ages: 18-22 years). Participants performed spikes in pre- and post-test, starting with a 5 m run-up from the left side of the net to a force platform. They underwent a four-week training program aimed at improving spike performance. The analyzed variables included the center of mass (COM), joint angles, angular velocities, moments, ground reaction forces (GRF), and forces in the three planes of the knee joint. For statistical analysis, paired t-tests and statistical parametric mapping (SPM) were employed to evaluate pre- and post-test differences in the measured variables ($\alpha = .05$). During the jumping phase, knee extension angular velocity and peak vertical GRF increased after training ($p < .05$), and SPM analysis revealed a higher knee flexion moment between 40 and 80% of the phase post-test ($p < .001$). In the airborne phase, the center of mass (COM) reached a greater height after the training program ($p < .05$). During the landing phase, the minimum COM height decreased post-test ($p < .05$), while flexion angular velocity increased ($p < .05$). In addition, the extension moment and vertical joint forces of the knee were reduced ($p < .05$), and vertical GRF remained consistently high at 35% of the landing phase ($p < .001$). The four-week specific training program effectively enhanced jump performance and reduced knee joint load, promoting both improved performance and safer landing mechanics.

Wrestling/Combat Sports

The burden of shoulder and elbow injuries in wrestling: A systematic review of incidence, injury types, and competition-level comparisons. Sports Health, Ahead of Print: 1-13, 2025.

Context: Wrestling is a physically demanding sport that places athletes at a high risk of musculoskeletal injuries, particularly to shoulder and elbow joints.



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Objective: This study summarizes published data on shoulder and elbow injuries in wrestling, determines their burden, and reports weighted average injury rates (wIRs).

Data sources: Databases searched included PubMed, Embase, Medline, Cochrane Library, and SPORTDiscus.

Study selection: Full-text studies in English evaluating shoulder or elbow injuries in competitive wrestlers with reported injury data specific to wrestlers, as well as to the shoulder or elbow were included. Exclusions were case reports, reviews, and studies not reporting orthopaedic injury data.

Study design: Systematic review.

Level of evidence: Level 4.

Data extraction: Extracted data included the first author, publication year, journal, country of the corresponding author, level of competition, method of data collection, duration of data collection, incidence of injury (injury rate [IR]) per athlete-exposure (AE), number of shoulder or elbow injuries, total number of injuries, total AEs, specific injury types, mechanism of injury, and time lost due to injury.

Results: Shoulder and elbow injuries together accounted for 21.2% of all wrestling injuries, with a wIR of 14.1 per 10,000 AEs. Shoulder injuries accounted for 14.1% of all injuries (wIR = 6.2 per 10,000 AEs), while elbow injuries accounted for 7.2% (wIR = 4.1 per 10,000 AEs). The most frequent injuries were shoulder strains/sprains (wIR = 4.2), including rotator cuff (wIR = 3.4) and acromioclavicular joint injuries (wIR = 1.5), shoulder instability (wIR = 2.5), and elbow instability, including ulnar collateral ligament injury (wIR = 1.8).

Conclusion: Shoulder and elbow injuries are common in wrestling, with shoulder injuries being more prevalent due to the joint's mobility and relative instability. This review identifies the most common injuries and serves as a valuable resource for physicians managing the care of wrestlers.



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Caffeinated chewing gum improves sympathetic nerve activity and wrestling performance: A double-blind crossover trial. International Journal of Sports Physiology and Performance, Ahead of Print: 1-8, 2025.

Purpose: This study investigated the effect of caffeinated chewing gum on sympathetic nerve activity and simulated wrestling performance.

Methods: Sixteen professional male wrestlers (age: 21.8 [1.0] y, height: 168.4 [4.5] cm, mass: 68.2 [8.7] kg) were randomly assigned to either a caffeinated-chewing-gum (CAF) trial or a placebo trial (PL) using a double-blind, randomized crossover study design. Participants warmed up for 15 minutes after chewing CAF containing 3 mg/kg body weight or caffeine-free placebo gum (PL) for 10 minutes. Participants were sequentially tested for grip strength and a specific wrestling performance test (SWPT). Saliva samples were collected when participants arrived at the laboratory and at the end of the SWPT to analyze caffeine and α -amylase concentrations.

Results: Caffeinated chewing gum significantly increased the number of throws in round 1 (CAF: 26.8 [3.3] times, PL: 24.0 [2.7] times; $P = .002$, Cohen $d = 0.92$), round 2 (CAF: 22.8 [3.3] times, PL: 20.4 [3.3] times; $P = .047$, Cohen $d = 0.72$), and total number of throws (CAF: 49.6 [5.7] times, PL: 44.5 [4.7] times; $P = .001$, Cohen $d = 0.97$), as measured by SWPT, compared with the PL. The saliva α -amylase concentrations were higher in the CAF trial than in the PL trial at the end of the SWPT ($P = .040$, Cohen $d = 0.52$).

Conclusions: The results of this study provide support that caffeinated chewing gum is effective in improving the number of throws in an SWPT. Increased sympathetic nerve activity may have improved the number of throws.

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