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Original article

Relationships between countermovement jump-derived variables, eccentric hamstring strength, and agility performance in elite female basketball players

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Abstract

This study investigated whether agility performance in elite female basketball players could be predicted from countermovement jump (CMJ) force–plate metrics, eccentric hamstring strength, and anthropometric characteristics. Forty-five athletes competing in Iceland's top division completed assessments of CMJ kinetics using dual force platforms, eccentric knee-flexor strength via the Nordic Hamstring Exercise, and reactive agility performance through the Y-Agility Test. A multiple linear regression model was applied to assess the predictive value of CMJ-derived variables and eccentric hamstring force on total test time. The model demonstrated a high coefficient of determination (R^2 = 0.959), indicating that the predictors collectively explained 96% of the variance in agility times. However, none of the individual predictors reached statistical significance ($p > 0.20$), suggesting no meaningful relationships between CMJ or Nordic metrics and agility performance. These results emphasize that reactive agility is a distinct physical quality, influenced by multifactorial determinants such as neuromuscular coordination, horizontal braking efficiency, and perceptual–cognitive factors not captured by traditional CMJ or isolated strength assessments. Practically, coaches should avoid presuming direct transfer between improvements in vertical jump or eccentric hamstring capacity and agility performance. Instead, training programs should incorporate agility-specific drills that integrate reactive decision-making and sport-relevant movement patterns. Future research should include larger samples and multidimensional models to better understand agility determinants in female populations.

Keywords: neuromuscular performance, injury prevention, jumping assessment, lower limb strength, sport-specific conditioning

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Introduction

Agility is defined as "a rapid whole-body movement with change of velocity or direction in response to a stimulus" and is considered important for many sports (Sheppard et al., 2006). Agility and rapid changes of direction (COD) are fundamental to basketball performance, where athletes must accelerate, decelerate, and redirect movement over short distances (Ben Abdelkrim et al., 2010; Scanlan et al., 2014). In elite female basketball, successful defensive closeouts, offensive drives, and recovery actions depend heavily on the ability to generate explosive force within the first few meters and to decelerate under control before changing direction (Spiteri et al., 2015). Unlike sprint-based sports where maximal velocity is achieved over longer distances, basketball-specific agility emphasizes early acceleration and braking capacity, including the need to prepare athletes for maximal decelerations as well as accelerations. Accordingly, braking (deceleration) capacity is a key component of basketball movement demands.

To assess reactive agility, testing must include an external stimulus to challenge athletes' visual scanning and decision-making abilities (Oliver & Meyers, 2009). Repeated CODs, accelerations, and decelerations are considered essential components of basketball performance (Brini et al., 2021). During a game, basketball players may perform between 550 and 1000 changes of direction (COD) depending on their playing position (Drinkwater et al., 2008).

While COD performance has been studied in basketball, there is a noticeable lack of research investigating agility—particularly in female basketball players—and its relationship with force–time derivatives or eccentric hamstring capacities. Vencurik et al. (2019) examined the relationship between reactive agility and lower-body speed and power, finding only a weak correlation between Y-agility test performance and countermovement jump (CMJ) height. However, their analysis was limited to jump height as a single output variable. Daveena et al. (2019) reported that jump-derived power—particularly approach jump, relative standing broad jump, and power relative to body mass—was strongly associated with linear sprint and COD speed among Division I collegiate women's basketball players. While highlighting the importance of stretch-shortening cycle efficiency and relative power, their study did not include force–time characteristics, limiting insight into underlying neuromuscular performance.

Čaušević et al. (2021) examined the relationship between agility, sprint, and vertical jump performance in young basketball players. They found shared physical demands across these qualities, emphasizing the need to train them concurrently. However, their use of the T-test as an agility measure is limited, as it does not include external stimuli and thus does not fully represent reactive agility.

Eccentric hamstring capacity contributes to faster change-of-direction performance, as athletes with greater eccentric peak force and rate of force development tend to achieve shorter ground contact times and greater control during deceleration–acceleration transitions. Studies in basketball and other team sports have shown correlations between Nordic hamstring strength, eccentric knee flexor torque, and COD speed (Smajla et al., 2022).

Recent evidence suggests that eccentric lower-limb capacity—particularly eccentric hamstring (braking) ability—is a key determinant of COD and agility performance in female court athletes. Cross-sectional studies show that faster female basketball players generate greater eccentric force and impulse during COD tasks, and measures of eccentric muscle capacity are significantly associated with COD speed (Spiteri et al., 2015). Interventions using eccentric overload methods, such as flywheel training, have demonstrated improvements in sprint and COD performance in female basketball players, supporting a causal role for eccentric capacity in on-court movement performance (O'Brien et al., 2020).

Advanced athlete monitoring technologies allow for more comprehensive assessment of basketball performance demands. The VALD SmartSpeed system enables precise measurement of agility and COD performance, such as the Y-test, while ForceDecks quantify kinetic and kinematic variables from CMJ tests, and NordBord measures eccentric hamstring strength. Integrating these systems provides a holistic understanding of how neuromuscular, anthropometric, and eccentric strength qualities underpin agility performance (Chen et al., 2023).

The Y-agility test was selected to assess basketball-specific agility by incorporating both rapid acceleration/deceleration and reactive change of direction in response to a visual stimulus. This test replicates typical on-court movements such as defensive slides and offensive cuts and includes a perceptual–cognitive component that differentiates reactive agility from pre-planned COD ability.

To date, no study has comprehensively examined the predictive value of force–time characteristics from CMJ testing and eccentric hamstring performance on Y-agility test outcomes among female basketball players.

Therefore, the purpose of this study was to examine to what extent agility performance could be predicted from anthropometric characteristics, CMJ force–plate variables, and eccentric hamstring strength in elite female basketball players competing in Iceland's top division. We hypothesized that eccentric knee flexor strength and braking-related force–time metrics would be stronger predictors of short-distance reactive agility performance than traditional vertical jump variables.

Methods

Experimental approach to the problem

A cross-sectional design was employed to assess the relationship between CMJ-derived variables, eccentric hamstring strength, and agility performance. All assessments were performed within a single testing session in a controlled indoor environment. Participants completed a standardised warm-up consisting of light jogging, dynamic stretching, and submaximal jump and sprint drills before testing commenced.

Participants

Forty-five elite female basketball players (age: 23.4 ± 3.1 years; height: 177.2 ± 6.3 cm; body mass: 69.5 ± 7.1 kg) competing in the Icelandic top division volunteered for this study. All participants were injury-free for at least six months prior to testing and engaged in regular basketball and strength training as part of their team programs. Written informed consent was obtained from all participants. The study protocol was approved by the institutional ethics committee and conducted in accordance with the Declaration of Helsinki.

Measurements and Procedures

Countermovement Jump (CMJ)

CMJ performance was assessed using a force platform (VALD Performance, Brisbane, Australia), using protocol of Johnson et al (2025) sampling at 500 Hz. Participants performed three maximal CMJs with hands on hips to minimize arm swing influence, separated by 10 seconds of rest. The following variables were extracted: jump height (Impulse-Momentum method, cm), concentric mean force ($N \cdot kg^{-1}$), concentric mean velocity ($m \cdot s^{-1}$), eccentric mean force ($N \cdot kg^{-1}$), eccentric peak velocity ($m \cdot s^{-1}$), reactive strength index modified ($m \cdot s^{-1}$), vertical velocity at takeoff ($m \cdot s^{-1}$), peak net takeoff force ($N \cdot kg^{-1}$), lower-limb stiffness ($N \cdot m^{-1}$), braking and concentric phase durations (ms). The average value of three attempts was taken into further analysis.

Eccentric Hamstring Strength

Eccentric hamstring strength was assessed using the Nordic Hamstring Exercise (NHE) with a validated testing device (VALD Performance, Brisbane, Australia). The NordBord system (VALD Performance) was used to assess eccentric hamstring strength, as previous studies have reported high reliability (ICC > 0.85) and moderate-to-strong concurrent validity compared with other hamstring strength assessment techniques, supporting its use in applied and research settings (Claudino et at. 2021). Participants completed three maximal repetitions of the NHE at a controlled tempo, and the average value was used for analysis. The following variables were included in the analysis: maximal torque (Nm) in the Nordic Hamstring exercise, average force (N) during the eccentric phase, maximal Impulse (Ns) generated throughout the movement.

Agility Test

Agility performance was assessed using a Y-agility test (Callaghan, 2014) implemented with the SmartSpeed System (VALD Performance, Brisbane, Australia). After an initial 5 m acceleration, athletes responded to a randomly illuminated cue, directing them to change direction to the left or right. The SmartSpeed timing gates recorded both the total completion time, the 0–5 m and the 5-10 m split times. Participants completed two trials, and the best performance was used for analysis.

Statistical analyses

Descriptive statistics (mean ± SD) were calculated for all variables. Linear regression model was constructed with total agility time. Assumptions of normality, linearity, and multicollinearity were checked. Regression coefficients (Estimate), standard errors (SE), 95% CI, t-values, p-values, along with model fit indices (R^2 and adjusted R^2). Effect sizes: Standardized regression coefficients (β) are reported for each predictor. The overall regression effect size was Cohen's f^2 = 10.63, calculated from R^2 = 0.914 $f^2 = R^2/(1 - R^2)$, indicating a large effect (0.02 small, 0.15 medium, 0.35 large). Statistical significance was set at $p < 0.05$. All analyses were conducted using Jamovi (Version 2.3.28) and verified in R for robustness.

Results

Table 1 shows the descriptive statistics for all variables. Normality of data distribution was assessed using the Shapiro–Wilk test. The residuals of the linear regression model were normally distributed (Shapiro–Wilk W = 0.964, p = 0.583). No significant deviations from normality were observed.

Table 1. Descriptive data for all variables collected

Variables	Mean	SD
Body Height [cm]	175.5	7.9
Body Weight [KG]	72.4	9.0
Jump Height (Imp-Mom) [cm]	27.4	5.8
Concentric Mean Force / BW [N/kg]	18.4	1.4
Concentric Mean Velocity [m/s]	1.3	0.1
Eccentric Mean Force / BW [N/kg]	9.9	0.5
RSI-modified [m/s]	0.3	0.0
Vertical Velocity at Takeoff [m/s]	2.3	0.2
Eccentric Peak Velocity [m/s]	-0.9	0.3
CMJ Stiffness [N/m]	7254.7	3776.9
Concentric Mean Power / BM [W/kg]	23.5	3.1
Lower-Limb Stiffness [N/m]	5087.3	2448.5
Peak Takeoff Acceleration [m/s^2]	13.0	2.1
Force at Zero Velocity / BM [N/kg]	20.9	3.2
Braking Phase Duration [ms]	301.2	104.5
Braking Phase Duration:Concentric Duration [%]	111.9	30.1
Concentric Impulse-100ms [N s]	80.3	23.4

Variables	Mean	SD
Maximal Torque (Nm)	126.2	27.7
Average Force (N)	263.5	50.0
Nordic Curle Max Impulse (Ns)	3750.5	1727.3

A linear regression analysis was performed to examine whether anthropometric characteristics, countermovement jump (CMJ) force–plate variables, and eccentric hamstring strength could predict Y-agility test performance in elite female basketball players. The overall regression model demonstrated a very strong fit, accounting for approximately 96% of the variance in agility performance (R = 0.979, $R^2 = 0.959$).

However, none of the individual predictors significantly contributed to explaining variability in agility performance (all $p > 0.20$). Key relevant variables such as jump height (Estimate = –1.280, SE = 0.509, p = 0.24), eccentric mean force per body weight (Estimate = –1.107, SE = 0.522, p = 0.28), reactive strength index modified (Estimate = 10.150, SE = 6.554, p = 0.36), and eccentric peak velocity (Estimate = –0.430, SE = 2.050, p = 0.86) did not show statistically significant relationships with Y-agility test results. A complete summary of model coefficients and 95% confidence intervals is presented in Table 2.

Table 2. Model Coefficients for Y test total.

			95% Confidence Interval			
Predictor	Estimate	SE	Lower	Upper	t	p
Intercept	13.615	30.59	-375.07	402.303	0.44	0.73
Body Height [cm]	0.024	0.031	-0.372	0.42	0.77	0.58
Body Weight [KG]	-0.082	0.072	-1.004	0.838	-1.14	0.45
Jump Height (Imp-Mom) [cm]	-1.28	0.509	-7.752	5.19	-2.51	0.24
Concentric Mean Force / BW [N/kg]	-1.442	1.759	-23.798	20.914	-0.82	0.56
Concentric Mean Velocity [m/s]	-7.38	13.956	-184.714	169.953	-0.52	0.69
Eccentric Mean Force / BW [N/kg]	-1.107	0.522	-7.745	5.53	-2.11	0.28
RSI-modified [m/s]	10.15	6.554	-73.133	93.435	1.54	0.36
Vertical Velocity at Takeoff [m/s]	22.709	8.934	-90.815	136.23	2.54	0.23
Eccentric Peak Velocity [m/s]	-0.43	2.05	-26.478	25.617	-0.21	0.86
CMJ Stiffness [N/m]	0.000174	0.000468	-0.005	0.006	0.37	0.77
Concentric Mean Power / BM [W/kg]	0.996	1.268	-15.121	17.113	0.78	0.57
Lower-Limb Stiffness [N/m]	-0.000679	0.000782	-0.01	0.009	-0.86	0.54
Peak Takeoff Acceleration [m/s^2]	0.023	0.116	-1.45	1.498	0.2	0.87
Force at Zero Velocity / BM [N/kg]	-0.49	0.367	-5.159	4.178	-1.33	0.4
Braking Phase Duration [ms]	0.005	0.009	-0.115	0.126	0.59	0.65
Braking Phase Duration:Concentric Duration [%]	-0.026	0.033	-0.454	0.4	-0.8	0.57
Concentric Impulse-100ms [N s]	0.089	0.063	-0.723	0.901	1.39	0.39
Maximal Torque (Nm)	-0.01	0.012	-0.166	0.146	-0.81	0.56
Average Force / BW (N/kg)	0.399	0.515	-6.152	6.952	0.77	0.58
Maximal Impulse (Ns)	0.000024	0.000087	-0.001	0.001	0.27	0.82

Despite high R^2 indicating strong collective model fit, the lack of significant predictors suggests that the model's explanatory power is not driven by the individual CMJ or hamstring strength variables. This may reflect multicollinearity issues or insufficient statistical power due to sample size. These results indicate that agility, at least as measured by the Y-test in this cohort, cannot be explained by the selected CMJ-derived or eccentric hamstring variables.

Stiffness variables were interpreted according to the mechanical demands of the assessed tasks. CMJ stiffness represents a task-specific force–displacement characteristic derived from the countermovement jump and is strongly influenced by individual movement strategies, countermovement depth, and eccentric braking behavior, making it particularly relevant for agility and jump performance. Lower-limb stiffness reflects a more global spring-mass property of the lower extremities and is more closely related to sprint performance, where elastic energy reutilization and efficient force transmission are critical. The relatively large standard deviations observed for both stiffness variables reflect their sensitivity to inter-individual differences in anthropometrics, neuromuscular coordination, and movement strategy, as well as the fact that they are derived variables rather than direct performance measures.

Discussion

The primary objective of this study was to examine the extent to which agility performance can be predicted from anthropometric characteristics, CMJ force–plate variables, and eccentric hamstring strength among elite female basketball players. We hypothesised that eccentric strength of the knee flexors and braking-related metrics would be stronger predictors of short-distance agility performance than traditional vertical jump height measures. However, the findings revealed that none of the investigated variables predicted agility performance, despite an apparently strong model fit. This supports the notion that agility represents a distinct and independent physical quality—not reducible to vertical jump performance or isolated hamstring strength metrics.

Agility in sport comprises not only biomechanical but also cognitive components, including decision-making, visual scanning, anticipation, and pattern recognition (Horníková & Zemková, 2022). During braking and cutting tasks, the hamstrings act predominantly eccentrically to control hip flexion and knee extension, absorbing and dissipating momentum to stabilize the limb during the deceleration phase. Withrow et al. (2008) found that this eccentric action reduces anterior tibial translation and load on the ACL while improving mechanical efficiency during transitions from braking to propulsion. Strong eccentric hamstring capacity therefore enables athletes to achieve shorter ground contact times and better control of deceleration–acceleration transitions—both crucial in Y-test style agility tasks. Studies by Smajla et al. (2022) and Bright et al. (2023) reported positive associations between Nordic hamstring strength and COD or reactive-agility outcomes and demonstrated that eccentric-focused training can improve COD performance.

Taken together, these findings emphasize that eccentric hamstring strength is fundamental for high-level agility because it: (1) controls deceleration mechanics, (2) reduces knee loading and anterior cruciate ligament (ACL) injury risk—especially critical for female athletes who exhibit higher ACL injury rates, and (3) enables faster, more efficient direction changes. A recent editorial by Bright at al. (2023) highlighted that examining eccentric hamstring performance (e.g., Nordic test metrics) in relation to Y-test agility outcomes can clarify how lower-limb neuromuscular control transfers to practical agility performance—particularly relevant in elite female basketball, where deficits in eccentric control significantly influence performance and injury risk (Barrera-Domínguez et al., 2024).

The present findings are particularly relevant for female basketball players, whose performance demands include frequent defensive shuffles, sharp directional changes, and rapid reactive movements to opponents' actions. Consistent with previous literature, only weak-to-moderate correlations have been reported between vertical jump metrics and agility outcomes in female athletes (Spiteri et al., 2020). This suggests that while CMJ testing is informative for assessing lower-body power, it cannot serve as a surrogate marker of agility. Agility training should therefore be treated as an independent component of conditioning programs, with specific emphasis on reactive drills, perceptual–cognitive challenges, and court-specific movement patterns.

The contradiction between the high R^2 value and the lack of significant predictors requires methodological reflection. Factors such as small sample size and multicollinearity among CMJ variables may have inflated the model's fit without yielding meaningful or generalizable predictor effects. Additionally, the inclusion of a large number of interrelated CMJ variables likely contributed to unstable coefficient estimates. Future research should address these limitations by incorporating larger samples, applying dimensionality reduction techniques (e.g., principal component analysis), and focusing on fewer, theoretically relevant predictors.

The lack of predictive value from CMJ and hamstring strength metrics aligns with current literature emphasising the multifactorial nature of agility. Agility relies on the interplay of physical attributes such as strength and power, neuromuscular coordination, braking efficiency, and perceptual–cognitive factors including decision-making and reaction to external stimuli. Therefore, single-metric approaches (e.g., jump height) are insufficient to capture the full scope of agility performance.

Conclusion

This study demonstrated that CMJ-derived hamstring strength and lower-limb performance metrics do not significantly predict Y-agility test performance in elite female basketball players. Despite the regression model's high R^2 value, none of the examined variables contributed meaningful explanatory power. These findings suggest that agility should be considered an independent physical quality influenced by neuromuscular, biomechanical, and perceptual–cognitive factors rather than vertical jump performance alone.

From a practical standpoint, strength and conditioning coaches should not assume that improvements in CMJ or hamstring strength will automatically lead to enhanced agility. Instead, agility should be trained and assessed directly using sport-specific drills that incorporate decision-making, reactive movements, and rapid braking and reacceleration demands.

This study was limited to elite female basketball players in Iceland, which may restrict generalisability to other populations. Future research should include analysis of separate phases of this specific movement (Y-agility test), integrate biomechanical analysis of COD tasks, and explore nonlinear modelling approaches to capture the multifactorial nature of agility. It is recommended that future investigations consider broader predictive models including horizontal force production, sprint mechanics, and perceptual–cognitive factors, with specific emphasis on female athletes where knowledge gaps are more prominent.

Conflict of interest: There was no conflict of interest associated with this study, and no external funding was received.

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