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Abstract

This study explored the influence of different counter movement jump (CMJ) goals on performance, kinetics, and kinematics between 56 highly-trained and elite track and field (T&F), football, and futsal athletes. Within and between-sport difference were compared when aiming to: (a) "jump as high as possible" (CMJ_h) and (b) "jump as fast as possible" (CMJ_f), using a mixed MANOVA and follow-up univariate mixed ANOVAs. Movement goals had a significant main effect on all variables ($p < .001$). Comparatively, CMJ_f elicited higher mean propulsive power normalized to body mass (MPP_{bm}, $\eta_p^2 = 0.794$) and reactive strength index modified (RSI_{MOD}, $\eta_p^2 = 0.755$), alongside lower jump height ($\eta_p^2 = 0.782$), contraction time (ConT, $\eta_p^2 = 0.857$), propulsive displacement ($\eta_p^2 = 0.751$), and countermovement velocity ($CM_{velocity}$, $\eta_p^2 = 0.600$). Sport interaction analyses revealed that T&F athletes consistently outperformed the other sports in RSI_{MOD} across both movement goals ($d = 1.105-1.598$). MPP_{bm} and ConT differed significantly between T&F and football ($d = 0.947-1.324$) A Movement goal × Sport interaction for $CM_{velocity}$ indicated that T&F and football athletes increased $CM_{velocity}$ under CMJ_h ($d = 1.242-1.635$, $p < 0.001$) compared to CMJ_f, whereas futsal players maintained similar downward motion across goals ($p = 0.938$). In conclusion, movement goals significantly modify CMJ performance variables in such athletes, and these effects are further influenced by sport specialization. Clear and goal-specific verbal instructions should be standardized in CMJ testing to ensure reliable athlete monitoring and performance evaluation.

Introduction

In the strength and conditioning (S&C) domain, jump tests are commonly used to evaluate neuromuscular capacity, monitor training-induced adaptations, and to assess readiness and recovery in athletes returning to sport post-injury[1,2]. Among these, the squat jump (SJ) and countermovement jump (CMJ) are popular amongst support practitioners for assessing lower-limb explosive strength, mechanical power, and readiness[3,4], and can indicate specific training progress[5]. In particular, each CMJ phase reflects distinct neuromechanical characteristics and, when analyzed through the force–time curve, informs about athletes' force production and control[6], and offers diagnostic insight into Muscle–Tendon Unit contraction dynamics beyond what is observable in squat and drop jumps[7]. Furthermore, various devices and technologies (e.g., force plates, inertial sensors, and motion capture) can monitor key parameters, offering flexibility depending on the context and available resources[8,9]. Therefore, S&C practitioners seemingly have a potential means to objectively inform their decision making when making recommendations.

CMJ typically results in greater power output and jump height[10] (JH) compared to the SJ. Early explanations attributed this advantage to a pre-stretch phase that optimizes elastic energy reuse, shortens eccentric–concentric coupling time, and enables more efficient force transfer through elastic elements, thereby enhancing mechanical efficiency and reducing energy cost [11,12]. More recent neuromechanical approaches emphasize reduced muscle slack and greater pre-activation of motor units[13], while possible neural contributions at spinal and corticospinal levels during stretch–shortening cycle actions remain debated[14]. Overall, these combined mechanisms help explain the greater improvements in rate of force development (RFD) observed in CMJ compared to SJ[15].

Notably, during applied CMJ assessments, practitioners can provide instructions that are informed by interpretive frameworks to enhance the athletes' neuromuscular performance. In doing so, this process recognizes the contribution of both central psychological and peripheral neuromuscular explanations underpinning execution; specifically, by guiding athletes towards a desired movement *goal*, this may enhance their focus towards key action intentions that facilitates

centralized predictive coding (i.e., simulation of what movements are required and how they may be subjectively experienced) prospectively, as explained by the active inference framework [16–18]. Crucially, research in motor learning and control shows that applied and fundamental factors such as instructional familiarity, personal and/or task relevance, and requested simulation modality (e.g., visual, kinesthetic, auditory) interact with an athlete's previous experiences, subjective beliefs, and memory system, to influence the precision and ease by which movement can be predicted and adapted to achieve different goals[19]. Therefore, in order to ensure both an accurate and meaningful application of augmented verbal instructions and, subsequently inform the movement execution, it is important in research and practice to consider the specific task goals provided based on such factors.

Indeed, the importance of specified movement goals for S&C is highlighted by previous research. Talpey et al.[20] observed in recreationally active men (i.e., Tier 1[21]), that different CMJ goals influenced performance outcomes: "maximize height" resulted in significantly greater JH and deeper countermovement depths, whereas "explosive leg extension" produced higher peak force. However, despite these goals relating to distinct motor intentions and mechanical differences, peak power output remained similar. Likewise, Pérez-Castilla et al.[22] further explored CMJ performance under two velocity goals (self-selected vs. fast) and three CM depths (larger, shorter, and self-preferred) in students (Tier 1[21]). They found that performing at a faster velocity enhanced mean force, power, and the reactive strength index (RSI), while having minimal effects on peak power, peak velocity, and JH. Additionally, a reduced CM depth improved force- and power-related outputs but with lower JH. Finally, Sánchez-Sixto et al.[23] investigated the effects of verbal instructions on local-level amateur basketball players (i.e., Tier 2[21]). When instructed "jump as high and as fast as possible", athletes improved across kinetic variables, including the RSI-Modified (RSI_{MOD}) when compared to a height-oriented jump goal alone, while JH remained consistent across conditions. Therefore, evidence shows that particular care is necessary during training and assessment to achieve a desired performance adaptation that could be based on interpretive factors.

Despite the insights provided by existing literature on the influence of movement goals on jump performance, these effects have not been thoroughly investigated in highly trained and elite (i.e., Tier 3–4[21]) athletes, or across sporting domains where the level of movement relevance and/or familiarity might differ. Therefore, this study aimed to explore the influence of different movement goals on CMJ performance between highly trained and elite track and field (T&F), football, and futsal athletes. Accordingly, we explored within and between CMJ kinematic and kinetic responses when performed using two movement goals for different sports. Across these sports, CMJ is known to be a core exercise of athletes regular practice and performance (i.e., T&F) or less commonly used in practice, despite athletes demonstrating high proficiency in the movement (i.e., football and futsal). We hypothesized that CMJ_f would produce higher RSI and MPP_{bm} but lower JH and contraction time (ConT) compared to CMJ_h, with sport-specific variations due to differing movement familiarity according to playing demands.

Methods

Sample Size Estimation and Justification

An *a priori* power analysis was conducted using G*Power (version 3.1.9.7, Universität Düsseldorf, Germany) to determine the minimum required sample size for a repeated-measures multivariate analysis of variance (RM-MANOVA) with three groups and two measurements (within-between subjects' factor). The analysis was based on an effect size of $f = 0.4$ (derived from previously reported instruction-related effects on variables relevant to the present study; e.g., RSI, [23]), an alpha level of 0.05, and a desired power of 0.80. The assumed correlation among repeated measures was set at 0.5, and the sphericity correction (ε) at 1.0. Under these assumptions, the analysis indicated that a total sample size of 64 participants would be sufficient. However, due to the use of a convenience sample of highly trained and elite athletes, the final sample comprised 56 participants, whose availability for controlled testing was limited. Moreover, further increases in sample size were

practically impossible, as data were collected from the entire available national team roster for certain groups. Thus, the achievable sample size was constrained both by resource limitations (athletes' availability) and by the finite size of the target populations. For these reasons, and despite being slightly below the *a priori* estimate, the final sample was considered acceptable given the ecological validity and specificity of the studied population [24].

Participants

Following the key scoring criteria for classifying Sport and Exercise Science Research[25], 56 athletes (49 males, seven female) competing at national and international levels (Tier 3–4) participated. Athletes were recruited across different continents (Europe and North America) and included 19 football players (M_{age}: 20.4 ± 1.3 years; M_{height}: 177.2 ± 5.9 cm; $M_{body\ mass}$: 71.7 ± 5.7 kg; years of participation: > 10 years; Tier: 3–4), 18 futsal players (M_{age}: 18.5 ± 1.1 years; M_{height}:176.4 ± 4.4 cm; $M_{body\ mass}$: 70.1 ± 4.2 kg; years of participation: > 10 years; Tier: 4), and 19 T&F athletes (10 jumpers and 9 sprinters; M_{age}: 20.1 ± 1.2 years; M_{height}: 178.8 ± 5.2 cm; $M_{body\ mass}$: 72.3 ± 4.8 kg; years of participation: > 10 years; Tier: 3). Athletes trained six days per week plus competition commitments (for T&F, depending on the period of the year). T&F athletes included a mixed-sex group; however, they were classified as having a highly advanced training status based on the maximum score of 4 points for each of the five conditions, following the criteria proposed by Santos Jr et al. (see Supplementary Material, Table S1, [26]). Moreover kinetic variables were normalized to body mass to reflect similar relative strength, which is essential when comparing force production capabilities between women and men[27]. All athletes were experienced with the CMJ as either exercise or testing protocols. Exclusion criteria included any lower-limb injury or surgery within 6 months, as well as the absence of participation in a strength training program. The study was approved by the Institutional Review Board of Psychology (IRBP) within the Department of Psychology at the University "G. d'Annunzio" of Chieti-Pescara (ref: 23002), and all procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki. Prior to their

involvement, all participants received detailed procedural information and provided signed informed consent.

Study Design

A mixed effects repeated-measures design was employed to explore the influence of two movement goals on performance, kinematic, and kinetic variables during the CMJ across different sports. The study was conducted over 2 days preceding the normal training session. On Day 1, athletes attended a task orientation briefing where they were explained the task, technological considerations, and technique required and were assessed to confirm adherence to these stipulations without recording data, while Day 2 was dedicated to the experimental trials. Measurements were conducted in the afternoon between 2–6 pm during the regular season, with at least 72 hrs of recovery after the competitions or strength training sessions, on a rigid, non-sprung gym floor.

The movement goals provided were standardized to ensure consistency across participants. Before each CMJ, the following verbal instructions were given: (a) "Jump as high as possible" (CMJ_h), (b) "Jump as fast as possible" (CMJ_f). Moreover, participants were instructed to perform the CMJ with a rapid eccentric descent phase[22] without relying on any extrinsic motivator (e.g., jumping toward a target[28]). The experimental protocol was administered in a randomized and counterbalanced order across the two different movement goal conditions. Specifically, the S&C coach randomly assigned the assessment order of the participants, while the tester counterbalanced the sequence of movement goal conditions across participants. To avoid potential data selection bias and to ensure a reproducible approach [29], the average across trials for each participant in each condition was analyzed for each condition.

Task

After completing the individual warm-up protocol [30,31] under the supervision of an S&C coach (see Supplementary Materials, Table S1), participants completed three trials for each condition as a specific warm-up. Subsequently, they performed three CMJ under each condition (six in total), with 90 s of rest between attempts, within a 1×1-m area, without time constraint.

Participants were allowed to choose their own stance width and were encouraged to be consistent. The depth of the CMJ was self-selected by each participant, while the use of the upper limbs was restricted by keeping their hands on their hips throughout the movement, as arm swing could act as a confounding factor influencing movement execution[32]. Trials exhibiting a pre-drop step during the unweighted phase were excluded and repeated, because they were considered technically invalid. Lastly, participants were instructed to land with knee flexion and controlled impact energy absorption to prevent any limitation of movement effort during the propulsive phase[33].

Jump Assessment

CMJ performance was assessed using a custom system based on the Bosch BNO055 Attitude and Heading Reference System (AHRS; Bosch Sensortec GmbH, Reutlingen, Germany), a wireless Bluetooth inertial measurement unit (IMU) that integrates a tri-axial accelerometer, gyroscope, and magnetometer, sampling at 100 Hz (see Supplementary Materials). The sensor was validated by Wang et al.[34] for estimating vertical JH, showing a high correlation (ICC(2,1) = 0.98; r = 0.99) with the gold-standard motion capture system. Additionally, sampling at 100 Hz has been shown to be sufficient for accurately estimating vertical JH[35].

The IMU was positioned at the estimated center of mass (approximately at the L5 vertebral region[36]) and secured tightly around the waist using an adjustable belt to minimize movement artifacts. Prior to and following each jump, participants remained in a quiet standing position for 5 s to enable the system to accurately detect the steady-state onset and offset of the movement (including

the landing phase). This ensured a correct estimate of the JH using a double integration of the gravity-compensated acceleration (see Supplementary Materials).

Data Processing

Raw acceleration signal was compensated for the effects of gravity and corrected for errors due to changes in sensor orientation, applying a quaternion-based transformation to obtain absolute vertical acceleration (AZ) in an Earth-fixed reference frame. The latter represents a strength point of this IMU, in that the resulting acceleration is evaluated considering the inclination of the cranio-caudal axis of the body, allowing to extract repeatable jump metrics. Thanks to the onboard sensor fusion, a particular algorithm that estimates unknown variables from a series of measurements over time was then applied as a filter to smooth noise while preserving key dynamic features (see Supplementary Materials – Jump Assessment for details about the quaternion-based transformations and the applied filter). Vertical displacement of the center of mass was estimated by double integration of the filtered acceleration, with drift corrections applied using the steady-state reference segments. Only trials in which vertical velocity at the point of maximum height returned close to zero ($\pm$ 0.1 $m \cdot s^{-1}$) were retained, ensuring physical plausibility and minimizing integration errors.

Each jump was detected through normalized cross-correlation between the vertical acceleration signal and a set of predefined CMJ template profiles. This automated procedure allowed for the identification of the jump center and subsequent segmentation of the movement into eccentric and concentric phases, based on the direction and magnitude of velocity. Specific temporal landmarks, such as the start and end of the eccentric and concentric phases, take-off, landing, and the point of maximum height, were extracted from the velocity and acceleration traces.

The analysis included performance, concentric, and jump strategy variables[37], specifically: JH was computed by integrating vertical velocity from the beginning of the concentric phase to the point of zero vertical velocity at peak height. Propulsive displacement (PD) was calculated as the

vertical distance travelled during the propulsive phase[33], defined from the end of the braking phase to end of propulsive phase (peak velocity). Countermovement velocity ($CM_{velocity}$) was derived as the peak downward velocity during the yielding phase[38], and ConT was determined as the time interval between the start of braking phase to the end net propulsive phase[33]. The RSI_{MOD} was obtained as the JH:ConT ratio. Finally, mean propulsive power normalized to body mass (MPP_{bm}) was calculated over the propulsive phase[33] based on acceleration and estimated displacement. All data acquisition and post-processing procedures were implemented using a custom algorithm developed in C++ (Microsoft Visual Studio, version 2022, USA). This software ensured efficient real-time signal computation and consistent identification of the six kinematic and kinetic variables across all trials.

Statistical Analysis

Prior to inferential analyses, data were screened for distribution characteristics. No outliers exceeding three standard deviations from the mean were detected, resulting in a final sample of 56 athletes. To evaluate MANOVA assumptions, univariate normality was assessed using the Shapiro–Wilk test within each Sport × Movement goal subgroup. Most variables did not significantly deviate from normality, although two showed mild departures ($p < 0.05$). Homogeneity of covariance matrices was examined using Box's M test, and univariate homogeneity of variances was evaluated using Levene's tests. As Box's M was significant and some dependent variables exhibited variance heterogeneity, multivariate effects were interpreted using Pillai's Trace, a statistic widely recommended for its robustness under violations of normality and heteroscedasticity[39].

To assess the intrasession reliability of each variable, we calculated the intraclass correlation coefficient (ICC) using a two-way mixed-effects model for consistency, and multiple raters/measurements [ICC(3,k)][40]. ICC values were reported together with their 95% confidence intervals and complemented by the coefficient of variation (CV%) and typical error (TE). Reliability

was interpreted as follows: values <0.50 = poor, 0.50–0.75 = moderate, 0.75–0.90 = good, and >0.90 = excellent reliability[40].

A mixed MANOVA was performed to examine the effects of the movement goals (CMJ$_h$ vs. CMJ$_f$; within-subjects factor) and sport (football, futsal, T&F; between-subjects factor) on the six dependent variables. When significant multivariate effects were detected, follow-up univariate ANOVAs were conducted for each dependent variable to examine within and between factors differences. In cases of significant interaction or main effects[41], Bonferroni-corrected pairwise comparisons were conducted as post hoc tests.

Effect sizes (ES) were calculated using partial eta squared (η_p^2) for mixed MANOVA and mixed ANOVA results, and Cohen's d for post hoc comparisons. Partial eta square values were interpreted according to established thresholds, with 0.02, 0.13, and 0.26 representing small, medium, and large effects, respectively[42]. Cohen's d values were classified as small ($d = 0.2$), medium ($d = 0.5$), and large ($d \geq 0.8$)[43]. Corresponding confidence intervals for η_p^2 were computed using the *eta_squared* function from the effectsize R package. Because $\eta^2_p = $ SSeffect/ (SSeffect + SSerror) is bounded between 0 and 1, confidence intervals extending beyond this theoretical range were truncated at these limits[44]. For η^2_p, the package computes lower bound (one-sided) confidence intervals; the upper bound is fixed at the theoretical maximum of 1. Accordingly, the reported intervals should be interpreted as indicating the minimum effect size compatible with the data at the 95% confidence level.

All descriptive statistics are reported as means ± standard deviations. Analyses were performed using RStudio (Posit Team, 2022), the packages car, ggplot2 and afex.

Results

ICCs results are presented in Table 1.

--Insert Table 1--

Descriptive statistics for each variable across movement goals are presented in Table 2.

---Insert Table 2---

ICC results showed good to excellent intrasession reliability ($ICC_{3,k}$ = 0.80–0.96) with CV% ranging from 3.5 to 10.5% in line with previous CMJ reliability studies[45,46].

The mixed MANOVA revealed significant main and interaction effects. Specifically, the main effect of movement goal was statistically significant (Pillai's Trace = 0.727, Approximate $F(6,101)$ = 44.791, $p < 0.001$), indicating that movement goal had an impact on the combined dependent variables. A significant main effect of sport was also observed (Pillai's Trace = 0.688, Approximate $F(12,204)$ = 8.912, $p < 0.001$), suggesting that the type of sport significantly influenced the dependent variables. Furthermore, the movement goal × sport interaction effect was statistically significant (Pillai's Trace = 0.316, Approximate $F(12,204)$ = 3.194, $p < 0.001$), indicating that the effect of movement goal on the dependent variables differed across sports.

The mixed ANOVA results are summarized in Tables 3 and 4 and Figures 1–6.

---Insert Table 3-4---

The main effect of the mixed ANOVA within movement goals (Table 3) was significant across all dependent variables ($p < 0.001$), with large effect sizes (η_p^2 = 0.600–0.857). These findings suggest that the type of movement goal had a significant impact on all CMJ variables examined.

The main effect of the mixed ANOVA between Sports (Table 4) was significant for RSI_{MOD}, MPP_{bm}, ConT, PD, and $CM_{velocity}$ ($p < 0.001$, η_p^2 = 0.128–374), but not for JH ($p > 0.05$) variable.

Post hoc analyses between Sports and Movement goals (see Supplementary Materials, Tables S3–S6) revealed that RSI_{MOD} was significantly higher for T&F compared to football (CMJ_f: $p = 0.005$, $d = 1.309$; CMJ_h: $p = 0.011$, $d = 1.105$) and futsal (CMJ_f: $p = 0.006$, $d = 1.306$; CMJ_h: $p < 0.001$, $d = 1.598$). No significant differences were found between futsal and football (CMJ_f: $p = 1.000$, $d = 0.003$; CMJ_h: $p = 1.000$, $d = -0.494$). MPP_{bm} was significantly higher in T&F compared to football (CMJ_f: $p = 0.027$, $d = 0.965$; CMJ_h: $p = 0.006$, $d = 1.324$) but not compared to futsal (CMJ_f: $p = 1.000$, $d = 0.498$; CMJ_h: $p = 0.093$, $d = 1.017$). No significant differences were found between futsal and football (CMJ_f: $p = 1.000$, $d = 0.468$; CMJ_h: $p = 1.000$, $d = 0.307$). ConT was significantly lower in T&F compared to football (CMJ_f: $p = 0.009$, $d = -0.947$; CMJ_h: $p = 0.022$, $d = -1.266$) and futsal, for the CMJ_h condition only (CMJ_f: $p = 0.304$, $d = -0.632$; CMJ_h: $p = 0.001$, $d = -1.627$). No significant differences were found between futsal and football (CMJ_f: $p = 1.000$, $d = -0.315$; CMJ_h: $p = 1.000$, $d = 0.361$). Finally, no significant differences in PD were found across sports.

In follow-up univariate mixed ANOVA, a significant Movement goal × Sport interaction emerged in the model only for the $CM_{velocity}$ ($F_{(2,53)} = 8.470$, $p = < 0.001$, $\eta_p^2 = 0.242$), indicating that the effects of movement goals were inconsistent across sports. Post hoc analysis (see Appendix, Table S8) revealed that futsal players exhibited significantly slower downward motion compared to T&F athletes ($p = 0.005$, $d = 1.112$) and football players ($p < 0.001$, $d = 1.258$), under the CMJ_h goal. No significant differences across sports were observed under the CMJ_f goal ($p = 1.000$). Additionally, futsal players showed no difference between the CMJ_h and CMJ_f goals ($p = 0.938$).

--Insert Figures 1–6--

Discussion

The present study explored the effects of two movement goals (CMJ_h and CMJ_f) and sport type (football, futsal, and T&F) on performance, kinetic, and kinematic variables[37] during CMJ. Results suggest that most variables differed across movement goals and sport types, which appear to be associated with variations in athletes' strategies during the CMJ. Specifically, when instructed to

perform the CMJ_f, athletes exhibited greater MPP_{bm} and RSI_{MOD}, along with lower JH, ConT, $CM_{velocity}$, and PD, compared to the CMJ_h goal. Differences between sports were observed for RSI_{MOD}, MPP_{bm}, ConT, PD, and $CM_{velocity}$ variables. Therefore, data extend previous studies showing a significant effect by examination of sport type and athlete level[20,23].

Despite significant differences across six variables, the PD changes might be hypothesized to underpin observed kinetic findings: the greater PD observed in CMJ_h across all sports suggests a universal strategy aimed at maximizing JH, which may be associated with achieving higher take-off velocity under an explicit height-oriented movement goal. Conversely, the reduced PD in CMJ_f may indicate that minimizing depth facilitates faster execution, likely explaining the associated increase in MPP_{bm} and reduction in ConT. As described by Gajewski et al.[47], increasing displacement tends to reduce power output. In the eccentric (lowering) phase, greater displacement may alter joint angles, ranges of movement, and muscle lengths, which could affect the muscle pre-stretch, muscle slack, the velocity, and acceleration during the propulsive phase. Thus, the current study suggests an interdisciplinary account of CMJ performance based on psychological and mechanical mechanisms.

Reflecting our unique study design characteristics, data advance previous studies examining a similar task. For instance, Sánchez-Sixto et al.[23] reported no significant differences in JH or propulsive power between height and fast–plus–height movement goals, whereas our results suggested significant differences in both variables. One possible explanation lies in that our study isolated height and fast execution movement goals, which may have allowed athletes to adopt clearer and simpler psycho-mechanical strategies. Additionally, our participants consisted of Tier 3–4 athletes[21], while Sánchez-Sixto et al.'s[23] participants were lower level Tier 2 basketball players with different neuromuscular capabilities for rapid force application and efficient jump mechanics. Lastly, their analysis selected the best trial for each condition based on the greatest jump height, whereas we analyzed the average of three trials. This indicates that, in their study, fast–plus–height movement goal attempts that did not result in high take-off velocities may have been excluded from the analysis. Despite these differences, both studies consistently showed increased RSI_{MOD} values

under instructions emphasizing fast execution, reinforcing the importance of movement goals in eliciting rapid force production regardless of participation level.

Similarly, our results differ from Handford et al.[48], who examined CMJ performance in resistance-trained (non-athlete) participants, using a combined instruction ("jump as high and as fast as possible") and compared two eccentric descent conditions. Because the movement goal was not separated, both tasks were performed under the same overarching movement goal and, critically, the participants may not have possessed the neuromechanical capacities needed to benefit from a faster countermovement, such as effective pre-stretch, reduced muscle slack, or pre-activation. This may have contributed to the absence of differences in JH. In contrast, by isolating height- and speed-focused goals in elite athletes, our study appeared to reveal clear variations in movement strategies and mechanical outputs

Sport main effect results showed that T&F athletes displayed superior RSI_{MOD}, a greater ability to generate momentum with shorter ConT, and overall higher performance values than football and futsal players across both movement goals. These findings may reflect a more efficient neuromuscular profile of T&F athletes, particularly in their ability to rapidly generate force during the CMJ task[49]. This advantage may be attributed to their regular exposure to training stimuli emphasizing high vertical impulse and CMJ performance. Additionally, T&F athletes outperformed football players in both MPP_{bm} and ConT across movement goals, whereas differences with futsal players were observed only for ConT under $CMJ_{h,}$ with no significant differences in MPP_{bm} or ConT in the CMJ_f condition. These patterns suggest that futsal, due to its inherently explosive nature (e.g., short sprints, accelerations, and decelerations in tight spaces [50,51]), may foster sport-specific neuromuscular adaptations that enhance lower-limb power, similar to T&F athletes. In contrast, the comparatively lower values observed in football players should not be interpreted as indicative of a general neuromuscular disadvantage. Rather, they may reflect the specific motor demands and training emphases typical of football, which involves a wider variety of movement patterns, many of

which are multi-directional, submaximal, or prolonged, and include longer recovery phases with lower neuromuscular intensity. However, these aspects have not been investigated empirically.

Regarding the Movement goal × Sport interaction, a significant effect was observed only for $CM_{velocity}$: football and T&F athletes showed faster downward motion $CM_{velocity}$ in the CMJ_h condition, whereases futsal players displayed similar $CM_{velocity}$ across both goals. A possible explanation is that futsal players, during the games and training, are not typically required to perform CMJ to maximize height and therefore may lack the specific neuromuscular expertise to increase downward motion for this purpose. Suggestively, therefore, the ability of an athlete to modify their movement, even within a non-competitive environment, needs to consider the nature of motor experience against specific sporting demands. To help explain potential psychological underpinnings, the active inference motor control perspective[16] suggests that intention—the conscious goal an athlete holds towards the movement—plays a critical role in generating an internal predictive model of the movement's perceptual effects in order to guide the motor execution and influence its outcome. Intention is regarded as a central organizing principle that directly influences how movements are structured and adapted based on on-going internal and external feedback[52]. Even when the movement class remains unchanged, different task intentions can lead to markedly different movement strategies[53,54]. For instance, during the CMJ, an athlete focusing on maximum JH may model their movements differently than if they do for a fast execution. Thus, the same movement class, when performed with different goals, can yield distinct movement patterns and outcomes, as indicated in our findings. Importantly, from this perspective, the athlete's psycho-motor ability, meaning the psychological capacity to regulate and adjust their movements based on intentional goals, is a fundamental skill that can be developed. Training this ability may enable athletes to manage their movement as a conscious process, rather than relying solely on automatic responses to instructions, and could be further facilitated by S&C coaches with augmented verbal instructions and visual modelling[55]. This reflects the growing need for interdisciplinary consideration within

applied settings that includes understanding how task goals serve to inform movement execution[56] and that should also inform future empirical testing.

Practical Implications

When monitoring athletes through CMJ assessments, providing appropriate goal-oriented information appears important to guiding mechanical output. Height-focused goals are typically associated with greater JH and longer ConT, whereas fast-oriented goals tend to reduce ConT and increase MPP_{bm} and RSI_{MOD}. These findings suggest the importance of tailoring movement goals to align with specific performance goals and athletes' sport-specific demands. Consistency in testing protocols is also essential when tracking longitudinal progress, comparing athletes, or evaluating the effectiveness of training interventions. Standardized instructions help reduce confounding sources of measurement variability and support the validity of both longitudinal and comparative analyses. Therefore, support practitioners should carefully adapt their instructional strategies, not only for the immediate task goal but also to the athlete's sporting needs, to optimize both the effectiveness of training interventions and the reliability of monitoring processes. We recommend that future research and applied assessments clearly report and adopt the instructions investigated in this study, "jump as high as possible" (CMJ_h) and "jump as fast as possible" (CMJ_f), to ensure consistent replication and comparison across studies and applied settings.

Limitations and Future Directions

Despite offering valuable insights, this study is not without limitations. We did not perform an intersession reliability assessment due to the limited availability of the athletes. Instead, we conducted an intrasession reliability analysis, which yielded good to excellent results ($ICC_{3,k} = 0.80–0.96$). In addition, the sample was slightly below that required by the power analysis for mixed-design ANOVAs, and the inclusion of a mixed-sex group for T&F athletes, limits the generalizability of the

findings to broader sporting contexts, confining their interpretation to the specific population investigated. Moreover, our analysis focused mainly on kinematic variables derived from a 100hz IMU, providing a valuable yet only partial picture of the mechanisms underpinning jump performance and potentially limiting the resolution of short temporal events and kinetic estimations.

To deepen the understanding of the relationship between movement goals and athletic outcomes, future investigations should integrate complementary methods such as electromyography to assess muscle activation patterns, kinematic analyses to examine movement trajectories and joint dynamics, and electroencephalography to explore cortical activity associated with motor control and self-reported foci. Indeed, mixed-methods approaches enable richer, more nuanced views of complexities between brain function, cognitive strategies, neuromuscular control, and motor performance.

Finally, this study captured only a narrow time frame within the broader context of athlete development. Longitudinal research, conducted across an entire season or multiple seasons, may determine how different movement goals change over time, their intended use based on applied problem solving, and whether their associated performance outcomes follow parallel or divergent trajectories. Furthermore, identifying whether one or both goals drive specific changes in CMJ-related performance variables would enable practitioners to tailor training interventions by prioritizing improvements or mitigating declines in the most task-relevant variables for each sport. Addressing these questions could enhance our understanding of how and why movement goals can be strategically employed to optimize athletic performance, both acutely and chronically.

Conclusion

This study was driven by the practical need to determine whether different movement goals influenced key CMJ variables, and whether highly trained and elite athletes from sport specializations responded differently. Findings suggest that all six dependent variables differed across the two

contrasting movement goals, emphasizing the importance of delivering clear, goal-oriented instructions during CMJ assessments. Additionally, athletes from different sports displayed distinct movement behaviors, indicating the necessity of considering sport-specific backgrounds when interpreting results and designing interventions. The present study also suggests that movement intentions are associated with variations in motor execution. Structured manipulation of movement goals, supported by a well-developed movement repertoire (as observed in the futsal players), enabled the realization of specific changes in intention, thereby optimizing training outcomes and potentially enhancing the ecological validity of athlete monitoring practices[57]. From an applied perspective, verbal goal framing significantly influences CMJ kinetic and kinematic performance. Practitioners should deliberately select and consistently report whether CMJ_h or CMJ_f is used, depending on whether the training or testing goal prioritizes jump height or execution speed.

Author contribution

Dario Pompa conceived and designed the study, acquired the data, performed the analyses, and drafted the manuscript. Howie J. Carson contributed to study design, data interpretation, and manuscript writing. Ruggero Romagnoli was responsible for data collection, literature search, and manuscript drafting. Antonio Lucadamo conducted the statistical analyses and contributed to manuscript writing. Francesco Lagala developed the software used for data analysis. Luca Bovolon contributed to statistical analyses, as well as manuscript review and editing. Alessandra Caporale contributed to statistical analyses, as well as manuscript review and editing. Vincenzo Manzi, Francesco Sartor, Marco Beato, and Marika Berchicci contributed to drafting and substantive revision of the manuscript. Maurizio Bertollo provided supervision, project administration, and critical review of the manuscript. All of the authors contributed to the article and approved the submitted version.

Declarations

Disclosure Statement

The authors report no conflict of interest

Data Availability

Data are available from the following open access repository: https://doi.org/10.7488/ds/7984

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Figure Captions

Figure 1. Boxplot of RSI_{MOD} (Reactive Strength Index Modified) measured during the counter movement jump (CMJ) task in the two movement goal conditions, "jump as high as possible" (CMJ_h, depicted in light blue) and "jump as fast as possible" (CMJ_f, depicted in pink), for football, futsal, and track and field (T&F) athletes. RSI_{MOD} was averaged across three consecutive trials, for each athlete and each goal condition. Horizontal bars indicate statistically significant differences across sports (* $p < 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$).

Figure 2. Boxplot of MPP_{bm} (Mean Propulsive Power normalized to body mass) measured during the counter movement jump (CMJ) task in the two movement goal conditions, "jump as high as possible" (CMJ_h, depicted in light blue) and "jump as fast as possible" (CMJ_f, depicted in pink), for football, futsal, and track and field (T&F) athletes. MPP_{bm} was averaged across three consecutive trials, for each athlete and each goal condition. Horizontal bars indicate statistically significant differences across sports (* $p < 0.05$, ** $p \leq 0.01$).

Figure 3. Boxplot of ConT (Contraction Time) measured during the counter movement jump (CMJ) task in the two movement goal conditions, "jump as high as possible" (CMJ_h, depicted in light blue) and "jump as fast as possible" (CMJ_f, depicted in pink), for football, futsal, and track and field (T&F) athletes. ConT was averaged across three consecutive trials, for each athlete and each goal condition. Horizontal bars indicate statistically significant differences across sports (* $p < 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$).

Figure 4. Boxplot of PD (Propulsive Displacement) measured during the counter movement jump (CMJ) task in the two movement goal conditions, "jump as high as possible" (CMJ_h, depicted in light blue) and "jump as fast as possible" (CMJ_f, depicted in pink), for football, futsal, and track and field (T&F) athletes. PD was averaged across three consecutive trials, for each athlete and each goal condition.

Figure 5. Boxplot of JH (Jump Height) measured during the counter movement jump (CMJ) task in the two movement goal conditions, "jump as high as possible" (CMJ_h, depicted in light blue) and

"jump as fast as possible" (CMJ$_f$, depicted in pink), for football, futsal, and track and field (T&F)

athletes. JH was averaged across three consecutive trials, for each athlete and each goal condition.

Figure 6. Boxplot of CM$_{velocity}$ (Countermovement Velocity) in the two movement goal conditions,

"jump as high as possible" (CMJ$_h$) and "jump as fast as possible" (CMJ$_f$), for football, futsal, and

track and field (T&F) athletes. CM$_{velocity}$ was averaged across three consecutive trials, for each

athlete and each goal condition. Negative values represent downward motion. Horizontal bars

indicate statistically significant differences across sports (** $p \leq 0.01$, *** $p \leq 0.001$).
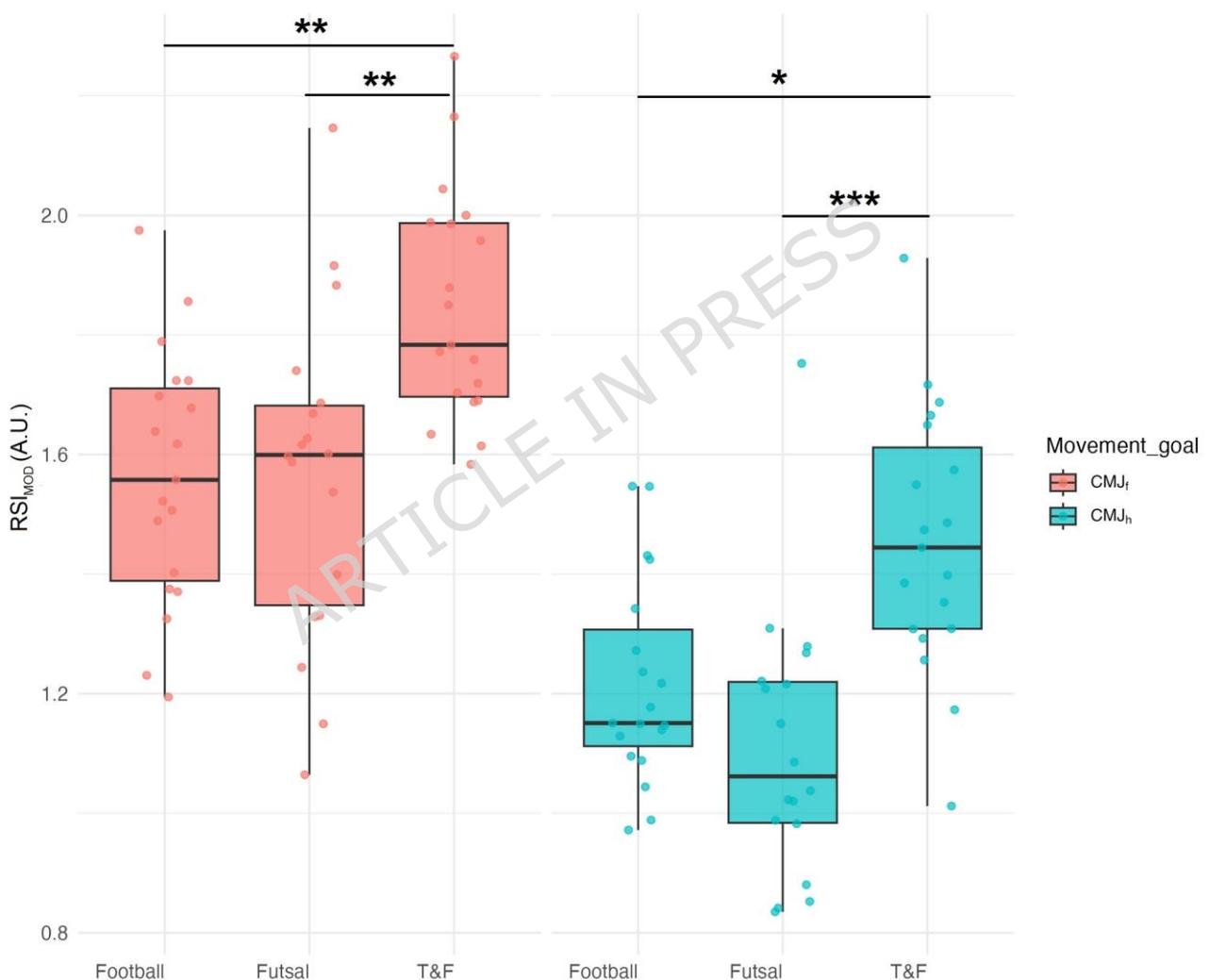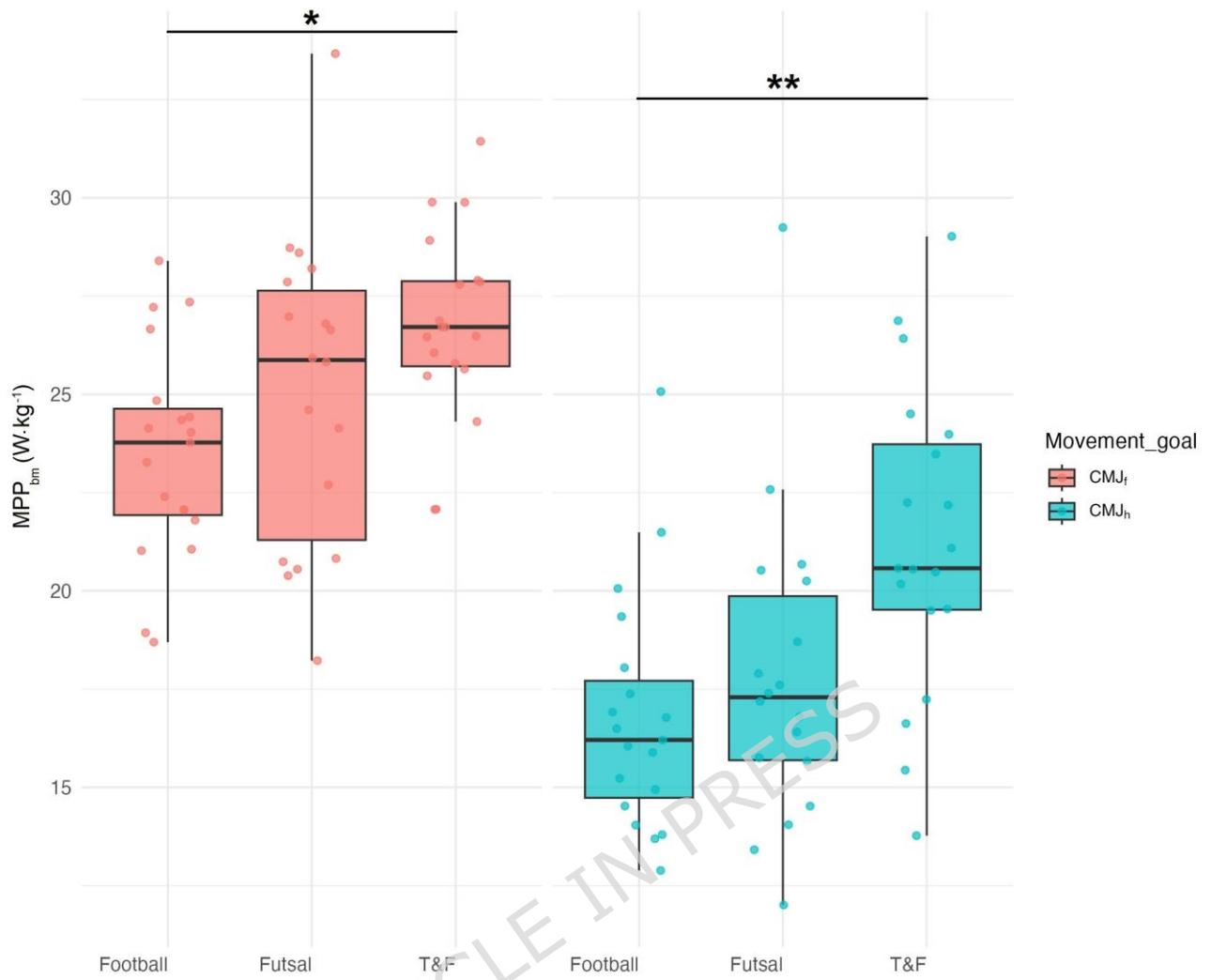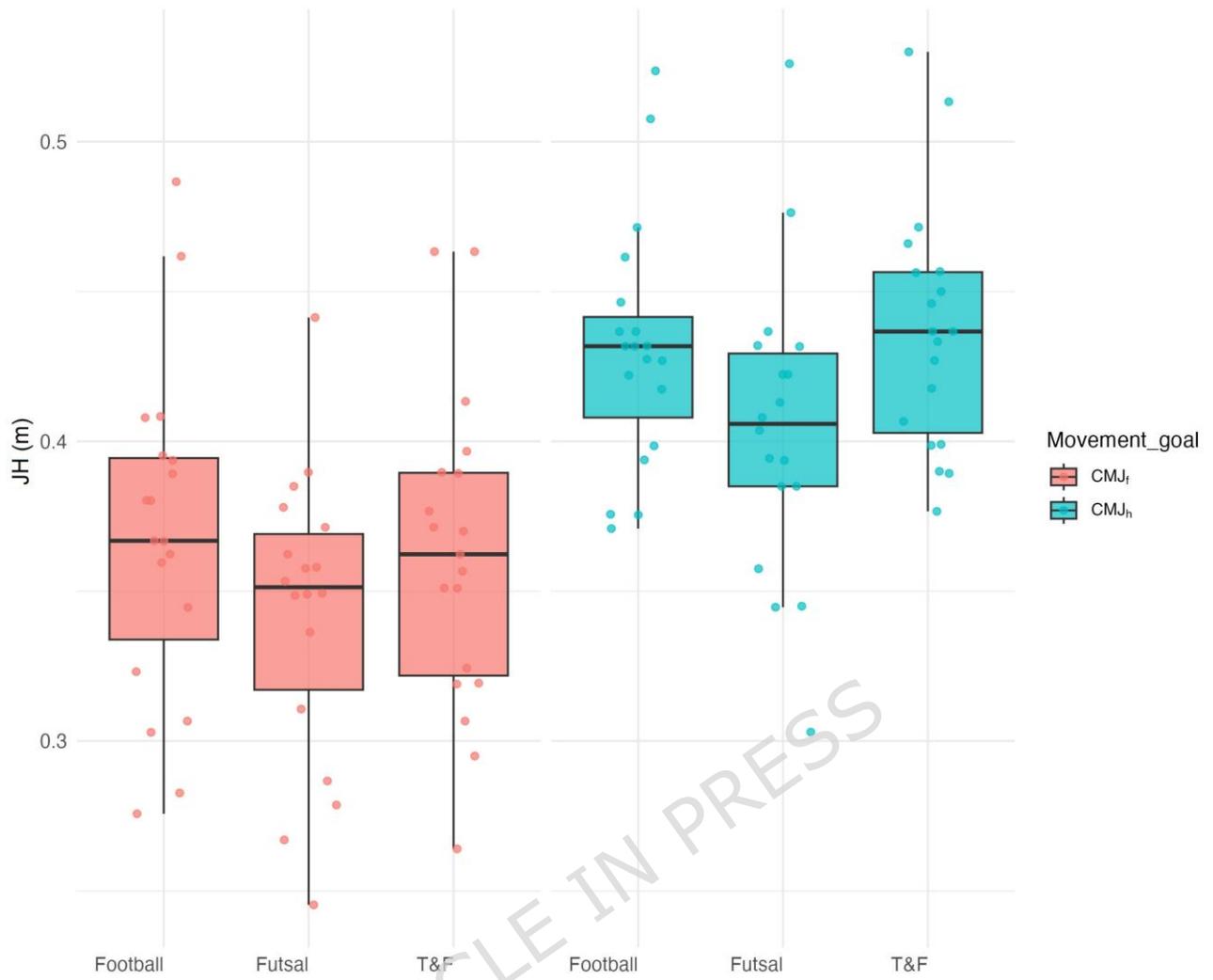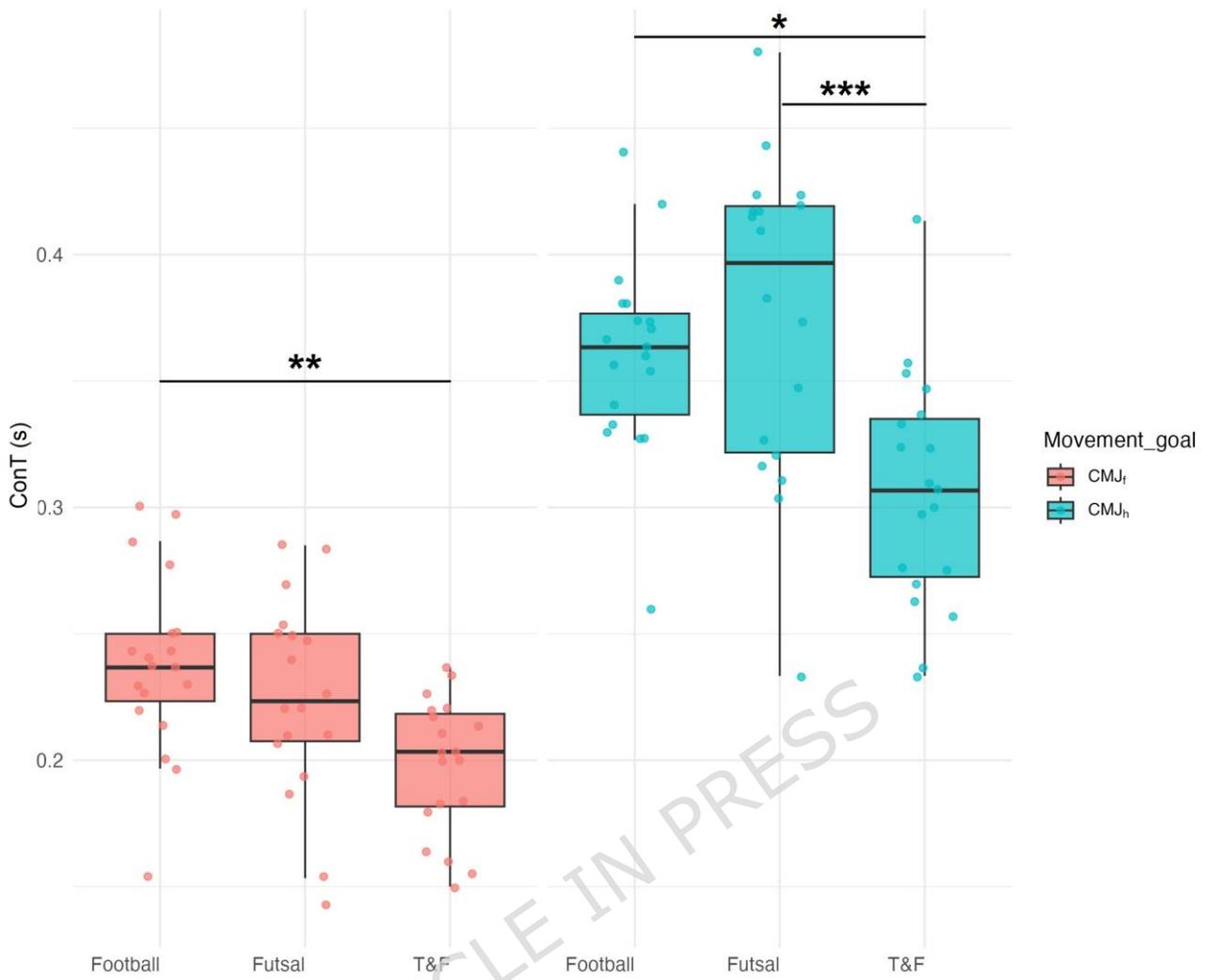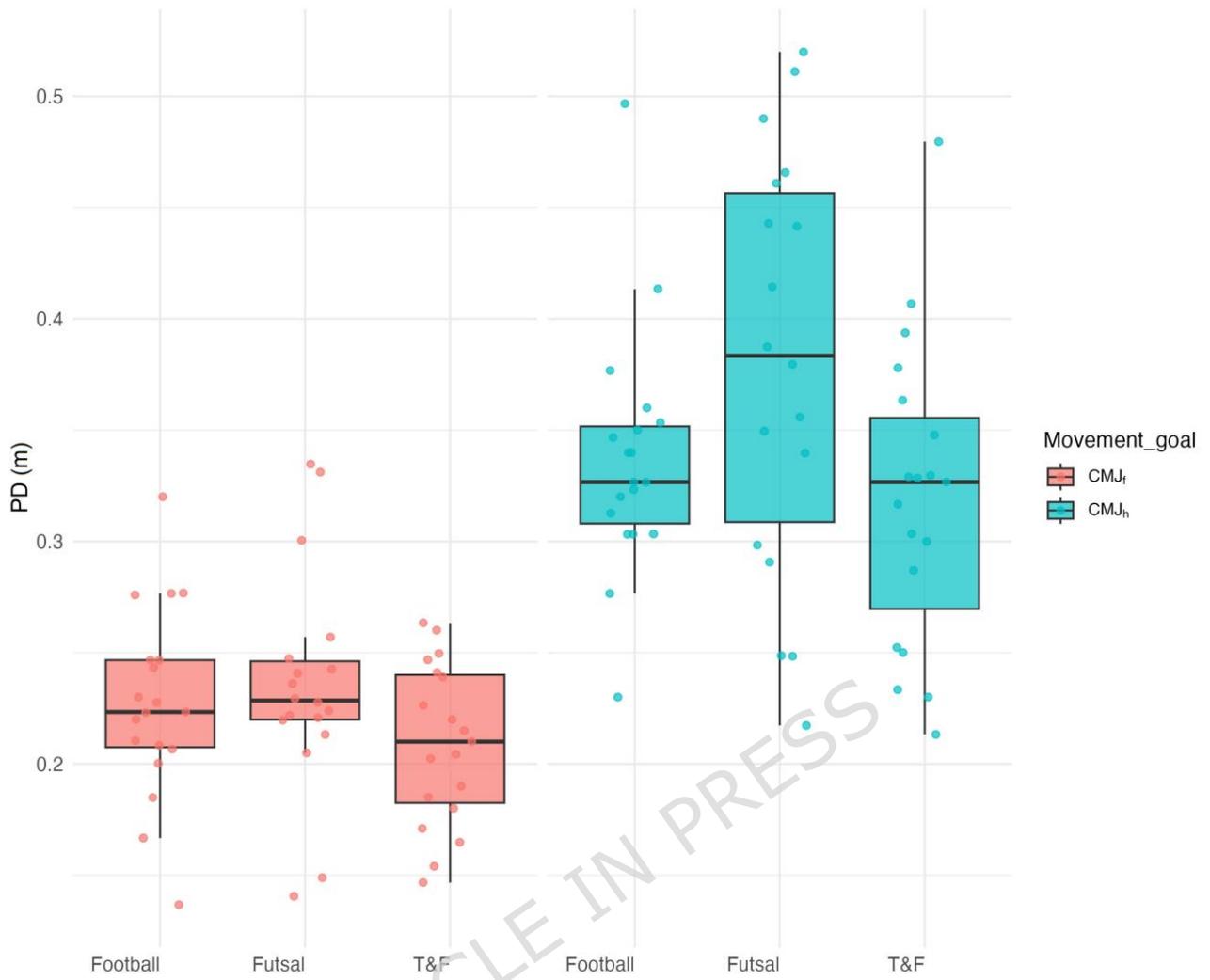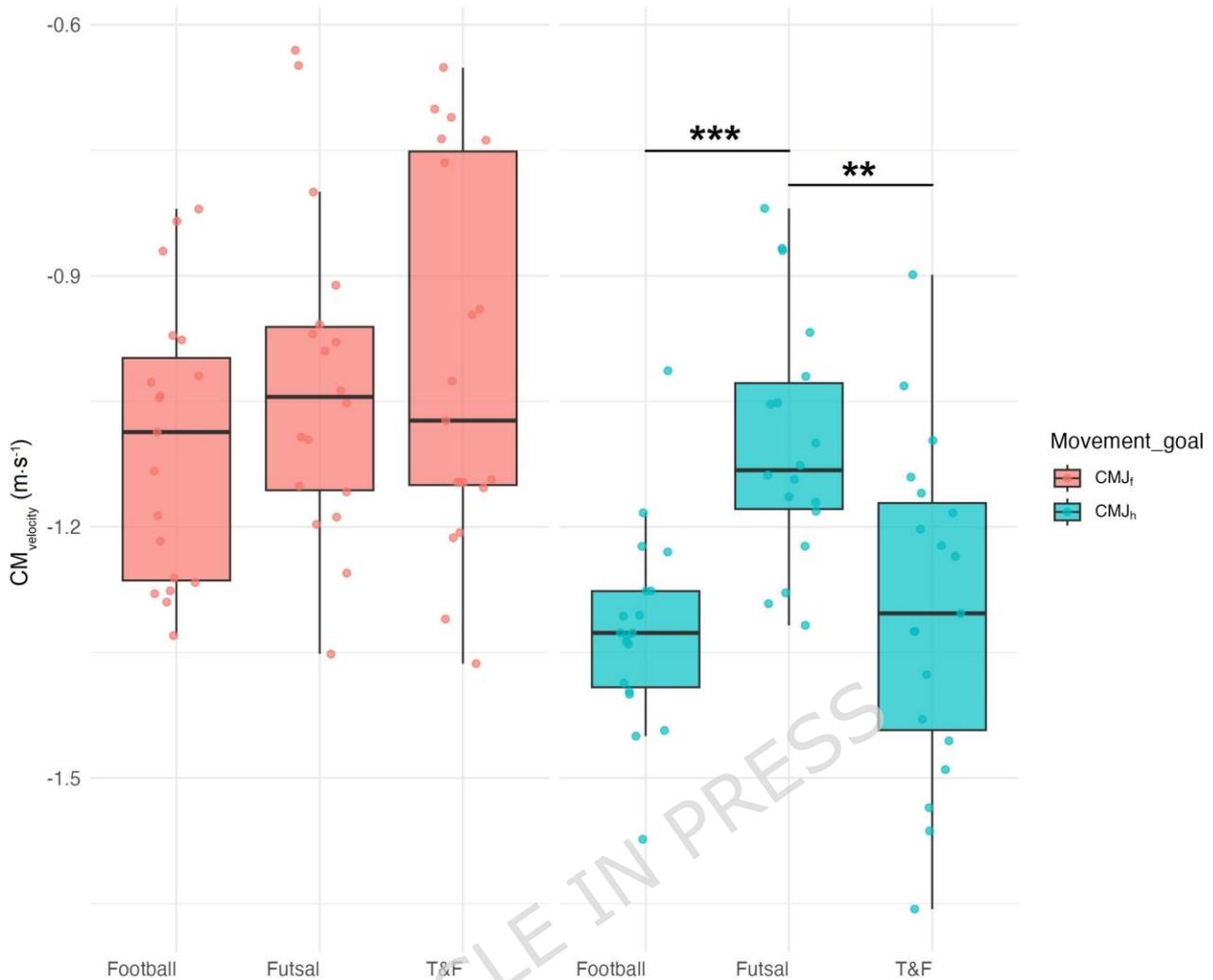
Table 1. Intrasession reliability

Variable$_{condition}$	ICC$_{3,k}$ [95% CI]	CV (%)	TE
RSI$_{MOD}$ **CMJh**	0.936 [0.901, 0.961]	7.8 ± 0.10	0.07
RSI$_{MOD}$ **CMJf**	0.884 [0.817, 0.929]	8.6 ± 0.14	0.10
MPP$_{bm}$ **CMJh**	0.945 [0.914, 0.966]	7.8 ± 1.44	1.02
MPP$_{bm}$ **CMJf**	0.859 [0.779, 0.914]	7.7± 1.94	1.37
JH **CMJh**	0.956 [0.932, 0.973]	3.5 ± 0.01	0.01
JH **CMJf**	0.933 [0.895, 0.959]	5.4 ± 0.02	0.01
ConT **CMJh**	0.917 [0.871, 0.949]	7.1 ± 0.02	0.02
ConT **CMJf**	0.859 [0.779, 0.914]	9.4 ± 0.02	0.01
PD **CMJh**	0.893 [0.833, 0.934]	9.8 ± 0.03	0.02
PD **CMJf**	0.875 [0.804, 0.923]	10.5 ± 0.02	0.02
CM$_{velocity}$ **CMJh**	0.814 [0.809, 0.885]	−10.2 ± 0.12	0.09
CM$_{velocity}$ **CMJf**	0.797 [0.681, 0.876]	−12.9 ± 0.13	0.09

ICC$_{3,k}$ = Intraclass correlation coefficient (two-way mixed-effects, consistency, average measures). Values are reported with 95% confidence intervals; CV (%) = Coefficient of variation; TE = Typical Error; CMJ$_h$ = verbal instruction "jump as high as possible"; CMJ$_f$ = verbal instruction "jump as fast as possible"; RSI$_{MOD}$ = Reactive Strength Index Modified; MPP$_{bm}$ = Mean Propulsive Power normalized to body mass; JH = Jump Height; ConT = Contraction Time; PD = Propulsive Displacement; CM$_{velocity}$ = Countermovement Velocity

Table 2. Descriptive statistics

Variable (unit)	CMJ_h	CMJ_f	Mean Difference [95% CI]
RSI_{MOD} (A.U.)	1.263 (±.250)	1.659 (±0.262)	0.396 [0.334, 0.458]
MPP_{bm} (W·kg^{-1})	18.629 (±4.082)	25.110 (±3.292)	6.481 [5.567, 7.395]
JH (m)	0.424 (±0.046)	0.358 (±0.052)	−0.066 [−0.076, −0.057]
ConT (s)	0.347 (±0.058)	0.220 (±0.038)	−0.126 [−0.141, −0.112]
PD (m)	0.345 (±0.077)	0.224 (±0.044)	−0.121 [−0.141, −0.102]
$CM_{velocity}$ (m·s^{-1})	−1.242 (±0.183)	−1.045 (±0.197)	0.197 [0.147, 0.246]

Values are presented as mean ± Standard Deviation for each condition, and as mean differences with 95% confidence intervals.

CMJ_h = verbal instruction "jump as high as possible"; CMJ_f = verbal instruction "jump as fast as possible"; RSI_{MOD} = Reactive Strength Index Modified; MPP_{bm} = Mean Propulsive Power normalized to body mass; JH = Jump Height; ConT = Contraction Time; PD = Propulsive Displacement; $CM_{velocity}$ = Countermovement Velocity

Table 3. Mixed-design ANOVAs – within-subject effects (Movement Goals)

Variable (unit)	F-test	p-value	ES [95% CI]
RSI_{MOD} (A.U.)	$F_{(1,53)} = 162.990$	< 0.001	$\eta_p^2 = 0.755$ [0.66, 1.00]
MPP_{bm} (W·kg^{-1})	$F_{(1,53)} = 204.865$	< 0.001	$\eta_p^2 = 0.794$ [0.71, 1.00]
JH (m)	$F_{(1,53)} = 189.632$	< 0.001	$\eta_p^2 = 0.782$ [0.69, 1.00]
ConT (s)	$F_{(1,53)} = 316.960$	< 0.001	$\eta_p^2 = 0.857$ [0.80, 1.00]
PD (m)	$F_{(1,53)} = 159.953$	< 0.001	$\eta_p^2 = 0.751$ [0.65, 1.00]
$CM_{velocity}$ (m·s^{-1})	$F_{(1,53)} = 79.550$	< 0.001	$\eta_p^2 = 0.600$ [0.46, 1.00]

Values are reported as F-statistics, p-values, and effect sizes with 95% confidence intervals.

RSI_{MOD} = Reactive Strength Index Modified; MPP_{bm} = Mean Propulsive Power normalized to body mass; JH = Jump Height; ConT = Contraction Time; PD = Propulsive Displacement; $CM_{velocity}$ = Countermovement Velocity

Table 4. Mixed-design ANOVAs – between-subject effects (Sports)

Variable (unit)	F-test	p-value	ES [95% CI]
RSI_{MOD} (A.U.)	$F_{(2,53)} = 15.853$	< 0.001	$\eta_p^2 = 0.374$ [0.20, 1.00]
MPP_{bm} (W·kg^{-1})	$F_{(2,53)} = 8.618$	< 0.001	$\eta_p^2 = 0.245$ [0.08, 1.00]
JH (m)	$F_{(2,53)} = 2.053$	0.138	$\eta_p^2 = 0.072$ [0.00, 1.00]
ConT (s)	$F_{(2,53)} = 12.785$	< 0.001	$\eta_p^2 = 0.325$ [0.15, 1.00]
PD (m)	$F_{(2,53)} = 3.906$	0.026	$\eta_p^2 = 0.128$ [0.01, 1.00]
$CM_{velocity}$ (m·s^{-1})	$F_{(2,53)} = 4.203$	0.020	$\eta_p^2 = 0.137$ [0.01, 1.00]

Values are reported as F-statistics, p-values, and effect sizes with 95% confidence intervals.

RSI_{MOD} = Reactive Strength Index modified; MPP_{bm} = Mean Propulsive Power normalized to body mass; JH = Jump Height; ConT = Contraction Time; PD = Propulsive Displacement; $CM_{velocity}$ = Countermovement Velocity.