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Within-Session Changes in Vertical Jump Performance Across a Standardized Physiological Testing Sequence in Elite Soccer Players

Koulla Parpa[1*], Cíntia França[2,3], Tina-Thea Nielsen[4], Konstantina Intziegianni[1], Anna Carolina Paludo[5], Marios Avraamides[5,6], Marcos Michaelides[1]

Affiliations: [1]Faculty of Sport and Exercise Science, UCLan University of Cyprus, Pyla, Cyprus, [2]Department of Physical Education and Sport, University of Madeira, 9020-105 Funchal, Portugal, [3]LARSyS, Interactive Technologies Institute, 9020-105 Funchal, Portugal, [4]Syddansk Universitet - University of Southern Denmark Human Physiology, Department of Biomechanics and Motor Control, [5]Department of Psychology, University of Cyprus, Nicosia, Cyprus, [6]CYENS Centre of Excellence, Nicosia, Cyprus

Correspondence: Koulla Parpa. Assistant Professor in Sports and Exercise Science, Director of Human Performance Laboratory, School of Sciences, University of Central Lancashire – Cyprus Campus, University Avenue 12-14, 7080, Pyla, Larnaka, Cyprus. E-mail: kparpa@uclan.ac.uk

Abstract

The purpose of this study was to examine whether vertical jump height differed between two assessments performed within a standardized physiological testing sequence in elite soccer players. A total of 227 elite male outfield soccer players completed a standardized sequence consisting of a general warm-up, baseline vertical jump assessment, isokinetic knee strength testing, maximal cardiopulmonary exercise testing, and a second jump assessment. Squat jump (SJ), countermovement jump (CMJ), and countermovement jump with arm swing were assessed using an Optojump system. Test-retest reliability of the jump assessments was excellent (ICC = 0.990–0.994). A 2 × 3 repeated-measures analysis of variance showed a significant main effect of time [$F(1,226) = 284.44$, $p < 0.001$, $\eta p^2 = 0.557$], whereas the time × jump-type interaction was not significant [$F(2,452) = 2.25$, $p = 0.107$, $\eta p^2 = 0.010$]. SJ increased from 40.74 ± 5.33 to 42.79 ± 5.31 cm (Δ = 2.05 cm; dz = 0.97), CMJ from 43.03 ± 5.10 to 44.91 ± 5.30 cm (Δ = 1.87 cm; dz = 0.87), and CMJ with arm swing from 48.32 ± 5.79 to 50.52 ± 5.76 cm (Δ = 2.20 cm; dz = 0.89). Jump height was higher at the second assessment across all three jump conditions. However, because the study did not include a control condition or counterbalanced testing order, the observed within-session differences cannot be attributed specifically to the intervening physiological testing procedures.

Keywords: *neuromuscular performance, countermovement jump, physiological testing, soccer*

@MJSSMontenegro
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Introduction

Explosive lower-body strength performance, commonly assessed through vertical jump tests such as the countermovement jump (CMJ) and squat jump (SJ), is widely used in elite soccer to monitor neuromuscular function, fatigue status, and readiness to perform (Guthrie et al., 2023; Lombard et al., 2021; Watkins et al., 2017). In addition to being valid and reliable, these assessments are sensitive to training-induced changes and are strongly associated with key performance actions such as sprinting, acceleration, and change of direction (McFarland et al., 2016; Swinton et al., 2014; Uysal et al., 2025). Consequently, vertical jump testing is frequently incorporated into athlete monitoring and performance evaluation protocols in elite soccer settings.

Concurrently, a comprehensive physiological evaluation of elite soccer players often includes the assessment of aerobic fitness and lower-limb muscle function through treadmill-based cardiopulmonary exercise testing and isokinetic dynamometry (Parpa and Michaelides, 2025; Parpa and Michaelides, 2022; Parpa and Michaelides, 2017). In applied settings, these assessments are often performed during the same session due to time constraints, especially during the pre-season assessment period. However, the sequencing of these procedures has important practical and methodological implications, as fatigue induced by earlier tests may alter subsequent neuromuscular performance (Gathercole et al., 2015) and, therefore, influence the interpretation of jump-based measures within the same testing session.

Understanding whether integrated testing batteries influence subsequent neuromuscular assessments is important because practitioners frequently use vertical jump testing to evaluate fatigue, readiness and recovery status in elite soccer. If prior physiological assessments systematically alter jump performance, interpretation of athlete monitoring data may be compromised. Previous research has indicated that vertical jump performance is sensitive to specific forms of acute exercise-induced fatigue, with reductions in jump height observed following exhaustive metabolic exercise and exercise involving substantial eccentric loading (Kamandulis et al., 2016). Reductions in CMJ height and power output have been reported after repeated sprint protocols, endurance exercise, and simulated game play, supporting the use of vertical jump testing as a marker of neuromuscular fatigue (Gathercole et al., 2015; Alba-Jimenez et al., 2022). Based on this evidence, it is generally assumed that performing maximal or near-maximal physiological tests before jump assessments would result in decreased performance due to accumulated peripheral and central fatigue.

Despite this assumption, the effect of integrated testing sequences on vertical jump performance within the same session remains unclear, especially in elite soccer populations. It is possible that, under certain conditions, preceding exercise may not impair subsequent explosive performance, with factors such as warm-up effects (Sotiropoulos et al., 2010), post-activation performance enhancement (PAPE) (Kasicki et al., 2024), and task familiarization (Bright et al., 2025) representing possible explanations for such responses. However, research examining changes in vertical jump performance during real-world, same-session testing protocols remains limited, especially when jump assessments are performed before and after other physiological evaluations. Establishing whether vertical jump performance is reduced, maintained, or improved across a combined testing session is important for practitioners, as it informs the scheduling, interpretation, and practical utility of neuromuscular assessments within elite soccer testing batteries.

To the authors' knowledge, no previous study has examined changes in vertical jump performance before and after completion of a real-world integrated physiological testing battery in elite soccer players. Therefore, the primary aim of this study was to determine whether vertical jump height differed between the baseline and second assessments performed within a standardized physiological testing sequence in elite soccer players. Based on previous evidence demonstrating reductions in jump performance following fatiguing exercise protocols, it was hypothesized that vertical jump performance would be lower following the testing session.

Materials and methods

Participants and design

The study employed a repeated-measures within-subject design to examine differences in vertical jump height between two assessments performed within a standardized physiological testing sequence. All players completed the same sequence consisting of a general warm-up, baseline jump assessment, isokinetic knee strength testing, maximal cardiopulmonary exercise testing, and a second jump assessment. The testing order and procedures were standardized across players and were completed within a single laboratory session. The total elapsed time between the baseline and second jump assessments was approximately 45 minutes. The final sample comprised 227 unique elite male outfield soccer players (age: 25.4 ± 5.3 years; stature: 180.3 ± 6.6 cm; body mass: 77.3 ± 7.2 kg) from four professional first-division clubs. Data were collected during standardized preseason laboratory testing across the 2023–2024 and 2024–2025 seasons. Goalkeepers were excluded because they did not complete the same testing sequence as the outfield players. Players were excluded if they had sustained a musculoskeletal injury within the preceding six weeks, had undergone recent surgery, or were unable to complete any component of the testing session. All players provided written informed consent before data collection. The study adhered to the ethical principles of the Declaration of Helsinki and was approved by the National Committee of Bioethics (EEBK EP 2022.01.29 and 2024.12.13).

Procedures

All testing was conducted during the preseason period in a controlled laboratory environment and followed the same standardized sequence (Figure 1).

Warm-up

Players completed a 5-minute warm-up on a mechanically braked ergometer (Monark 894E Peak Bike, Vansbro, Sweden) at 100 W and 70 rpm, followed by 5 minutes of self-selected dynamic stretching and mobility exercises.

Vertical jump assessment

Jump performance was assessed using an Optojump system (Microgate, Italy), an optical measurement device consisting of parallel transmitting and receiving bars equipped with infrared LEDs. The system detects interruptions in the light beams during take-off and landing to calculate flight time, contact time, and jump height with millisecond precision.

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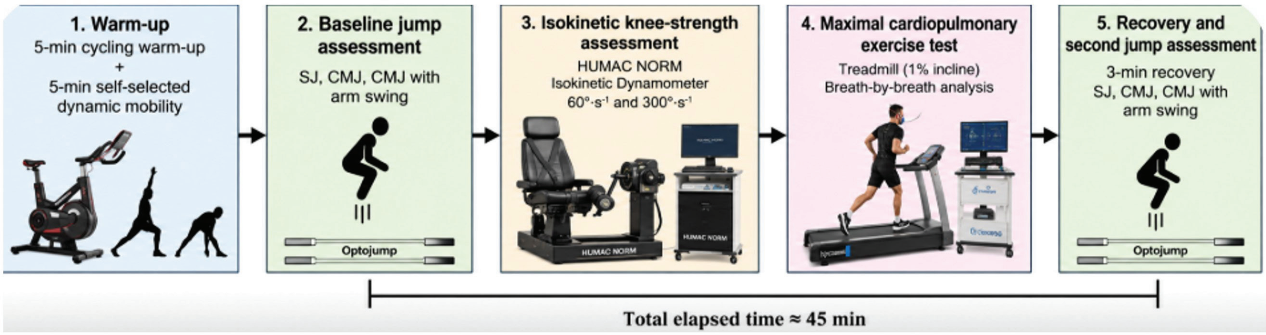

Figure 1. Standardized physiological testing sequence. SJ, squat jump; CMJ, countermovement jump. The total elapsed time between the baseline and second jump assessments was approximately 45 min.

The system's bars were connected to a personal computer, which instantly provided the measured outcomes. Players performed three jump conditions in the following standardized order: 1) squat jump (SJ), 2) countermovement jump (CMJ), and 3) countermovement jump with arm swing. For the SJ, players descended to approximately 100° of knee flexion, maintained this position for 3 s to minimize countermovement, and then jumped vertically with their hands on their hips. For the CMJ, players began from an upright position and performed a rapid countermovement followed immediately by vertical propulsion, with their hands maintained on their hips. For the CMJ with arm swing, the countermovement was performed with unrestricted arm movement. Players were familiar with the jump procedures because these assessments formed part of their routine laboratory testing and had been performed on several previous occasions. Players who were new to the testing protocol or did not have previous experience with the jump assessments completed two familiarization trials before the recorded attempts. The jump order was standardized for all players (SJ, CMJ, and CMJ with arm swing), and the same verbal encouragement was provided throughout testing. Three maximal attempts were completed for each jump condition, separated by 30 s of recovery, and the highest jump height was retained to represent maximal performance in each condition.

Isokinetic testing

Isokinetic knee strength was assessed concentrically for both the quadriceps and hamstrings using the Humac Norm Dynamometer (CSMI, Stoughton, MA, USA). Subjects were positioned according to manufacturer guidelines and performed a standardized familiarization consisting of five submaximal repetitions of concentric knee flexion and extension. More specifically, the players were seated with the thigh at 85°relative to the trunk, and the dynamometer's axis was aligned with the lateral epicondyle of the knee as described in previously published studies (Parpa and Michaelides, 2017; Parpa et al., 2024). Knee range of motion was set to 0–100 ° while the torso and thigh were secured with straps and a belt, and the ankle was secured with an adjustable strap. Following familiarization, each player completed a test that included 3 maximal concentric repetitions at $60°\cdot s^{-1}$ and 5 at $300°\cdot s^{-1}$. Both dominant and non-dominant limbs were tested individually.

Cardiopulmonary exercise testing

The players performed an incremental maximal cardiopulmonary exercise test (CPET) on a treadmill (h/p/Cosmos Quasar med, Germany). Environmental conditions were standardized, and all players followed exactly the same testing protocol. Throughout the test, the inclination was kept constant at 1%. The test began at 8 km/h and increased by 2 km/h every 3 minutes and 15 seconds, until the players reached volitional fatigue. A breath-by-breath analysis was conducted using a Cosmed Quark CPET system (Rome, Italy). $\dot{V}O_2max$ was accepted when at least two of the following three criteria were achieved: (1) a plateau in $\dot{V}O_2$ despite an increase in workload, (2) a respiratory exchange ratio >1.10, and (3) a peak heart rate within ±5% of the age-predicted maximum heart rate.

Post-testing jump assessment

Following completion of the cardiopulmonary test, players rested for 3 minutes, after which the same jump protocol (SJ, CMJ, and CMJ with arm swing) was repeated under identical conditions. All subjects completed the testing protocol in the same order and under identical conditions. The duration and structure of the testing session were standardized across all players.

Statistics

All statistical analyses were performed using IBM SPSS Statistics version 28.0 for Windows (IBM Corp., Armonk, NY, USA). Descriptive data are presented as mean ± standard deviation (SD). A 2 × 3 repeated-measures analysis of variance (ANOVA) was used to examine the effects of time (baseline and second assessment) and jump type (SJ, CMJ, and CMJ with arm swing) on jump height. The assumption of sphericity was assessed using Mauchly's test, and Greenhouse-Geisser corrections were applied when this assumption was violated. Effect sizes for the ANOVA were reported as partial eta-squared (ηp^2). Planned paired-samples t-tests were used to compare baseline and second-assessment values within each jump condition. For these comparisons, standardized effect sizes were calculated as Cohen's dz, defined as the mean within-player difference divided by the standard deviation of the difference scores. Ninety-five percent confidence intervals were calculated for the mean differences and Cohen's dz. Statistical significance was set at $p < 0.05$. Test-retest reliability of the vertical jump assessments was evaluated in a subsample of 20 professional soccer players who repeated the assessments 48 h later under the same testing conditions. Reliability was quantified using a two-way random-effects, single-measure intraclass correlation coefficient with absolute agreement [ICC(2,1)]. Absolute measurement error was quantified using the standard error of measurement (SEM), and the minimal detectable change at the 95% confidence level (MDC95) was calculated as SEM × 1.96 × √2. Results

The vertical jump assessments demonstrated excellent test-retest reliability. ICC(2,1) values were 0.991 (95% CI: 0.977–0.996) for SJ, 0.990 (95% CI: 0.975–0.996) for CMJ, and 0.994 (95% CI: 0.984–0.997) for CMJ with arm swing. The corresponding SEM values were 0.37, 0.46, and 0.41 cm, while MDC95 values were 1.03, 1.28, and 1.14 cm, respectively. A 2 × 3 repeated-measures ANOVA demonstrated a significant main effect of time, with jump height higher at the second assessment than at baseline when averaged across the three jump conditions [$F(1,226) = 284.44$, $p < 0.001$, $\eta p^2 = 0.557$]. A significant main effect of jump type was also observed [$F(1.672,377.890) = 1438.82$, $p < 0.001$, $\eta p^2 = 0.864$; Greenhouse-Geisser corrected]. In contrast, the time × jump-type interaction was not significant [$F(2,452) = 2.25$, $p = 0.107$, $\eta p^2 = 0.010$], indicating that there was no evidence that the magnitude of the within-session difference varied among the three jump conditions. Paired-samples t-tests showed that jump height was higher at the second assessment in all three jump conditions (Table 1, Table 2, Figure 2). SJ increased from 40.74 ± 5.33 to 42.79 ± 5.31 cm, corresponding to a mean within-session difference of 2.05 cm [95% CI: 1.77 to 2.32, $t(226) = 14.65$, $p < 0.001$, dz = 0.97]. CMJ increased from 43.03 ± 5.10 to 44.91 ± 5.30 cm, with a mean difference of 1.87 cm [95% CI: 1.59 to 2.16, $t(226) = 13.06$, $p < 0.001$, dz = 0.87]. CMJ with arm swing increased from 48.32 ± 5.79 to 50.52 ± 5.76 cm, with a mean difference of 2.20 cm [95% CI: 1.87 to 2.52, $t(226) = 13.41$, $p < 0.001$, dz = 0.89]. The corresponding relative differences were 5.03%, 4.36%, and 4.55%, respectively.

Table 1. Descriptive statistics and within-session differences in vertical jump height (N = 227)

Variable	Baseline (cm)	Second assessment (cm)	Mean difference (cm)	95% CI	% difference
Squat jump (SJ)	40.74 ± 5.33	42.79 ± 5.31	+2.05	1.77 to 2.32	+5.03
Countermovement jump (CMJ)	43.03 ± 5.10	44.91 ± 5.30	+1.87	1.59 to 2.16	+4.36
CMJ with arm swing	48.32 ± 5.79	50.52 ± 5.76	+2.20	1.87 to 2.52	+4.55

Table 2. Paired comparisons of vertical jump height between baseline and the second assessment (N = 227)

Variable	t (df)	p	Cohen's dz	95% CI for dz
Squat jump (SJ)	14.65 (226)	<0.001	0.97	0.81 to 1.13
Countermovement jump (CMJ)	13.06 (226)	<0.001	0.87	0.71 to 1.02
CMJ with arm swing	13.41 (226)	<0.001	0.89	0.74 to 1.04

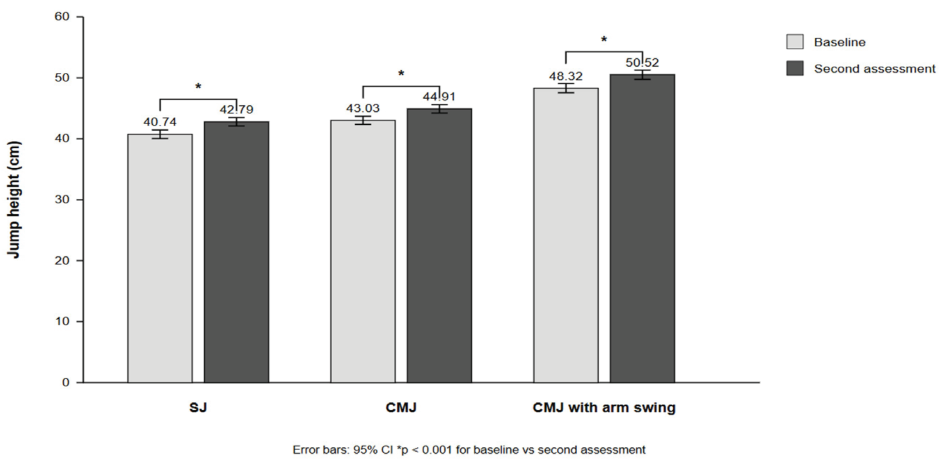

Figure 2. Vertical jump height at baseline and the second assessment for squat jump (SJ), countermovement jump (CMJ), and countermovement jump with arm swing. Values are means with 95% confidence intervals. $p < 0.001$ for the paired comparison between baseline and the second assessment.

Discussion

The main finding of the present study was that vertical jump height was higher at the second assessment than at baseline during the standardized physiological testing session. This pattern was observed for SJ, CMJ, and CMJ with arm swing, with mean within-session differences of 2.05, 1.87, and 2.20 cm, respectively. The time × jump-type interaction was not significant, indicating no evidence that the magnitude of the within-session difference varied among the three jump conditions. These findings were contrary to our initial hypothesis that jump performance would be lower at the second assessment following the potentially fatiguing testing sequence. Importantly, the present design does not allow the observed differences to be attributed specifically to the isokinetic assessment, cardiopulmonary exercise test, or any other component of the testing sequence. Several factors may have contributed to the higher values observed at the second jump assessment. One possibility is a potentiation-related response associated with the preceding physical activity. Previous research has shown that explosive performance can be temporarily enhanced following an appropriate conditioning activity, although the magnitude and direction of the response depend on factors including the characteristics of the preceding activity and the recovery interval (Chiu et al., 2003; Seitz and Haff, 2016; Kasicki et al., 2024). However, the present study was not designed to identify PAPE, and no physiological measures

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related to its underlying mechanisms were collected. Moreover, the preceding activity consisted of a warm-up, isokinetic strength assessment, and maximal treadmill exercise rather than a conventional conditioning activity specifically designed to elicit PAPE. PAPE should therefore be regarded as only one possible explanation for the present findings. Continued warm-up may also have contributed, as warm-up procedures have previously been shown to influence vertical jump performance (Sotiropoulos et al., 2010). Repeated exposure to the jump task may represent another possible explanation, although most players were already familiar with the testing procedures. Thus, the higher values observed at the second assessment may reflect potentiation-related responses, continued warm-up, repeated task exposure, time-dependent changes in readiness, or interactions among these factors rather than a single mechanism. The present findings differ from those reported by Gathercole et al. (2015), who observed reductions in jump and sprint performance following a fatiguing Yo-Yo-based exercise protocol. The difference between the findings may reflect the substantially different testing protocols. Gathercole et al. examined responses to an exercise protocol intended to induce fatigue and monitored subsequent recovery, whereas the present study examined two jump assessments performed within a standardized, same-session physiological testing sequence used in professional soccer players. Similarly, Kamandulis et al. (2016) reported that changes in jump height depended on the source of the preceding stress, with reductions following exhaustive cycling and muscle-damaging drop jumps but different responses under other experimental conditions. Therefore, these findings suggest that the response of vertical jump height to preceding activity is likely to depend on the nature of the activity, the recovery interval, and the testing context.

The magnitude of the observed within-session differences should also be considered in relation to measurement error. Mean differences were 2.05 cm for SJ, 1.87 cm for CMJ, and 2.20 cm for CMJ with arm swing, corresponding to relative differences of 5.03%, 4.36%, and 4.55%, respectively. These group mean differences were greater than the MDC95 values obtained from the test-retest subsample, which were 1.03 cm for SJ, 1.28 cm for CMJ, and 1.14 cm for CMJ with arm swing. This comparison suggests that the observed differences at the group level were greater than the estimated measurement error of the respective assessments. However, this should not be interpreted as evidence that every individual player experienced a meaningful change, because the present comparison concerns group mean differences rather than classification of individual responses. These findings have practical implications for sports scientists and performance practitioners working in elite soccer. In applied high-performance settings, multiple physiological assessments are often scheduled within the same session because of time constraints. In the present testing sequence, jump height at the second assessment was approximately 4.4–5.0% higher than at baseline. Practitioners should therefore recognize that jump values obtained at different points within a testing session may not be directly comparable when the preceding activities or testing order differ. This is particularly relevant when small changes in jump performance are used to inform judgments regarding neuromuscular status or readiness. Standardizing the timing and position of jump testing within an assessment battery is therefore important when comparing results across testing sessions or using jump measures for longitudinal athlete monitoring. The present study has several limitations that should be acknowledged. First, no control condition was included, and therefore, it cannot be determined whether similar within-session differences would have occurred in the absence of isokinetic and cardiopulmonary testing. Second, the testing order was fixed and was not randomized or counterbalanced, which limits causal interpretation regarding the contribution of each component of the testing sequence. Third, physiological mechanisms potentially contributing to the higher values at the second assessment were not directly measured. Therefore, explanations related to PAPE or other potentiation-related responses, continued warm-up, changes in muscle temperature, neuromuscular activation, repeated task exposure or time-dependent changes in readiness remain speculative. Fourth, the findings are limited to elite male outfield soccer players and may not generalize to female players, youth players, or athletes from other sports. Lastly, only the acute response within a single testing session was examined. Future studies should compare different testing orders, include a control condition in a counterbalanced design, and directly assess potential explanatory mechanisms to clarify the factors contributing to within-session differences under integrated testing conditions.

Conclusions

Vertical jump height was higher at the second assessment than at baseline during a standardized physiological testing session in elite male soccer players, with this pattern observed for SJ, CMJ, and CMJ with arm swing. However, because the study did not include a control condition or counterbalanced testing order, the observed within-session differences cannot be attributed specifically to the intervening physiological testing procedures. Potentiation-related responses, continued warm-up, repeated task exposure, time-dependent changes in readiness, or a combination of these factors may have contributed to the findings. These results emphasize the importance of standardizing the timing and order of jump assessments when they are used for athlete monitoring.

Conflicts of Interest

The authors declare no conflict of interest.

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