Accepted Manuscript

Submission Date: 2024-02-09
Accepted Date: 2024-07-16
Accepted Manuscript online: 2024-07-16

International Journal of Sports Medicine

Physical performance changes in season are associated with GPS data in soccer players

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DOI: 10.1055/a-2367-6289

Please cite this article as: Zandavalli L A, Grazioli R, Izquierdo M et al. Physical performance changes in season are associated with GPS data in soccer players. International Journal of Sports Medicine 2024. doi: 10.1055/a-2367-6289

Conflict of Interest: The authors declare that they have no conflict of interest.

This study was supported by National Council for Scientific and Technological Development (CNPq)., Coordination for the Improvement of Higher Education Personnel (CAPES)

Abstract:
This study investigated the associations between preseason and in-season performance with external workload in professional soccer players. Twenty-one players completed hamstring strength, countermovement jump (CMJ), 20-m sprint, and Yo-Yo intermittent recovery tests before (preseason) and after 8 weeks (in-season). External workload (total distance, high-intensity running distance, number of sprints, and power plays) was quantified during this period, and used to divide the average above and below subgroups outcome by outcome for further analyses. Significance was accepted when P≤0.05. Hamstring strength declined from pre- to in-season [-6%; p=0.014; effect size (ES): -0.41], while Yo-Yo performance improved (46%; p=0.001; ES: 1.31). When divided by high-intensity running distance, only the below-average subgroup improved CMJ performance (5%; p=0.030). For minutes played, the above-average subgroup improved Yo-Yo performance (41%; p<0.001), but not the below-average subgroup. Furthermore, playing time correlated with improved Yo-Yo performance (p=0.040; r=0.534). Improved 20-m sprint performance associated with more sprints performed (p=0.045; r=-0.453). Physical capabilities changed over a competitive season and were related to, and differentiated by, external workload. Because hamstring strength decreased and CMJ only improved in players exposed to less high-intensity external load, practitioners should individualize approaches to counteract these conditions when high external workload is performed over the season.

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Physical performance changes in season are associated with GPS data in soccer players

ABSTRACT

This study investigated the associations between preseason and in-season performance with external workload in professional soccer players. Twenty-one players completed hamstring strength, countermovement jump (CMJ), 20-m sprint, and Yo-Yo intermittent recovery tests before (preseason) and after 8 weeks (in-season). External workload (total distance, high-intensity running distance, number of sprints, and power plays) was quantified during this period, and used to divide the average above and below subgroups outcome by outcome for further analyses. Significance was accepted when P≤0.05. Hamstring strength declined from pre- to in-season [-6%; p=0.014; effect size (ES): -0.41], while Yo-Yo performance improved (46%; p=0.001; ES: 1.31). When divided by high-intensity running distance, only the below-average subgroup improved CMJ performance (5%; p=0.030). For minutes played, the above-average subgroup improved Yo-Yo performance (41%; p<0.001), but not the below-average subgroup. Furthermore, playing time correlated with improved Yo-Yo performance (p=0.040; r=0.534). Improved 20-m sprint performance associated with more sprints performed (p=0.045; r=-0.453). Physical capabilities changed over a competitive season and were related to, and differentiated by, external workload. Because hamstring strength decreased and CMJ only improved in players exposed to less high-intensity external load, practitioners should individualize approaches to counteract these conditions when high external workload is performed over the season.

Key Words: Game Analysis; Performance; Strength; Team Sport; Testing.

INTRODUCTION

The scenario of modern high-performance soccer provides several challenges. The championships have chaotic schedules, which means a squad of 30-35 players will be exposed to approximately 60-80 matches during a season, most of them occurring with an interval lower than 5 days as well as under long travelling [1]. In addition, the physical capabilities involving these matches and training events are complex. It means that cardiorespiratory and neuromuscular functions are concurrent and, most importantly, the external workload during a season will impact the physical status of these players [2,3].

There are important physiological markers able to identify the status as well as the oscillation of physical conditioning during a pre-season/competitive season. For example, some studies have shown that neuromuscular status may be monitored through countermovement jump (CMJ) [4] and eccentric hamstring strength [5], while Yo-Yo test is an important marker for intermittent cardiorespiratory fitness, once it is closely related to soccer performance on the pitch [6].

On the other hand, electronic performance and tracking systems (EPTS), such as global positioning systems (GPS), provide high-fidelity data streams extracted from every training session and match [7]. However, there is limited investigation into the association between GPS-derived external workload and neuromuscular and cardiorespiratory performance changes during the early competitive season in professional soccer players. Recently, Younesi et al., [8] assessed the changes in aerobic fitness and CMJ across the season and explored relationships with external workload in professional soccer players. These authors found moderate correlations between workload measures (i.e., total distance, high-speed running, distance sprint and mechanical work) and aerobic fitness as well as CMJ improvements after the initial training period. Notwithstanding, it seems that the associations between external workload and the changes in other performance outcomes, such as sprint performance and eccentric hamstring strength have not been explored in the literature. Considering this gap, the primary purpose of this study was to examine changes in physical performance markers (i.e., eccentric hamstring strength, CMJ height, 20m sprint time, and Yo-Yo test) from preseason to early in-season. Additionally, this study aimed to explore the association between individual physical performance changes and external workload metrics (i.e., GPS data) during this period. We hypothesized that neuromuscular and cardiorespiratory fitness would demonstrate variations over this timeframe, and these variations would associate with external workload metrics.

METHODS

Experimental approach to the problem

Players were evaluated at two different times: in the beginning of the pre-season and eight weeks later, in the early competitive season (in-season). This eight-week period comprised six weeks of pre-season preparation, followed by two weeks of competitive season. The assessments were conducted at the club (outdoor) over two consecutive days, after 48h of recovery, according to the training schedules not to alter the team's training routine. On the first day, jumping performance, hamstring strength, and sprint performance were assessed, respectively. On the second day, the intermittent cardiorespiratory fitness test was applied. After eight weeks, the same assessments were conducted during the same timeframe, with same recovery (48h), at the same time of day (8:30-9:30am), following the same order as the initial evaluation, and wind speed as well as temperature were similar at both pre- and post-test sessions - i.e., 0.8-1.2 m.s-1 and 26-29ºC, relative humidity: 76.8%-77.4%, Digital anemometer, KP-8016 KNUP, Brazil. In both periods, before starting the assessments, athletes performed 10 minutes of a specific warm-up including moderate running, dynamic stretching, skipping exercises, and preparatory acceleration drills. Moreover, tests were overseen by the same experienced assessors, which were proficient in the test protocols, and staff of the team to ensure players' commitment. Players were familiarized with testing procedures and received verbal encouragement to execute the tests to the best of their ability. During the eight-week period between evaluations, forty-six training sessions, three official matches, and five friendly matches were conducted. The 8 matches were performed with 8 days, 11 days, 3 days (outside), 7 days (outside), 4 days and, 11 days (outside) of recovery between each one, and three games were performed at the opponent's stadium (outside) with a total land travel distance of ~ 300km, with the trip taking place the day before the match and the return trip taking place shortly after the match. The respective games were performed in the afternoon (~4:00 to 6:00 pm). Additionally, athletes had nine days off, meaning no training sessions on those days (Table 1 provides details about the training routine over the 8 weeks). During the study period, the whole squad participated of the entire training sessions. Regarding the matches, the GPS data was collected from all players, independent of the minutes played.

Participants

The total sample comprised twenty-one male Brazilian soccer players (age: 25.9 [5.4] years; height: 179.2 [8.4] cm; weight: 79.3 [9.7] kg) from a professional team participating in the State first league and national championships. It was a non-probabilistic convenience sampling approach. Because we only had access to one club, all available athletes of this club were evaluated and no a priori sample size calculation was performed. As eligibility criteria, participants should be asymptomatic and free of injuries, participating in professional soccer training sessions on average 6 times per week, and not using any type of stimulants that could affect their performance. The study was approved by the Local University Research Ethics Committee (approval no. 2903.811), which is in accordance with Helsinki Declaration. Players signed a consent form before the commencement of the research.

TABLE 1 NEAR HERE

Procedures

External workload

The external workload was evaluated by quantifying the total time played and monitoring data through a 10 Hz GPS (Catapult Sports, Melbourne, Australia, number of satellites: 12; dilution of precision: 0.96) worn by all players on the upper part of the torso within a vest designed specifically for this purpose. Previous studies have tested the affirmative validity and reliability of this technology [9-11]. Devices were activated prior to each training session or match, including warm-ups, and raw data files were exported using a software (Player Tek Cloud, Catapult Sports, Melbourne, Australia). The metrics analyzed were the total time played (in minutes) covering both unofficial and official matches, denoted as "minutes played" by each athlete; the average number of "sprints," characterized by running distance and actions surpassing 25 km/h in both training sessions and matches; the average total distance covered by each athlete (in meters) during both training and matches; Power plays, that are a manufacturer produced statistic which count the number of significant actions estimated to elicit a power output of 20 w·kg-1 BM for at least 1 second performed by an athlete during a defined time period. The GPS device registers a power play as a running event >5.0 m·s-1 or an acceleration >2.0 m·s-2, in training and matches and the average training and matches distance covered by the athlete at high intensity (m) considering a speed between 19.8 and 25km/h [12].

Eccentric hamstring strength

The players were tested with a previous reported protocol using a custom-made device with load cells to measure the bilateral eccentric knee flexors strength during the Nordic hamstring exercise (NHE) [13-15]. The player started the test in kneeling position over a padded board (with the hip neutral and the torso upright) and progressively moved the torso forward using only the knee joint (i.e., maintaining the hips and spine neutral). One of the researchers was responsible for supervising the correct execution of the Nordic Hamstring Exercise, controlling the execution time and verbally encouraging the player to continue eccentrically contracting the hamstrings until the end of the exercise. The player used his upper limbs to absorb the fall and to return to the initial position. During the testing, the left and right ankles were individually secured by ankle braces placed superior to the lateral malleolus and fixed to two independent load cells (E-lastic, E-sporte Soluções Esportivas, Brasilia, Brazil) perpendicularly attached to the board. Force data of each load cell were simultaneously transferred via Bluetooth to a mobile cellphone (sample rate = 10 Hz). Players performed at least 3 valid repetitions of the NHE, with a minimum 10-second interval between them. Force values were registered in every repetition, and the bilateral peak value (Newtons) was used for statistical analysis. The test-retest reliability coefficient (ICC) was 0.96 and coefficient variation was 4.7%.

Vertical jump performance

Vertical jump performance was assessed through the height achieved in the countermovement jump (CMJ). Players executed three attempts, each separated by a 10-second rest interval, on a contact platform (Elite Jump System; S2 Sports, São Paulo, Brazil). The movement was initiated from a standing position with hands on hips and athletes were instructed to begin the downward movement followed by full extension of the legs, freely determining the CMJ amplitude. The CMJ best attempt, achieved by the highest jump height value, based on flight time, was used for further analysis. The test-retest reliability coefficient (ICC) was 0.96 and coefficient variation was 2.75%.

Linear sprint performance

Two pairs of single-beamed photocells (Speed-Test, Cefise, São Paulo, Brazil) were positioned above the hip line and the sensors of photocells were positioned, adjusted, and aligned with the greater trochanter of the athletes, at distances of 0- and 20-m along the sprinting course. The soccer players sprinted twice, starting from a standing position, 1-m behind the starting line. The athletes started the sprint with the dominant leg [16]. Pre- and postmeasurements were conducted on the same synthetic soccer turf field, with players wearing their cleats. A 3-min rest interval was allowed between attempts and the fastest time was considered for analysis. The test-retest reliability coefficient (ICC) was 0.93 and coefficient variation was 1.40%.

Intermittent cardiorespiratory fitness

The Yo-Yo Intermittent Recovery Test level 1 (YYIR1) consisted of 2 x 20-m runs back and forth between two lines at a progressively increasing speed controlled by audio bleeps [6]. Outfield players, excluding goolkepers, performed the test. When players failed twice to reach the corresponding line within the due time, the distance covered was recorded and defined as the test result. Each bout was interspersed with a 10-s rest interval. The total distance covered during the YYIR1 (including the last route covered, even if the athlete accomplished it incompletely) was taken as testing score [6]. The test-retest reliability coefficient (ICC) was 0.91 and coefficient variation was 8%.

Statistical Analyses

The mean and confidence interval 95% (CI 95%) were described and the normality of the data was tested by the Shapiro-Wilk test. The primary overall analyses to compare the different moments in the whole athletes group was performed by paired T tests. The effect size (ES) was calculated using Cohen's d represented by ES = ($Mean_{Post}$-$Mean_{Pre}$/Standard $Deviation_{Pre}$), considering the following values as: d between 0.2 and 0.49 = *small* effect; *d* between 0.5 and 0.79 = *medium* effect; and, d > 0.8 as a *large* effect [17]. To verify possible associations between changes in physical performance outcomes (neuromuscular, sprint time and intermittent cardiorespiratory fitness) with the external workload variables (average total distance covered, total game time, average number of sprints, average number of power actions and the average distance traveled at high speed) was used Pearson test for data with normal distribution and Spearman test for non-parametric data. Correlation magnitudes thresholds were small (0.1), *moderate* (0.3), *large* (0.5), *very large* (0.7) and *extremely large* (0.9) [18]. Moreover, to verify whether different magnitudes of external workload performance is related to neuromuscular, sprint and intermittent aerobic performances throughout the period, the players were divided into 50th percentiles: 50% above (upper 50th) and 50% below (lower 50th) average considering distance covered at high-intensity, total minutes and total distance (GPS data on supplementary file). Afterwards, we compared these groups over time for all performance outcomes throughout General Estimating Equations (GEE) to verify the effect of time, group and the interaction group vs. time. Pairwise comparisons were performed using Bonferroni post-hoc tests. The tests were carried out using the Statistical Package for Social Science for Windows (SPSS) version 20.0 software and the significance level adopted was $p < 0.05$.

RESULTS

Overall analysis

Table 2 shows the comparison of physical performance outcomes between early preseason and early in-season. There was a significant reduction in absolute eccentric hamstring strength ($p = 0.014$, ES = -0.41, *small*) and a significant increase in cardiorespiratory fitness ($p = 0.001$, ES = 1.31, *large*). No other significant changes in physical performance outcomes were observed across the study period for the whole cohort of athletes.

TABLE 2 NEAR HERE

Between groups analyses based on GPS data

Data on GPS variables are presented in Table S1 (Supplementary file). When comparing players with the highest (upper 50th percentile) versus lowest (lower 50th percentile) high-intensity running distances, there was a strong trend toward a significant time × group interaction ($p = 0.054$) for CMJ performance (Table 3). Post-hoc analysis revealed a significant increase in CMJ values from preseason to early in-season only for the lowest high-intensity running distance group (lower 50th percentile; $p = 0.030$). No CMJ changes were observed across the study period for athletes covering greater high-intensity running distances (upper 50th percentile; $p = 0.512$).

TABLE 3 NEAR HERE

When comparing athletes with the highest (upper 50th percentile) versus lowest (lower 50th percentile) match minutes played, a significant time × group interaction was observed for the intermittent cardiorespiratory fitness test ($p = 0.004$) (Table 4). Post-hoc analysis revealed that athletes playing more minutes (upper 50th percentile) showed greater improvements in intermittent cardiorespiratory test distance from preseason to early in-season ($p<0.001$). In contrast, players with lower match minutes (lower 50th percentile) exhibited no changes in this measure across assessments ($p = 0.094$).

TABLE 4 NEAR HERE

When comparing players covering the greatest (upper 50th percentile) versus lowest (lower 50th percentile) total distances (Table S2, Supplementary file), there were no significant group × time interactions for neuromuscular, sprint, or cardiorespiratory performance outcomes. However, a significant main effect for time was observed for intermittent cardiorespiratory test distance ($p<0.001$), indicating improvements from preseason to early in-season in both the upper and lower 50th percentile total distance groups. Independent of the GPS variable of stratification, there was a significant effect of time for absolute eccentric hamstring strength ($P<0.05$). An example of the association between mean pre to in-season difference in the eccentric hamstring strength with average total distance is presented in the Figure S1 (Supplementary file).

Association between GPS data and physical performance outcomes

Data on associations between GPS data and physical performance are presented in the Table S3 (Supplementary file). Regarding the associations between external workload and physical performance changes, improvements in intermittent cardiorespiratory test distance from preseason to early in-season significantly correlated with average match minutes played (rho = 0.534, *large*, p = 0.040) (Figure 1). Additionally, changes in 20 m linear sprint time between assessments inversely correlated with the number of sprints performed during training and matches (r = -0.453, *moderate*, p = 0.045) (Figure 2). That is, more performed sprints associated with greater reductions in 20 m sprint times. No other significant correlations were observed (Table S3)

FIGURE 1 NEAR HERE

FIGURE 2 NEAR HERE

DISCUSSION

The main findings of this study were: (i) the absolute eccentric hamstring strength significantly declined from preseason to early in-season over the 8-

week study period, while intermittent cardiorespiratory fitness significantly improved, especially in athletes playing more match minutes; (ii) players with lower high-intensity running distance tended to increase CMJ height; and (iii) greater average sprints performed during training and matches was associated with enhanced 20-m linear sprint performance. Our hypothesis was supported, as the 8-week transition from preseason to in-season provoked reductions in eccentric hamstring strength yet increases in cardiorespiratory fitness. Additionally, associations emerged between physical performance changes and GPS-derived external workloads. Therefore, once hamstring strength declined and CMJ was only improved in those athletes performing less high-intensity actions, strength and conditioning coaches should include individualized training strategies and workload management to counteract these conditions when high external workload is performed along the season.

In elite soccer, pre-season and early in-season constitute the period of greatest workload [19-21], as coaches focus on physical conditioning [22]. Consequently, the high pre-season external workloads and subsequent congested competition may cause residual fatigue, affecting physical capacities and improving injury risk [23-25]. There are some studies aiming to investigate the effects of external and internal workload on physical conditioning, especially cardiorespiratory fitness. Recently, Martin et al. [26] measured changes on intermittent running across different periods of the season, using 6-minute continuous running test at a constant speed and a high-speed intermittent test with changes of direction. The moderate to large relationships found between all measures of workload and changes in physical capacities suggest that training prescription during the preseason was effective in improving players' aerobic fitness and intermittent running capacity. However, these authors did not assess neuromuscular capabilities, which could present different behavior compared to cardiorespiratory measures, as observed in the present study. Using a different protocol, Younesi et al. [8] analyzed changes on aerobic fitness, CMJ, and explored relationships with training workload in professional soccer players. The authors predominantly used the Vameval and the 30-15 intermittent fitness tests, with both performed with the final speed achieved on the last lap of the run, unlike the present study which uses the Yo-Yo Intermittent Recovery test. Similar results to ours were found in relation to cardiorespiratory and sprint abilities (i.e., the Vameval test increased and 20-m sprint time decreased compared to the initial training period). However, contrary to our findings, when analyzing CMJ values after the initial period, the authors found improvements in this outcome.

The controversial results pointed out that our findings add novel information to literature, demonstrating some level of interference effect on CMJ and NHE depending on the external workload magnitude. It is important to highlight that low levels of eccentric hamstring strength assessed during NHE increase the risk of future hamstring strain injuries [13, 27]. It should be highlighted that, independent of the GPS variable of stratification, there was a reduction absolute eccentric hamstring strength in both groups (i.e., lower and upper 50^{th} percentile). Thus, strength and conditioning coaches as well as medical staff should be aware that strength exercises focused in the hamstrings should be applied in all players independently of minutes played or covered high-intensity distance to prevent such decreases.

The lack of CMJ changes in the present study could stem from no specialized plyometric training (Table 1). However, when stratified by high-intensity running volumes, players covering lower distances at high-intensity improved CMJ performance. Conversely, those classified in the upper 50th percentile for high-intensity running showed no CMJ changes. This aligns with the interference effect described in aerobic-dominant sports [28,29]; high cardiorespiratory workloads during the season hinder neuromuscular adaptations [30,31]. In contrast, 27% and 42% Yo-Yo test improvements following 4-week preseason and 8-week in-season programs, respectively, are demonstrated in previous research [32]. Taking together, these results highlight the importance of balancing resistance/power and cardiorespiratory training to obtain the best results from both training modalities without significant interference effect.

Although the physiological mechanisms regulating the effects of external workload on neuromuscular function in team-sports athletes are not completely elucidated, there appear to be manifold signaling responses induced by endurance exercise capable of inhibiting neuromuscular abilities [33,34]. Since previous studies demonstrated that decreases of strength/power capabilities are not related to changes on muscle activity/recruitment, it is suggested that the mechanism behind the interference effects would be related to peripheral factors such as glycogen depletion and carbohydrate oxidation and not to neural factors [33,34]. However, the present study did not assess these issues, and future studies are needed to demonstrate the effects of soccer workload on muscle glycogen depletion and its relationship with a possible interference effect. Therewithal, future investigations are also necessary to assess physical changes and external workload during the whole season.

The current study has limitations. The complete force-angle curve during Nordic Hamstring Exercise testing was not monitored. Only peak force values were considered; thus, potential alterations in angle of force application were not evaluated, which could impact peak force [35]. Additionally, our single-team design restricted sample size and made a control group impossible. On the other hand, the present study has also strengths that should be highlighted. Our study reflects the unpredictable, dynamic, and "real-world" challenges of professional sports reality. The stratification based on external workload magnitude is a novelty of the present study, and it has important practical applications. It indicates that the different magnitude of the external workload applied directly influences the changes in physical capabilities observed between players on the same team. Therefore, it is important to emphasize that no previous research aimed to evaluate the eccentric hamstring strength, a crucial outcome for soccer players [5], as well as establishing thresholds of external workload to observe changes on different physical capabilities, as assessed in the present study.

CONCLUSION

Even over a short early season timeframe, professional soccer players demonstrated performance fluctuations associated with external loads. While intermittent cardiorespiratory fitness improved, the eccentric hamstring strength declined. External workload relationships included inverse associations between high-intensity running and CMJ height yet positive associations with

Yo-Yo test performance. Sprint volumes were positively correlated with changes in 20-m sprint times.

The early season hamstring strength declines may be treated with caution at the start of competition, necessitating preventive protocols and specialized training for extended periods. Additionally, unimproved countermovement jumps in some players reveal an imbalance between strength/power and technical/tactical workloads in soccer, emphasizing the importance of balancing these capacities year-round. Moreover, the greater sprint exposures related to enhanced 20-m sprint performance, highlights the need for compensatory speed training in non-starters lacking sufficient pitch sprints during soccer-specific training. Crucially, the associations between physical performance fluctuations and GPS-derived workloads demonstrated highly individualized responses dependent on seasonal external demands. Accordingly, although general scientific recommendations for professional teams are reported in this study, analyses should emphasize individual changes based on respective external workloads rather than group averages. Our results provided important insights for strength and conditioning coaches to monitor performance variations and relationships with external workloads when programming training across the season for professional soccer players.

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List of Tables

1) **Table 1:**

Title: Training routine of football players during the 8-week period.

Legend:
BM, body mass; NHE (Nordic hamstring exercise); reps, repetitions; RST (Resisted Sprint Training).

2) **Table 2:**

Title: Comparison between early pre-season values and the early competitive season for physical performance outcomes (Mean and CI%95).

Legend:
*Significant difference between moments ($p<0.05$).
Δ%: percentage change; ES: effect size; CMJ: countermovement jump.

3) **Table 3:**

Title: Distance covered at high intensity (m) and physical performance outcomes (Mean and CI%95).

Legend:
CMJ: countermovement jump; ES: effect size;
[#]Trend toward significant time vs. group interaction.
*Significant difference compared to pre-season values ($P<0.05$).
[a] Intermittent cardiorespiratory fitness results were based in the analysis of 8 and 7 participants in the groups considered of higher and lower distance covered at high-intensity, respectively.

4) **Table 4:**

Title: Minutes played (min) and performance outcomes (Mean and CI%95).

Legend:
CMJ: countermovement jump; ES: effect size.
† Significant time vs. group interaction.
Significant difference compared to pre-season values: * ($P<0.05$), **($P<0.001$).
[a]Intermittent cardiorespiratory fitness results were based in the analysis of 8 and 7 participants in the groups considered of higher and lower performance, respectively.

Figure legends

1) Figure 1. Correlation between Intermittent Cardiorespiratory Fitness average Minutes played

2) Figure 2. Correlation between linear sprint performance with average number of sprints

3) Supplementary Figure (S1). Regression analysis between the mean pre to in-season difference in the of eccentric hamstring strength with average total distance.

Supplementary File

Table S1: Global positioning system data (Mean and confidence interval 95%):

	Whole Group (n=19)	Upper 50th (n=10)	Lower 50th (n=9)
Distance covered at high intensity (m)	225.3 (200.6, 249.9)	255.1 (252.5, 257.6)	192.2 (146.5, 237.9)
Played Minutes (min)	259.8 (184.4, 335.2)	374.5 (290.4, 458.6)	132.3 (79.4, 185.2)
Total distance (m)	4802.3 (4600.3, 5004.4)	5052.0 (5005.5, 5098.2)	4525.0 (4159.6, 4890.6)

Table S2: Effect total distance covered (m) on neuromuscular performance (Mean and confidence interval 95%).

	Group with upper 50th total distance (n=10)			Group with lower 50th total distance (n=9)			Time vs. group interaction
	Pre-season	In-season	ES	Pre-season	In-season	ES	*P values*
CMJ (cm)	42.1 (38.5, 45.8)	42.8 (38.5, 47.2)	0.11	38.9 (35.4, 42.4)	40.1 (36.3, 43.8)	0.21	0.761
Linear sprint performance (s)	2.79 (2.76, 2.83)	2.76 (2.70, 2.82)	-0.50	2.89 (2.79, 2.98)	2.86 (2.74, 2.97)	-0.20	0.963
Hamstring Strength absolute (N)	377.2 (341.4, 413.0)	357.0* (335.2, 378.7)	-0.33	388.45 (345.7, 431.2)	362.67* (323.2, 402.2)	-0.37	0.763
Hamstring Strength relative(N/Kg)	5.05 (4.8, 5.3)	4.62 (4.4, 4.9)	-1.0	4.73 (4.2, 5.2)	4.52 (4.2, 4.8)	-0.26	0.586
Intermittent Cardiorespiratory Fitness (m) [a]	1727.5 (1374.2, 2080.8)	2405* (1767.1, 3042.9)	1.24	1577.1 (1217.4, 1936.9)	2271.4* (1835.9, 2706.9)	1.32	0.959

CMJ: countermovement jump; ES: effect size.
*Significant difference compared to pre-season values (P<0.05).
[a]Intermittent cardiorespiratory fitness results were based in the analysis of 8 and 7 participants in the groups considered of higher and lower performance, respectively.

Table S3: Correlations between intermittent cardiorespiratory fitness, absolute and relative hamstring strength, linear sprint performance and vertical jump with external load (GPS) outcomes.

	Correlation coefficients	*P values*
Intermittent Cardiorespiratory Fitness[b] (m) (n=15)		
Total distance (m)	-0.214	0.444
Minutes played (min)	0.534	0.040*
Distance at high intensity (m)	-0.212	0.448
Sprint actions	-0.316	0.235
Power play	-0.186	0.508
Hamstring Strength absolute[a] (N) (n=19)		
Total distance (m)	0.303	0.207
Minutes played (min)	0.004	0.988
Distance at high intensity (m)	0.267	0.268
Sprint actions	0.015	0.952
Power play	0.225	0.354
Hamstring Strength relative[b] (N/kg) (n=19)		
Total distance (m)	-0.005	0.983
Minutes played (min)	-0.107	0.663
Distance at high intensity (m)	-0.044	0.857
Sprint actions	-0.344	0.149
Power play	-0.155	0.527
Linear sprint performance[a] (s) (n=20)		
Total distance (m)	-0.068	0.775
Minutes played (min)	0.267	0.255
Distance at high intensity (m)	-0.220	0.352
Sprint actions	-0.453	0.045*
Power play	-0.205	0.386
CMJ[a] (cm) (n=20)		
Total distance (m)	-0.253	0.282
Minutes played (min)	-0.244	0.301
Distance at high intensity (m)	-0.320	0.169
Sprint actions	-0.157	0.509
Power play	-0.250	0.289

CMJ: countermovement jump.

[a] Pearson correlation coefficients (r values); [b] Spearman correlation coefficients (rho values).

*Denotes statistical significance ($p<0.05$).

Table 1: Training routine of football players during the 8-week period:

Strength training (once a week)	Resisted sprint training (1 or 2 times a week)	Soccer specific training
1–2 sets of 12 reps of unloaded unilateral stiff	First and second session: 3 x 4 reps	Day 1: RST, small sided games with multiple configurations and/or tactical training (offensive and defensive transitions; 50 min)
1–2 sets of 8 reps of NHE	Third and fourth session: 3 x 5 reps	Day 2: Technical tasks (eg, passing accuracy, ball possession, and technical training according to playing position; 40 min)
1–2 sets of 8 reps of jump squat with ∼40% BM	Fifth session: 4 x 4 reps	Day 3: Defensive tasks (eg, pressing, ball interceptions, and clearances) and positioning (50 min)
1–2 sets of 8 reps of step-up hip extension with 20 kg of external load	Sixth session: 3 x 4 reps	Day 4: Dribbling, shooting, and offensive tasks (60 min)
1–2 sets of 8 reps of squat with ∼50% BM	Seventh and eighth session: 3 x 4 reps	Day 5: Technical–tactical training (30 min)
1–2 sets of lateral squat with 10 kg of external load	Ninth session: 1 x 6 reps	Day 6: Recreative small-sided games (20 min) Day 7: Official or friendly match

BM, body mass; NHE (Nordic hamstring exercise); reps, repetitions; RST (Resisted Sprint Training).

Table 2: Comparison between early pre-season values and the early competitive season for physical performance outcomes (Mean and CI %95):

	Pre-season	In-season	Δ (%)	P *values*	ES
CMJ (cm) (n=21)	40.6 (37.95, 43.2)	41.1 (38.0, 44.2)	1.37 ± 9.24	0.526	0.09
Linear sprint performance (s) (n=21)	2.83 (2.77, 2.89)	2.80 (2.73, 2.87)	-0.96 ± 3.14	0.186	-0.25
Hamstring Strength absolute (N) (n=20)	385.2 (355.8, 414.7)	359.5 (336.7, 382.4)	-5.64 ± 11.34	0.014*	-0.41
Hamstring Strength relative ($N.kg^{-1}$) (n=20)	4.88 (4.59, 5.17)	4.54 (4.31, 4.77)	-5.18 ± 19.30	0.091	-0.54
Intermittent Cardiorespiratory Fitness (m) (n=15)	1657.3 (1368.0, 1946.0)	2342.7 (1892.2, 2793.2)	45.62 ± 50.35	0.001*	1.31

*Significant difference between moments (p<0.05).

Δ%: percentage change; ES: effect size; CMJ: countermovement jump.

Table 3: Distance covered at high intensity (m) and physical performance outcomes (Mean and CI%95):

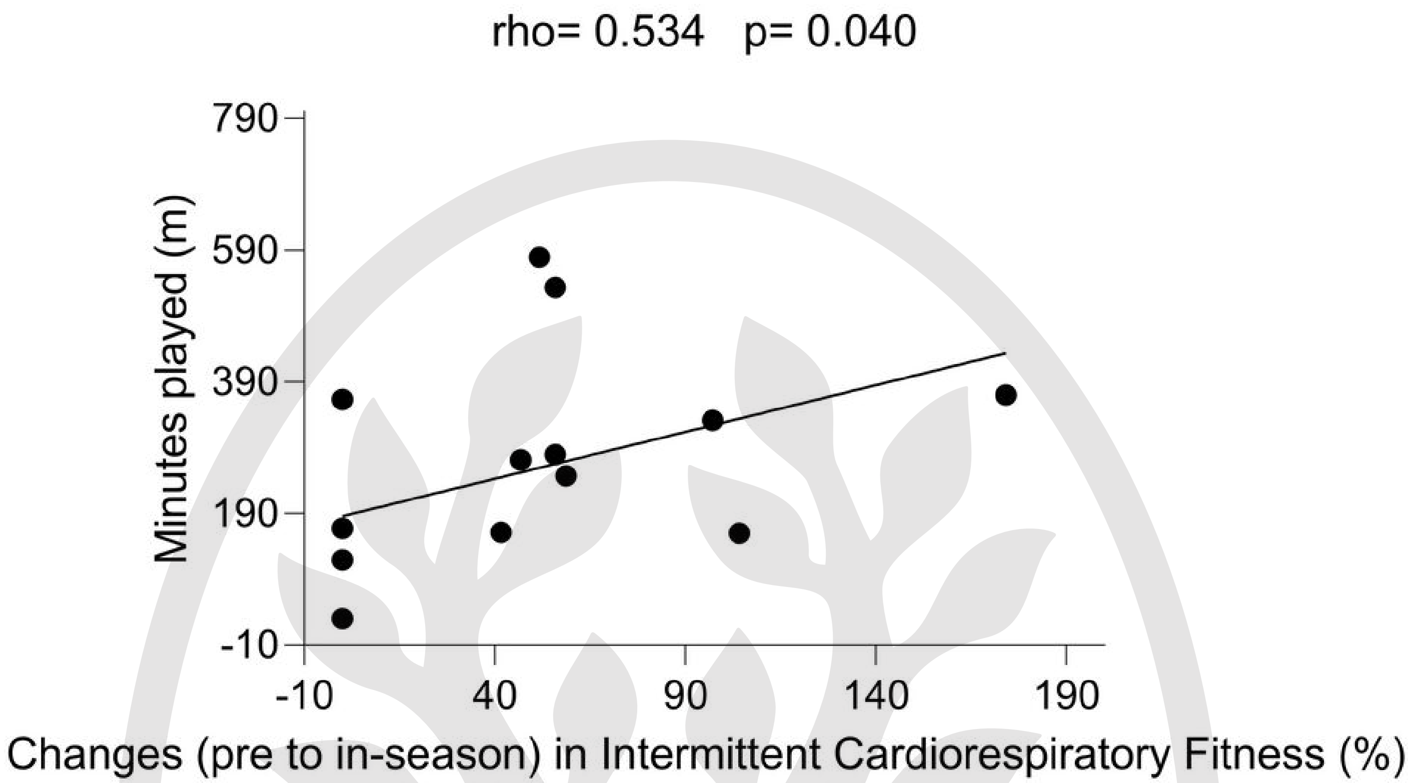
	Group with upper 50th distance covered at high intensity (n=10)			Group with lower 50th distance covered at high intensity (n=9)			Time vs. group interaction
	Pre-season	In-season	ES	Pre-season	In-season	ES	*P values*
CMJ (cm)	43.7 (39.7, 47.6)	43.0 (38.8, 47.2)	-0.10	38.7 (35.4, 41.9)	40.7* (36.3, 45.1)	0.37	0.054[#]
Linear sprint performance (s)	2.79 (2.75, 2.83)	2.76 (2.70, 2.81)	-0.50	2.88 (2.78, 2.98)	2.85 (2.73, 2.96)	-0.20	0.922
Absolute hamstring strength (N)	375.2 (339.7, 410.75)	349.0* (324, 374)	-0.43	390.0 (347.6, 432.3)	369.2* (332.9, 405.5)	-0.30	0.774
Relative hamstring strength (N/Kg)	4.97 (4.75, 5.2)	4.48 (4.16, 4.79)	-1.36	4.73 (4.24, 5.22)	4.60 (4.30, 4.89)	-0.16	0.365
Intermittent Cardiorespiratory Fitness (m) [a]	1722.5 (1370.1, 2074.9)	2425.0* (1780.8, 3069.3)	1.29	1583.0 (1220.7, 1945.0)	2248.6* (1830.1, 2667.0)	1.26	0.911

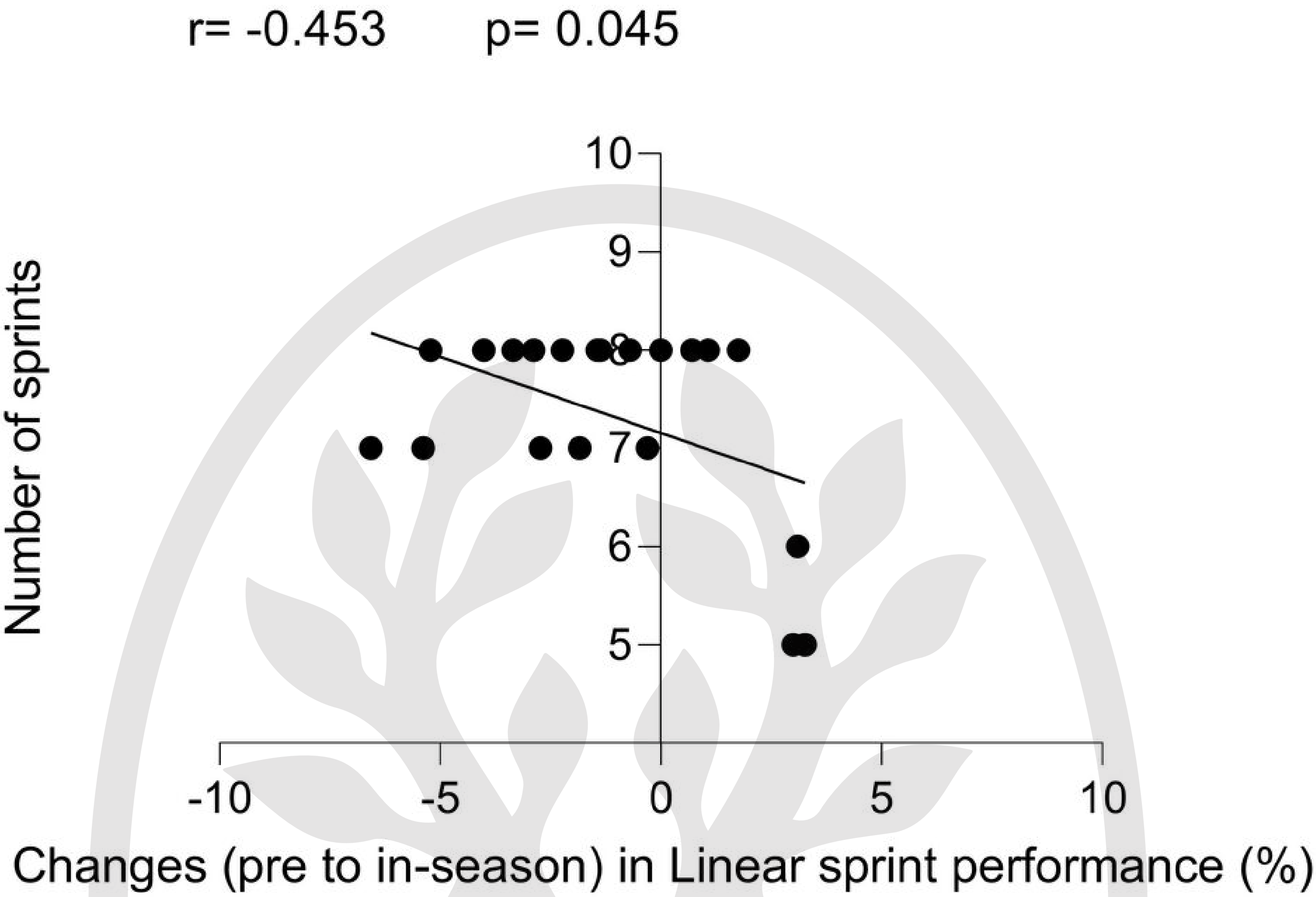
CMJ: countermovement jump; ES: effect size;
[#]Trend toward significant time vs. group interaction.
*Significant difference compared to pre-season values (P<0.05).
[a] Intermittent cardiorespiratory fitness results were based in the analysis of 8 and 7 participants in the groups considered of higher and lower distance covered at high-intensity, respectively.

Table 4: Minutes played (min) and performance outcomes (Mean and CI%95):

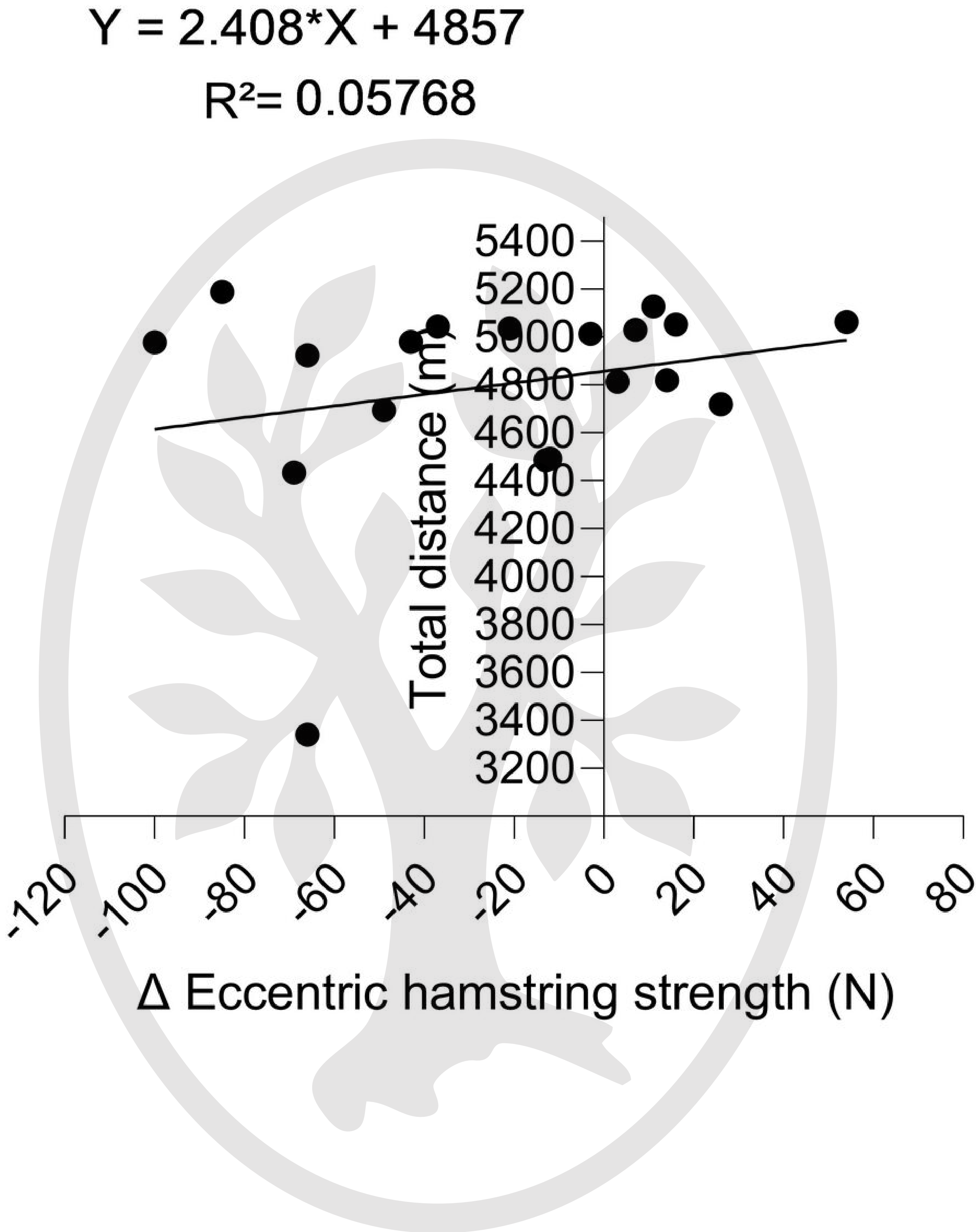
	Group with upper 50th minutes played (n=10)			Group with lower 50th minutes played (n=9)			Time vs. group interaction
	Pre-season	In-season	ES	Pre-season	In-season	ES	*P values*
CMJ (cm)	40.5 (37.1, 43.9)	41.4 (37.0, 45.8)	0.15	40.7 (36.6, 44.8)	41.6 (37.7, 45.5)	0.13	0.983
Linear sprint performance (s)	2.80 (2.76, 2.84)	2.79 (2.72, 2.86)	-0.14	2.88 (2.78, 2.98)	2.82 (2.70, 2.93)	-0.40	0.106
Hamstring Strength absolute (N)	386.9 (341.9, 431.9)	370.9* (339.0, 402.9)	-0.20	377.7 (347.5, 408)	347.2* (319.5, 374.8)	-0.62	0.423
Hamstring Strength relative(N/Kg)	4.84 (4.49, 5.18)	4.54 (4.24, 4.83)	-0.50	4.96 (4.53, 5.4)	4.61 (4.3, 4.91)	-0.50	0.888
Intermittent Cardiorespiratory Fitness (m) [a]	1712.5 (1451.2, 973.8)	2747.5** (2396, 3099)	2.56	1594.3 (1140.6, 2048)	1880 (1292.9, 2467.1)	0.43	0.004†

CMJ: countermovement jump; ES: effect size.
† Significant time vs. group interaction.
Significant difference compared to pre-season values: * (P<0.05), **(P<0.001).
[a]Intermittent cardiorespiratory fitness results were based in the analysis of 8 and 7 participants in the groups considered of higher and lower performance, respectively.


rho= 0.534 p= 0.040
790
590
390
190
-10
Minutes played (m)
-10
40
90
140
190
Changes (pre to in-season) in Intermittent Cardiorespiratory Fitness (%)



r= -0.453 p= 0.045
Number of sprints
10
9
8
7
6
5
-10
-5
0
5
10
Changes (pre to in-season) in Linear sprint performance (%)


Y = 2.408*X + 4857
R²= 0.05768
Total distance (m)
5400
5200
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
-120
-100
-80
-60
-40
-20
0
20
40
60
80
Δ Eccentric hamstring strength (N)