Performance and Muscle Architecture Comparisons Between Starters and Nonstarters in National Collegiate Athletic Association Division I Women’s Soccer


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INTRODUCTION

The National Collegiate Athletic Association (NCAA) soccer season lasts for ~3 months, with the potential for an additional month of postseason play. During the competitive season, games are generally played twice per week with less than 48 hours between matches and occasionally include travel. With a demanding game schedule, adequate recovery may not be achieved by the athlete, potentially leading to decreased performance over the course of the season, especially in starting players (31). This is likely due to the increased exercise volume (e.g., greater repetitions in practice and playing time in games) and physiological stress that is associated with greater playing time (25,31). Although some investigators have reported maintenance of physical performance measures during a competitive season (29,39), others have reported decrements in power (31), strength (25), and speed (25). These latter studies may reflect early signs of overreaching that can potentially influence game outcomes. Therefore, monitoring these variables throughout the competitive season may provide coaches an ability to detect decrements in performance before it manifests itself into actual game losses and allow for sufficient rest and recovery for the athlete to return to optimal performance.

KEY WORDS sport science, power, athletes, ultrasonography, reaction, tracking

ABSTRACT

Jajtner, AR, Hoffman, JR, Scanlon, TC, Wells, AJ, Townsend, JR, Beyer, KS, Mangine, GT, McCormack, WP, Bohner, JD, Fragala, MS, and Stout, JR. Performance and muscle architecture comparisons between starters and nonstarters in National Collegiate Athletic Association Division I women’s soccer. J Strength Cond Res 27(9): 2355–2365, 2013—This study compared performance and muscle architecture (MA) changes in starters (S) and nonstarters (NS) during a National Collegiate Athletic Association Division I women’s soccer season. Twenty-eight women (19.9 ± 1.1 years; 1.71 ± 0.08 m; 64.7 ± 6.4 kg) were monitored for vertical jump power (VJP), repeated line drills (LDs), 3-dimensional multiple object tracking (3D-MOT), and reaction time (RT) at preseason, midseason, and postseason. Muscle architecture changes using ultrasonography were assessed at preseason and postseason. Comparisons between S (n = 11; 70.0 ± 1.46 min per game) and NS (n = 17; 8.4 ± 8.0 min per game) were performed to make magnitude-based inferences. No differences were seen in VJP during the season in either group. Starters were more likely (81.1%) to decrease LD time than NS, with no differences in fatigue rate. Starters and NS improved 3D-MOT (1.14 ± 0.41 to 1.55 ± 0.43) and RT (0.37 ± 0.05 to 0.34 ± 0.33 seconds), with no differences between groups. Rectus femoris (RF) echo intensity improved (65.57 ± 1.50 to 61.26 ± 1.59) in both groups, with no interactions observed. Cross-sectional area (20.84 ± 3.58 to 21.46 ± 3.66 cm²) increased and pennation angle (PANG) (12.58 ± 2.56 to 11.78 ± 2.03°) decreased for both groups in the vastus lateralis (VL). Muscle architecture comparisons between groups revealed S likely decreased VL muscle thickness (MT) and PANG (81.6 and 79.4%, respectively) and possibly decreased RF MT and PANG (65.7 and 59.4%, respectively) when compared with NS. Results indicate that VJP and LD fatigue rate are not changed during a competitive season, but S become faster than NS. Three-dimensional multiple object tracking and RT improve regardless of playing time. Changes in MA indicate that practices alone provide sufficient stimulus for improving muscle quality during the competitive season.
Effect of Playing Time on Performance and MA in Soccer

The development of an in-season sport-specific assessment program provides coaches with sensitive data measures that can provide an early indicator of fatigue with the opportunity to make adjustments to training programs and ultimately avoid undesired performance decrements (38). It is often the sport scientist or strength and conditioning professional that perform these assessments and present the evidence to the sport coach to potentially alter or reduce practice schedules. These measures often include both physical and psychological profiling (16,17,25,29), enabling sport scientists to examine multiple indicators of potential fatigue. The broad array of testing provides the ability to examine multisystem effects that may interact with actual game performance. For instance, a decrease in lower-body power by itself may not result in large changes in practice duration or intensity. However, if it is coupled with a decrease in the athlete’s subjective measures of fatigue, focus or energy and perhaps a change in reaction time (RT) or other physical measure, this would provide stronger evidence to present to the sport coach to enhance player recovery and restoration.

Sporis et al. (40) have recently suggested that speed and power are important measures of fitness profiling in soccer athletes. However, those assessments alone only provide an indicator of performance, but not necessarily the athlete’s physical condition to play (19). The line drill (LD) has been often used to measure anaerobic capacity and is often used to indicate anaerobic fitness (11,20). Although the LD has been used extensively with basketball players (11,20,32), it is also employed in American football (21) and soccer (43). Although the use of performance tests like the LD and vertical jump are well established, recent technological advances have allowed for a greater sensitivity to assess performance change, physiological adaptation, or perhaps maladaptation during the competitive season. The use of ultrasound measures has been suggested as a potential noninvasive technique that may be employed to monitor changes in muscle size and architecture and as a diagnostic tool for injury recognition (8,15,30,36,37). Although the use of ultrasound has been primarily focused on injury diagnosis (18,30), recent studies have suggested that muscle quality can be assessed by gray scale analysis from cross-sectional ultrasonographic images and is referred to as echo intensity (EI) (8,15). Echo intensity is sensitive to structural changes in the muscle over time, including increased fibrous tissue (14,34), whereas the image used to determine EI can monitor differences in muscle size (9). In addition, sport outcomes are often decided by the athlete’s ability to track multiple moving objects across their field of vision (41). As the athlete fatigues their ability to maintain tracking, ability may be compromised. Decrease in tracking may result in a delayed reaction to game stimuli resulting in a potential negative outcome. The ability to monitor this performance may provide greater sensitivity to the broad assessment battery used by sport science staffs. Therefore, the purpose of this study was to examine the effects of a NCAA women’s Division I soccer season on changes in physical performance and muscle architecture (MA). In addition, the effect of playing time (comparison between starters [S] and nonstarters [NS]) on these assessments was also examined.

Methods

Experimental Approach to the Problem

Players from the university’s women’s soccer team (n = 28) completed assessments at 3 different time points throughout the competitive season: preseason, midseason, and postseason. Assessments were separated by approximately 1 month. All testing was performed as part of the sport science assessment program. Anthropometric measures included height and weight. Performance measures included lower-body power (vertical jump power [VJP]) and the LD. Additional measures included visual analog scales (VASs) to subjectively measure energy, focus, fatigue, and alertness and multiple object tracking and RT. Muscle size and architecture, as quantified by ultrasound, were assessed at preseason and postseason time points only. Playing time for each athlete was recorded after each game, and players were then split into 2 different groups dependent on average minutes played per game. Players averaging greater than 40 min per game (n = 11) were considered S, whereas players that averaged less than 40 minutes (n = 17) were considered NS. This provided the ability to retrospectively examine the influence of playing time on performance measures from deidentified data.

Subjects

Twenty-eight female NCAA Division I soccer players (S: age: 20.5 ± 1.2 years, height: 1.69 ± 0.05 m, body mass: 64.2 ± 6.0 kg; and NS: age: 19.5 ± 0.9 years, height: 1.73 ± 0.09 m, body mass: 65.1 ± 6.8 kg) agreed to participate in the study. The players were members of the University of Central Florida women’s soccer team which finished the 2012 NCAA season ranked 20th in Division I, with a record of 17-5-2. The players gave their informed consent as part of their sport requirements, which is consistent with our institution’s policies for use of human subject research.

Procedures

In-Season Resistance Training Program. The in-season strength and conditioning training program was developed by study investigators and supervised by the University’s coaching staff. The training program consisted of 8 exercises (4 core exercises) performed twice per week, with 72 hours separating each training session. The training program was the same for both S and NS. Core exercises included squats, high pulls, bench press, and either dumbbell lunge (workout 1) or squat jumps (workout 2). In addition, athletes also performed the seated dumbbell shoulder press, leg curl, standing calf raise, and triceps extension exercises. Three sets of 6–8 repetitions were performed for each exercise, except the high pull (4–6 repetitions) and squat jump (3 repetitions) exercises.

Muscle Architecture. Measurements of muscle thickness (MT), cross-sectional area (CSA), pennation angle (PANG), and EI were collected via noninvasive ultrasonography. Echo
intensity is an arbitrary measure of muscle quality based on a gray scale analysis of the muscle (15). All measures were collected on the vastus lateralis (VL) and rectus femoris (RF) of the subject’s dominant leg and performed by the same technician to minimize error. Intraclass correlation coefficients and standard error of measurements for the technician were determined before data collection.

Before measurement, subjects laid in a supine position for 15 minutes with a rolled towel beneath the knee to allow for a 10-degree bend as measured by a goniometer. After 15 minutes, measurements were taken using a 12 MHz linear probe (General Electric LOGIQ P5, Wauwatosa, WI) coated with a water-based conduction gel; Parker Laboratories, Inc., Fairfield, NJ, USA). Settings for the ultrasound were standardized to ensure EI consistency (frequency set at 12 MHz, gain set at 50, dynamic range set at 72, and depth set at 5 cm) (15).

Measurements for the RF were taken at 50% of the distance from the anterior, inferior suprapatellar spine to the most proximal point of the patella (9). Cross-sectional area was then obtained with an image sweep in the transverse plane, perpendicular to the muscle tissue (Intraclass Coefficient Correlation [ICC], SEM; RF: 0.99, 0.46 cm²). For measurements of MT, the probe was oriented longitudinally in the sagittal plane parallel to the muscle tissue (ICC, SEM; RF: 0.96, 0.11 cm). Vastus lateralis measurements were taken in the same fashion as previously stated; however, the sampling location was determined by 50% the straight-line distance between the greater trochanter and the lateral epicondyle of the femur (2) (ICC, SEM; CSA: 0.99, 1.26 cm²; MT: 0.89, 0.12 cm). Once images were collected, analysis was completed using Image J software (version 1.45s; National Institutes of Health, Bethesda, MD, USA). Cross-sectional area and EI (ICC, SEM; RF: 0.91, 3.47; VL: 0.93, 5.1) were measured on the transverse image sweep using a known distance of 1 cm within the image to calibrate to software (35). Briefly, CSA was measured by tracing the outline of the RF or VL in Image J using the freeclass tool, whereas EI was determined using the standard histogram function, a quantification of gray scale with arbitrary units ranging from 0 to 255 in the area previously determined for CSA. When traced in Image J, this area excluded the muscle fascia to minimize the effects on gray scale (8.15). In the longitudinal image, the intersection of deep aponeurosis and the fascicle of each muscle (RF and VL) was used to determine the pennation angle (ICC, SEM; RF: 0.73, 2.8°; VL: −0.05, 2.02°).

Line Drill. All players, excluding goalkeepers (n = 18), completed three 200-m shuttle runs. Each run consisted of the athlete sprinting to a cone 10-m away and back, then immediately sprinting to a cone 20-m away and back, then 30-m and back, and finally to a cone 40-m away and back. Once each 200-m shuttle was completed, athletes were allowed 2 minutes of recovery before completing the next sprint. During the recovery period, heart rates were collected immediately post, 1-minute post, and 2-minutes postrun. All trials were completed on an outdoor Martin Surface running track. The track conditions were the same for all 3 testing sessions. The validity and reliability of LD has been previously reported (11).

Lower-Body Power. To measure lower-body power, each player performed 5 consecutive countermovement jumps. During each jump, players stood with their hands on their waist at all times and were instructed to maximize the height of each jump while minimizing the contact time with the ground between jumps. Subjects wore a belt connected to a Tendo Power Output Unit (Tendo Sports Machines, Trenčín, Slovak Republic). The velocity of each jump was calculated and the mean power output (VJP) for each repetition was recorded and used for subsequent analysis. Test–retest reliability of the Tendo unit in our laboratory has consistently had R > 90%.

Multiple Object Tracking. Each athlete completed 1 session on the core setting of the Neurotracker (CogniSens Athletic Inc., Montreal, Quebec, Canada) 3-dimensional multiple object tracking system (3D-MOT). Results were quantified by a threshold speed, expressed as an arbitrary number on a log scale. Typically, values range from 0 to ~3 in trained athletes (13). Participants were placed in a dark room, 7 feet in front of a projection screen while wearing glasses to make objects appear 3-dimensionally. Each core session consisted of 20 individual sessions lasting 8 seconds, in which 8 yellow balls moved around a 3-dimensional cube, bouncing of the walls, and each other. Before each session, 4 of the 8 yellow balls were highlighted white, and subjects were instructed to track each of the balls that turned white. Once the balls returned to their original color, they began their movement. After each trial, the balls were assigned a number, and the athlete identified the 4 balls they believed to be correct. If the athlete answered correctly, the speed was increased; if the athlete answered incorrectly, the speed was decreased. After the 20 trials were complete, a threshold speed was determined for each subject based on their performance during the 20 trials. Previous research has reported that the threshold speed observed is related to an improved ability to perceive biologic movement (28).

Reaction Time. Lower-body RT was measured with a 20-second reaction test on the Quick Board (LLC, Memphis, TN, USA) reaction timer. Subjects stood on a board of 5 circles, in a 2 × 1 × 2 pattern. Subjects straddled the middle circle and reacted to a visual stimulus located on a display box that depicted 1 of 5 potential lights that corresponded with the circles on the board. On activation of the light, the subject attempted to move the foot closest to the circle that corresponded to the visual stimulus. On a successful connection, the next stimulus would appear. The total number of successful attempts for the 20-second test and the average time between the activation of the light and the response to the corresponding circle was recorded.
Upper-body RT was assessed using the Dynavision D2 Visuomotor Training Device (D2; Dynavision International LLC, West Chester, OH, USA). The D2 is a light-training reaction device, designed to train sensory motor integration through the visual system. It consists of a board (4 × 4 foot) that can be raised or lowered relative to the height of the operator. It contains 64 target buttons arranged into 5 concentric circles surrounding a center screen that can be illuminated to serve as a stimulus for the subject. For each test, the participant stood in front of the board with the center screen at eye level and so that the outermost of the buttons were within reach. A total of 3 different reaction tests were conducted.

The first assessment measured the participant's visual, motor, and physical RT to a stimulus with the dominant hand. The test was initiated when a participant placed and held his/her hand on an illuminated “home” button. At this point, a stimulus would present in 1 of 5 locations, parallel to the home button. Visual RT (ICC3,1 = 0.83; \( SEM = 0.021 \) seconds) was measured as the amount of time it took to identify the stimulus and initiate a reaction by leaving the home button. Motor response time (ICC3,1 = 0.79; \( SEM = 0.049 \) seconds) was measured as the amount of time (measured in 1/100’s of a second) it took to physically strike the stimulus after the initial visual reaction and is measured as the amount of time between the hand leaving the home button and striking the stimulus. Physical RT was a measurement of the total elapsed time from the introduction of the target stimulus to the physical completion of the task (returning to the home button after striking the stimulus). This was repeated 10 times per assessment.

Subjective Measures of Energy, Focus, Alertness, and Fatigue. Subjects were instructed to assess their subjective feelings of energy, focus, alertness, and alertness using a 15-cm VAS. The scale was anchored by the words “low” and “high” to represent extreme ratings where the greater measured value represented the greater feeling. Questions were structured as “My level of energy is,” “My level of focus is,” “My level of alertness is,” and “My level of fatigue is.” The VAS was assessed at each test date and players were asked to rate their feelings at that time by marking on the corresponding line. The validity and reliability of VAS in assessing fatigue and energy has been previously established (27).

Results

Age, height, weight, and playing time for S and NS are presented in Table 1. Significant differences were observed between S and NS in age \( (p = 0.017) \), total minutes played \( (p < 0.001) \), and average number of minutes per game played \( (p < 0.001) \). There were no statistical differences between S and NS in height or body mass.

Vertical jump power and LD performance comparisons between S vs. NS are presented in Table 2. There were no significant main effects across time or group, and no significant interactions noted for vertical jump peak or mean power. Similar results were observed for the LD with no significant interactions for measures of average time, fastest time, or fatigue index. Comparisons between S and NS in pre-season to postseason results of vertical jump power and LD changes using magnitude-based inferences are depicted in Table 3. Comparisons of S and NS on vertical jump peak and mean power changes indicated “Unclear” differences (Table 3). Magnitude-based inferences for the LD revealed a “likely negative” (81.1%) difference in the athletes fastest LD from pre-season to postseason, indicating that S decreased time (i.e., became faster) in the LD during the season compared with NS. All other comparisons between S and NS for LD were “unclear.”

Multiple object tracking and reaction data are presented in Table 4. When collapsed across groups, a significant main effect for time was seen in the 3D-MOT from preseason \( (1.14 \pm 0.41) \) to mid-season \( (1.42 \pm 0.38) \) and to the post-season \( (1.55 \pm 0.43) \) \((p = 0.036\) and \(< 0.001\), respectively). Significant main effects for time were also seen in visual RT from pre-season \( (0.366 \pm 0.05 \text{ seconds}) \) and mid-season \( (0.351 \pm 0.33 \text{ seconds}) \) to postseason \( (0.336 \pm 0.33 \text{ seconds}) \) using pairwise comparisons with a Bonferroni adjustment, whereas significant interactions were analyzed with a Sheffe posthoc test. Changes over the course of the season were also assessed in all measures. Delta scores were correlated to playing time using a Pearson correlation. An alpha level of 0.05 \((\alpha < 0.05)\) was set for all analyses. Additionally, magnitude-based inferences were completed on delta scores \((\Delta = \text{postseason} - \text{preseason})\) via a published spreadsheet (7,23).

### Table 1. Comparisons of starters and nonstarters.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Starters (n = 11)</th>
<th>Nonstarters (n = 17)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>20.46 ± 1.27</td>
<td>19.50 ± 0.86</td>
<td>0.028</td>
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<tr>
<td>Height (m)</td>
<td>1.69 ± 0.05</td>
<td>1.72 ± 0.09</td>
<td>0.161</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.36 ± 6.17</td>
<td>65.25 ± 6.63</td>
<td>0.425</td>
</tr>
<tr>
<td>Average playing time per game (min)</td>
<td>66.39 ± 16.08</td>
<td>8.9 ± 8.07</td>
<td>&gt;0.001</td>
</tr>
</tbody>
</table>

*All data are reported as mean ± SD.
**Table 2.** Vertical jump power and line drill performance comparisons between starters vs. nonstarters over the course of a competitive soccer season.*

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Starters mid</th>
<th>Post</th>
<th>Pre</th>
<th>Nonstarters mid</th>
<th>Post</th>
<th>Time p</th>
<th>Group p</th>
<th>Group × time p</th>
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<tbody>
<tr>
<td><strong>Vertical jump</strong></td>
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<tr>
<td>Peak power (W)</td>
<td>1415</td>
<td>1413 ± 153</td>
<td>1413</td>
<td>1332</td>
<td>1407 ± 282</td>
<td>1434</td>
<td>0.712</td>
<td>0.835</td>
<td>0.718</td>
</tr>
<tr>
<td>Mean power (W)</td>
<td>794</td>
<td>756 ± 128</td>
<td>788</td>
<td>715</td>
<td>784 ± 163</td>
<td>769</td>
<td>0.801</td>
<td>0.708</td>
<td>0.435</td>
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<tr>
<td><strong>Line drill</strong></td>
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<tr>
<td>Average time (s)</td>
<td>40.50</td>
<td>40.38 ± 0.74</td>
<td>40.13</td>
<td>40.27</td>
<td>40.18 ± 1.17</td>
<td>40.27</td>
<td>0.687</td>
<td>0.824</td>
<td>0.635</td>
</tr>
<tr>
<td>Fastest time (s)</td>
<td>37.88</td>
<td>37.75 ± 0.89</td>
<td>38.25</td>
<td>38.45</td>
<td>38.09 ± 1.14</td>
<td>38.27</td>
<td>0.341</td>
<td>0.535</td>
<td>0.503</td>
</tr>
<tr>
<td>Fatigue index (%)</td>
<td>90.75</td>
<td>90.38 ± 3.29</td>
<td>93.25</td>
<td>90.83</td>
<td>89.42 ± 2.02</td>
<td>89.08</td>
<td>0.421</td>
<td>0.82</td>
<td>0.092</td>
</tr>
</tbody>
</table>

*Pre = preseason; Mid = midseason; Post = postseason. All data are reported as mean ± SD.

**Table 3.** Magnitude-based inferences on changes in vertical jump power and line drill from preseason to postseason.

<table>
<thead>
<tr>
<th></th>
<th>Starters</th>
<th>Nonstarters</th>
<th>p</th>
<th>Threshold</th>
<th>Positive</th>
<th>Percent trivial</th>
<th>Negative</th>
<th>Mean effect</th>
<th>Inference</th>
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<tbody>
<tr>
<td><strong>Vertical jump</strong></td>
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<td></td>
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<tr>
<td>Peak power (W)</td>
<td>−19.56</td>
<td>−11.93 ± 185.24</td>
<td>0.918</td>
<td>33.4</td>
<td>33.6</td>
<td>26.8</td>
<td>39.5</td>
<td>−7.6 ± 165.5</td>
<td>Unclear</td>
</tr>
<tr>
<td>Mean power (W)</td>
<td>−2.33</td>
<td>−7.79 ± 94.97</td>
<td>0.893</td>
<td>18.4</td>
<td>40.6</td>
<td>26.2</td>
<td>33.2</td>
<td>5.5 ± 93.1</td>
<td>Unclear</td>
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<tr>
<td><strong>Line drill</strong></td>
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<tr>
<td>Average time (s)</td>
<td>0.09</td>
<td>0.12 ± 0.79</td>
<td>0.918</td>
<td>0.146</td>
<td>34.5</td>
<td>25.8</td>
<td>39.6</td>
<td>0.0 ± 0.8</td>
<td>Unclear</td>
</tr>
<tr>
<td>Fastest time (s)</td>
<td>−0.62</td>
<td>0.22 ± 0.86</td>
<td>0.510</td>
<td>0.196</td>
<td>3.7</td>
<td>9.0</td>
<td>87.3</td>
<td>−0.8 ± 0.9</td>
<td>Likely negative</td>
</tr>
<tr>
<td>Fatigue index (%)</td>
<td>0.02</td>
<td>−0.01 ± 0.05</td>
<td>0.245</td>
<td>0.012</td>
<td>69.2</td>
<td>18.4</td>
<td>12.4</td>
<td>0.0 ± 0.1</td>
<td>Unclear</td>
</tr>
</tbody>
</table>
### Table 4. Subjective measures, multiple object tracking, and reaction time across the competitive season.*

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Starters mid</th>
<th>Post</th>
<th>Pre</th>
<th>Nonstarters mid</th>
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<th>Time p</th>
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<th>Group × time p</th>
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<tr>
<td><strong>Visual analog scales</strong></td>
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<tr>
<td>Energy (cm)</td>
<td>10.5 ± 1.3</td>
<td>7.3 ± 2.4</td>
<td>6.6 ± 2.3</td>
<td>10.7 ± 2.0</td>
<td>8.4 ± 2.6</td>
<td>7.4 ± 3.0</td>
<td>&lt;0.001</td>
<td>0.290</td>
<td>0.760</td>
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<tr>
<td>Focus (cm)</td>
<td>10.4 ± 3.1</td>
<td>9.1 ± 2.8</td>
<td>6.3 ± 1.6</td>
<td>11.3 ± 2.3</td>
<td>10.0 ± 3.2</td>
<td>9.1 ± 3.2</td>
<td>&lt;0.001</td>
<td>0.107</td>
<td>0.157</td>
</tr>
<tr>
<td>Fatigue (cm)</td>
<td>6.9 ± 2.4</td>
<td>10.6 ± 2.0</td>
<td>10.2 ± 2.8</td>
<td>6.5 ± 2.8</td>
<td>9.0 ± 3.3</td>
<td>9.6 ± 3.4</td>
<td>&lt;0.001</td>
<td>0.214</td>
<td>0.753</td>
</tr>
<tr>
<td>Alertness (cm)</td>
<td>10.4 ± 2.1</td>
<td>8.6 ± 3.3</td>
<td>7.1 ± 1.7</td>
<td>10.6 ± 2.5</td>
<td>9.7 ± 2.6</td>
<td>8.2 ± 3.5</td>
<td>&lt;0.001</td>
<td>0.385</td>
<td>0.723</td>
</tr>
<tr>
<td>Multiple object tracking (AU)</td>
<td>1.13 ± 0.37</td>
<td>1.40 ± 0.42</td>
<td>1.57 ± 0.41</td>
<td>1.16 ± 0.45</td>
<td>1.44 ± 0.34</td>
<td>1.53 ± 0.47</td>
<td>&lt;0.001</td>
<td>0.926</td>
<td>0.893</td>
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<tr>
<td><strong>Upper-body reaction</strong></td>
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<tr>
<td>Visual reaction (s)</td>
<td>0.38 ± 0.06</td>
<td>0.35 ± 0.03</td>
<td>0.35 ± 0.04</td>
<td>0.35 ± 0.04</td>
<td>0.35 ± 0.03</td>
<td>0.39 ± 0.04</td>
<td>0.001</td>
<td>0.203</td>
<td>0.123</td>
</tr>
<tr>
<td>Motor reaction (s)</td>
<td>0.27 ± 0.04</td>
<td>0.25 ± 0.03</td>
<td>0.23 ± 0.05</td>
<td>0.25 ± 0.07</td>
<td>0.26 ± 0.08</td>
<td>0.23 ± 0.04</td>
<td>0.147</td>
<td>0.977</td>
<td>0.614</td>
</tr>
<tr>
<td><strong>Lower-body reaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct hits</td>
<td>26.3 ± 2.8</td>
<td>29.0 ± 3.0</td>
<td>27.8 ± 3.0</td>
<td>27.1 ± 2.5</td>
<td>28.7 ± 3.0</td>
<td>28.4 ± 2.3</td>
<td>0.001</td>
<td>0.700</td>
<td>0.510</td>
</tr>
</tbody>
</table>

*Pre = preseason; Mid = midseason; Post = postseason; AU = arbitrary units. All data are reported as mean ± SD.

### Table 5. Magnitude-based inferences of changes in subjective measures, multiple object tracking, and reaction time from preseason to postseason.*

<table>
<thead>
<tr>
<th></th>
<th>Starters</th>
<th>Nonstarters</th>
<th>p</th>
<th>Threshold</th>
<th>Positive</th>
<th>Percent trivial</th>
<th>Negative</th>
<th>Mean effect</th>
<th>Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual analog scales</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy (cm)</td>
<td>−41.4 ± 27.3</td>
<td>−32.6 ± 37.5</td>
<td>0.512</td>
<td>6.6</td>
<td>19.5</td>
<td>25.5</td>
<td>54.9</td>
<td>−8.8 ± 30.2</td>
<td>Unclear</td>
</tr>
<tr>
<td>Focus (cm)</td>
<td>−33.9 ± 55.3</td>
<td>−32.6 ± 36.6</td>
<td>0.938</td>
<td>30.2</td>
<td>20.7</td>
<td>56.7</td>
<td>22.6</td>
<td>−1.3 ± 64.9</td>
<td>Possibly trivial</td>
</tr>
<tr>
<td>Fatigue (cm)</td>
<td>34.0 ± 39.9</td>
<td>30.6 ± 46.3</td>
<td>0.843</td>
<td>8.6</td>
<td>44.1</td>
<td>19.4</td>
<td>36.5</td>
<td>3.4 ± 58.8</td>
<td>Unclear</td>
</tr>
<tr>
<td>Alertness (cm)</td>
<td>−33.9 ± 26.3</td>
<td>−24.1 ± 19.0</td>
<td>0.272</td>
<td>4.4</td>
<td>22.2</td>
<td>16.3</td>
<td>61.5</td>
<td>−9.8 ± 31.3</td>
<td>Possibly negative</td>
</tr>
<tr>
<td>Multiple object tracking (AU)</td>
<td>0.36 ± 0.51</td>
<td>0.30 ± 0.42</td>
<td>0.758</td>
<td>0.088</td>
<td>47.0</td>
<td>18.5</td>
<td>34.5</td>
<td>0.1 ± 0.6</td>
<td>Unclear</td>
</tr>
<tr>
<td><strong>Upper-body reaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual reaction (s)</td>
<td>−0.04 ± 0.04</td>
<td>−0.06 ± 0.12</td>
<td>0.616</td>
<td>0.02</td>
<td>50.0</td>
<td>20.7</td>
<td>29.3</td>
<td>0.0 ± 0.1</td>
<td>Unclear</td>
</tr>
<tr>
<td>Motor reaction (s)</td>
<td>−0.03 ± 0.05</td>
<td>−0.02 ± 0.08</td>
<td>0.782</td>
<td>0.014</td>
<td>32.8</td>
<td>20.1</td>
<td>47.0</td>
<td>0.0 ± 0.1</td>
<td>Unclear</td>
</tr>
<tr>
<td><strong>Lower-body reaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct hits</td>
<td>3.3 ± 7.0</td>
<td>1.94 ± 8.89</td>
<td>0.292</td>
<td>1.46</td>
<td>63.4</td>
<td>17.8</td>
<td>18.8</td>
<td>3.3 ± 9.1</td>
<td>Unclear</td>
</tr>
</tbody>
</table>

*AU = arbitrary units.
**Table 6.** Muscle architecture comparisons between starters and nonstarters.*

<table>
<thead>
<tr>
<th></th>
<th>Muscular Architecture</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
<th>Time p</th>
<th>Group p</th>
<th>Interaction p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rectus femoris</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle thickness (cm)</td>
<td></td>
<td>2.43 ± 0.24</td>
<td>2.34 ± 0.21</td>
<td>2.31 ± 0.32</td>
<td>2.31 ± 0.21</td>
<td>0.261</td>
<td>0.441</td>
<td>0.282</td>
</tr>
<tr>
<td>Cross-sectional area (cm²)</td>
<td></td>
<td>11.81 ± 1.60</td>
<td>11.89 ± 1.12</td>
<td>11.03 ± 1.75</td>
<td>11.24 ± 1.48</td>
<td>0.468</td>
<td>0.263</td>
<td>0.753</td>
</tr>
<tr>
<td>Pennation angle (°)</td>
<td></td>
<td>11.37 ± 2.88</td>
<td>10.95 ± 1.76</td>
<td>12.53 ± 2.99</td>
<td>12.71 ± 2.80</td>
<td>0.724</td>
<td>0.202</td>
<td>0.383</td>
</tr>
<tr>
<td>Echo intensity (AU)</td>
<td></td>
<td>64.61 ± 6.35</td>
<td>59.87 ± 6.39</td>
<td>66.54 ± 7.37</td>
<td>62.65 ± 8.03</td>
<td>0.005</td>
<td>0.403</td>
<td>0.759</td>
</tr>
<tr>
<td><strong>Vastus lateralis</strong></td>
<td></td>
<td>1.49 ± 0.23</td>
<td>1.46 ± 0.21</td>
<td>1.38 ± 0.23</td>
<td>1.34 ± 0.14</td>
<td>0.137</td>
<td>0.188</td>
<td>0.997</td>
</tr>
<tr>
<td>Muscle thickness (cm)</td>
<td></td>
<td>21.72 ± 4.64</td>
<td>22.26 ± 4.77</td>
<td>20.28 ± 2.76</td>
<td>20.95 ± 2.81</td>
<td>0.022</td>
<td>0.380</td>
<td>0.794</td>
</tr>
<tr>
<td>Cross-sectional area (cm²)</td>
<td></td>
<td>14.37 ± 2.84</td>
<td>12.57 ± 2.79</td>
<td>11.44 ± 1.57</td>
<td>11.27 ± 1.22</td>
<td>0.024</td>
<td>0.013</td>
<td>0.056</td>
</tr>
<tr>
<td>Pennation angle (°)</td>
<td></td>
<td>11.37 ± 2.88</td>
<td>10.95 ± 1.76</td>
<td>12.53 ± 2.99</td>
<td>12.71 ± 2.80</td>
<td>0.724</td>
<td>0.202</td>
<td>0.383</td>
</tr>
<tr>
<td>Echo intensity (AU)</td>
<td></td>
<td>69.08 ± 7.19</td>
<td>68.32 ± 6.80</td>
<td>70.11 ± 6.87</td>
<td>70.54 ± 5.40</td>
<td>0.887</td>
<td>0.523</td>
<td>0.609</td>
</tr>
</tbody>
</table>

*Pre = preseason; Post = postseason; AU = arbitrary Units. All data are reported as mean ± SD.

**Table 7.** Magnitude-based inferences on changes in muscle architecture from preseason to postseason.*

<table>
<thead>
<tr>
<th></th>
<th>Starters</th>
<th>Non-starters</th>
<th>p</th>
<th>Threshold</th>
<th>Pos.</th>
<th>Percent trivial</th>
<th>Neg.</th>
<th>Mean effect</th>
<th>Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rectus femoris</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle thickness (cm)</td>
<td>-0.10 ± 0.10</td>
<td>0.00 ± 0.24</td>
<td>0.282</td>
<td>0.04</td>
<td>10.0</td>
<td>18.8</td>
<td>71.2</td>
<td>-0.1 ± 0.2</td>
<td>Possibly negative</td>
</tr>
<tr>
<td>Cross-sectional area (cm²)</td>
<td>0.09 ± 0.79</td>
<td>0.22 ± 1.06</td>
<td>0.753</td>
<td>0.19</td>
<td>28.0</td>
<td>26.3</td>
<td>45.7</td>
<td>-0.1 ± 0.9</td>
<td>Unclear</td>
</tr>
<tr>
<td>Pennation angle (°)</td>
<td>-0.43 ± 1.34</td>
<td>0.18 ± 1.73</td>
<td>0.383</td>
<td>0.32</td>
<td>15.5</td>
<td>21.8</td>
<td>62.7</td>
<td>-0.6 ± 1.5</td>
<td>Possibly negative</td>
</tr>
<tr>
<td>Echo intensity (AU)</td>
<td>-4.75 ± 3.77</td>
<td>-3.88 ± 7.68</td>
<td>0.758</td>
<td>1.27</td>
<td>27.3</td>
<td>27.2</td>
<td>45.5</td>
<td>-0.9 ± 6.0</td>
<td>Unclear</td>
</tr>
<tr>
<td><strong>Vastus lateralis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle thickness (cm)</td>
<td>-0.06 ± 0.03</td>
<td>0.03 ± 0.13</td>
<td>0.997</td>
<td>0.02</td>
<td>3.1</td>
<td>7.9</td>
<td>89.0</td>
<td>-0.1 ± 0.1</td>
<td>Likely negative</td>
</tr>
<tr>
<td>Cross-sectional area (cm²)</td>
<td>0.54 ± 1.17</td>
<td>0.67 ± 1.11</td>
<td>0.764</td>
<td>0.22</td>
<td>24.3</td>
<td>33.0</td>
<td>42.7</td>
<td>-0.1 ± 0.9</td>
<td>Unclear</td>
</tr>
<tr>
<td>Pennation angle (°)</td>
<td>-1.81 ± 1.89</td>
<td>-0.17 ± 1.90</td>
<td>0.056</td>
<td>0.404</td>
<td>3.8</td>
<td>9.7</td>
<td>86.5</td>
<td>-1.6 ± 1.9</td>
<td>Likely negative</td>
</tr>
<tr>
<td>Echo intensity (AU)</td>
<td>-0.75 ± 4.00</td>
<td>0.44 ± 6.00</td>
<td>0.608</td>
<td>1.048</td>
<td>22.6</td>
<td>25.4</td>
<td>51.9</td>
<td>-1.2 ± 5.1</td>
<td>Unclear</td>
</tr>
</tbody>
</table>

*AU = arbitrary units.
Effect of Playing Time on Performance and MA in Soccer

(p = 0.002 and 0.048, respectively) and in lower-body quick-
ness (26.7 ± 2.7 hits) to mid-season (28.8 ± 3.2 hits) and
postseason (28.1 ± 2.42 hits) (p = 0.002 and 0.033, re-
spectively). No main effects were seen for group, and no sig-
ificant interactions were observed across the season.

Comparisons between S and NS in pre-season to postseason
results of multiple object tracking and reaction changes
using magnitude-based inferences are depicted in Table 5.
All comparisons between S and NS in these measures were
“unclear” or “trivial.”

Muscle architectural comparisons between S and NS are
presented in Table 6. The analysis of EI for RF revealed
a significant main effect (p = 0.005) for time. A decrease
from pre-season (65.57 ± 1.50) to postseason (61.26 ± 1.59)
values was observed. Significant main effects were also
noted for time in VL CSA from pre-season (20.84 ± 3.58
cm²) to postseason (21.46 ± 3.66 cm²) (p = 0.022) and VL
PANG (12.58 ± 2.56° to 11.78 ± 2.03°, respectively) (p =
0.024). A significant main effect for groups was observed for
VL PANG. Starters had a significantly (p = 0.013) greater VL
PANG (13.47 ± 2.88°) than NS (11.35 ± 1.38°). A trend
toward an interaction (p = 0.056) was also seen between S
and NS for VL PANG. No other significant interactions
between S and NS were observed in MA. Comparisons
between S and NS in pre-season to postseason results of
MA changes using magnitude-based inferences are depicted
in Table 7. A “possibly negative” relation was observed
between S and NS on RF MT and RF PANG (65.7 and
59.4%, respectively). Additionally, “likely negative” differen-
ces between S and NS occurred for VL MT (81.6%) and VL
PANG (79.4%), indicating S were likely to have a greater
decrease in VL MT and VL PANG over the course of the
season when compared with NS.

Subjective measures of energy, focus, fatigue, and alertness
are displayed in Table 4. Significant main effects for time
were seen for every measure. Subjective measures of energy,
focus, and alertness all significantly decreased across time,
whereas subjective feelings of fatigue increased for all players.
No significant main effect for group was noted, and no sig-
ificant interactions between time and group were seen in
any of the subjective feelings. Thus, playing time in games
did not appear to cause any significant effect on these mes-
ures. However, trends toward significance were noted in the
correlation between focus and percent time played (r =
−0.35; p = 0.078), total minutes played (r = −0.344; p =
0.079), and average minutes played (r = −0.344; p = 0.079).

Comparisons between S and NS in regard to subjective
measures of energy, focus, fatigue, and alertness with
magnitude-based inferences are presented in Table 5. Re-
results indicated that the change from pre-season to postsea-
son for energy and fatigue are “unclear,” whereas subjective
feelings of focus were “possibly trivial” (56.7%). Subjective
measures of alertness were “possibly negative” (61.5%),
indicating that alertness decreased in S more than in NS
during the season.

**Discussion**

The ability to maintain physiological performance during
a season of competition may be challenging considering the
physical and mental demands (e.g., practice, competitions,
class attendance, and studying) common to collegiate athletes
(25,31). The main findings of this study indicate that athletes,
regardless of playing time, are able to maintain power and
anaerobic running performance throughout the season. These
results support previous studies by Magal et al. (29) who also
reported that soccer players were able to maintain power
performance during a competitive season and others who
reported that LD performance is maintained throughout
a competitive season in basketball players (17,32).

An interesting aspect of this study was the improved
speed for the LD in S only. This is consistent with other
studies from our laboratory that have demonstrated
improved power performance during a season of competi-
tion in S vs. NS in NCAA Division I women’s basketball
players (17) and in professional basketball players (16). In
contrast, McLean et al. (31) observed, also in NCAA Division
I women soccer players, a decrease in power during the
season in S, whereas NS were able to maintain power. These
decreases though were observed during weeks 10–12 of the
season and then returned to pre-season levels by the season’s
conclusion. This likely reflected a brief period of fatigue or
overreaching or possibly a normal fluctuation of perform-
ance variability (33). Considering that the athletes were
monitored at only pre-season, mid-season, and postseason,
we may not have been able to track these performance fluc-
tuations. During a 12-week season, some consideration of
more frequent assessments may be warranted.

Performance measures also included upper- and lower-
body RT and multiple object tracking. The ability to
recognize and react to various stimuli on a soccer field are
important contributors to successful soccer performance
(4,42,44). Although the ability to see and react to game
stimuli are skills that appear to be required for superior com-
petitive performance, the ability to improve these factors
during a season of competition is not readily understood.
Our laboratory’s previous studies with collegiate and profes-
sional basketball players have shown that lower-body reaction
to a visual stimulus is maintained throughout the competitive
season (16,17). The results from this present study suggest that
both upper- and lower-body reaction to visual stimuli is
significantly improved in both S and NS. It is possible that
differences between basketball and soccer may have contrib-
uted to these different outcomes. Basketball is an anaerobic
sport, whereas soccer relies on both aerobic and anaerobic
contributions (5). Although speculative, it is possible that
a greater focus on team preparation for agility, quickness,
and explosive power during offseason and preseason training
in basketball players may have resulted in a higher level of
preparedness at the onset of a season compared with soccer
players. Another aspect to consider is the uniqueness of the
D2 to measure upper-body reaction. It provides specific measures of both visual and motor RT. The visual reaction, which was significantly improved during the season, measures how quickly a visual stimulus is seen, whereas the motor reaction, which was not improved during the season, measures how quickly the hand can move to the new stimulus. This appears to be the first study to examine these specific performance changes. A recent study has suggested visual reaction, as measured by the D2, is very sensitive to performance changes during a competition (22).

The ability to track objects has recently been shown to be an important attribute for baseball players (41), and athletes in general appear to have a greater ability to track objects than nonathletes (12). In addition, tracking ability may also be able to differentiate between athletes of varying abilities (12). Previous research has shown that athletes can improve tracking or their perceptual cognitive ability through training on the 3D-MOT (13). Considering that the athletes in this study did not perform any specific training on the 3D-MOT device, the significant improvements noted appear to be the result of soccer training. In lieu of the similar improvements between S and NS, it appears that practice alone is sufficient to stimulate improvements in tracking ability. It is acknowledged that the magnitude of improvement may be related to a learning affect; however, Faubert and Sidebottom (13) have suggested that any learning effect would be noted if training sessions occurred within 2 weeks of each other. Performance improvements from sessions that occur beyond that timeline do not appear to be maintained, thus it appears that the improvements noted in this study can be attributed to the influence of daily soccer practice and not to a learning effect resulting from repeated testing.

The ability to maintain or improve performance across the season may be partially explained by the changes observed in MA. The athletes in this study decreased EI in the RF, which has been suggested to reflect an increase in muscle quality (8,15). This is likely related to the importance of RF activation for maximizing explosive movements in hip and knee extension when kicking the soccer ball (6). There did not appear to be any benefit or additional stress associated with playing time regarding changes in EI. In addition, a season of competition or playing time did not appear to affect any of the other MA measures of the RF. Comparison of S and NS through magnitude-based inferential analysis suggested possible effects of playing time on MT and PANG. Considering the improvement in EI, maintenance of VJP and improvement in the LD, the relevance of this may not have large practical significance. It further emphasizes the importance of examining multiple variables in regard to monitoring athletic performance.

When collapsed across time, S was seen to have a significantly greater VL PANG than NS. This may reflect a competitive advantage for S as an indicator for potentially greater lower-body power performance than NS (10). Interestingly, both groups experienced significant declines in CSA during the competitive season and S tended to decrease PANG to a greater extent than NS. Changes in CSA and PANG generally parallel one another, as previous research has reported, demonstrating a significant correlation ($r = 0.62$) between CSA and PANG (1). A decrease in PANG may provide some benefit to S. Although previous research has shown that a greater PANG is associated with higher vertical jump heights power (10), others have demonstrated that a lower VL PANG is associated with sprinting ability (3,26). This may partially explain the improved speed performance in the LD of S during the season. In addition, the difference in magnitude of change observed in PANG and MT of the VL between S and NS is in agreement with previous research (24), and further supports the mechanism for improved speed performance in S.

The decreases in subjective measures of energy focus and alertness along with an increase in fatigue are consistent with what is generally seen during a competitive season (16,17). However, changes in these subjective measures do not appear to influence athletic performance. Although levels of alertness appear to decrease from preseason to post-season more in S than in NS, changes in the levels of focus showed a trend toward correlating with playing time. These results do suggest that playing time does influence player's focus and alertness during the season. This is consistent with a previous investigation in NCAA Division I female basketball players (17). However, the present results are in contrast to a recent investigation on professional basketball players, which found a decrease of energy in S, but no differences between S and NS on measures of alertness (16). By themselves, subjective measures of alertness, focus, energy, and fatigue may not provide sufficient information to categorize training adaptation or maladaptation, but they may provide a more complete picture of the physiological and psychological changes occurring during a season that can assist the coach or sport scientist in adjusting in-season training programs.

In conclusion, the results of this study indicate that performance measures are maintained during a competitive soccer season in NCAA Division I soccer women, regardless of playing time. Playing time does appear to provide a greater stimulus to enhance speed during the season, which may be facilitated by changes in MA. These changes appear to occur regardless of any changes in subjective measures of energy, fatigue, focus, and alertness.

**Practical Applications**

Results of this study indicate that speed, power, 3D-MOT, and RT can be maintained or improved during a NCAA Division I women’s soccer season. In addition, the stimulus of playing in competitive games appears to enhance speed performance in those athletes, which are consistent with MA adaptations. Coaches may consider additional scrimmages at game level intensity during practice for players who are not part of the regular playing rotation.
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REFERENCES


