SHORT COMMUNICATION

Effect of playing time on countermovement jump performance over a competitive season in female collegiate athletes

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Objectives: This investigation examined if the amount of playing time effected countermovement jump performance over the course of a competitive collegiate soccer season.

Methods: 22 NCAA Division I female soccer athletes participated in this investigation. Participants were tested at three points throughout the competitive season: pre, mid, and post. At each testing session, participants completed 3 CMJ trials. All testing was performed using a portable force platform with ground reaction forces sampled at 1000Hz. Participants were put in one of two groups based on playing above or below 50 percent of the available A mixed-methods repeated-measures ANOVA was used to determine if significant differences were present across the season.

Results: The percentage of minutes played during the season did not appear to have an impact on CMJ performance as no interactions were found. Propulsive mean force did significantly increase from pre to mid ($p = 0.04$) and post testing ($p = 0.01$).

Conclusions: CMJ performance did not change in the high or low minute groups over the course of a competitive season. As individuals respond to training loads differently examining individual change rather than group change could provide better insight into the response to the training loads over a season.

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Key words: ■ athlete monitoring ■ countermovement jump ■ force-time analysis ■ female athletes

INTRODUCTION

The game of soccer requires high levels of aerobic fitness and muscular power to succeed on the field.[1] As such, it is important to examine the changes in these qualities during a competitive season. One assessment commonly used to monitor lower extremity neuromuscular performance is the countermovement jump (CMJ).[2] This task also allows both sports science practitioners and researchers to test athletes regularly without inducing any additional fatigue to the athlete.

Previous investigations into the changes of physical qualities throughout a competitive season have been performed across various team sports with differing findings regarding CMJ performance specifically. No significant differences were seen in a sample of male soccer athletes in both squat and CMJ jump heights.[3] Similar findings occurred in a sample of collegiate female soccer athletes over a competitive season, where no differences were found in CMJ jump height.[4] In contrast, Ishida, et al.[5] found jump height, reactive strength index modified (RSImod), and peak power to all increase from the early stages of the competitive season to the middle and end of the season in a sample of female collegiate soccer athletes. This points to a potential issue in using jump height as a meaningful variable to monitor neuromuscular fatigue. A recent suggestion has been made that metrics such as RSImod, time to take off (TTT), and propulsive phase duration should be used when investigating neuromuscular fatigue in athletes.[2,6] Additionally, a recent investigation of seasonal changes in collegiate male basketball supported this framework with significant changes in underlying mechanics (propulsive duration and propulsive peak and mean force) with no significant changes in jump height.[7] Thus, indicating a potential shift in the strategy that an individual utilizes to obtain a given jump height.

Previous investigations that have examined seasonal changes in jump performance have used positional groupings or evaluated the entire team as a whole.[5,8,9] This may cause a potential issue as positional demands differ during match play, and each individual has different internal and external loads/stress.[10,11] Additionally, it has been shown that starters had a much higher external training load than nonstarters during match play in male collegiate soccer athletes.[12] As starting roles on a team can change based on several factors such as injury, playing performance, disciplinary action, etc., examining changes in starters and nonstarters over a season of collegiate soccer may create an unclear picture of changes that may occur. As starters typically play a greater number of minutes per game than nonstarters, using the cumulative playing time over a season could be a means of grouping individuals on a team to examine changes in CMJ performance. As previous investigations have shown little change in jump

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height over a competitive season in soccer athletes,[3,4] there is a lack of investigations in examining the changes potential changes in jump strategies over a competitive season, especially with regard to playing status. Thus, this investigation examines changes in the CMJ force-time strategies used over a NCAA division I soccer season based on the number of minutes played.

METHODS

A longitudinal observational study design was implemented to investigate the changes in CMJ strategies over the course of a competitive season. CMJ assessments took place at the start of the competition season, midseason, and the final week of the regular season.

Participants

Twenty-two Division I NCAA female soccer athletes took part in this investigation (age 19.65 ± 0.74 years, height 168.88 ± 8.14 cm, body mass 68.03 ± 7.60 kg). Each participant completed all three testing sessions as a part of their routine athlete monitoring program. All participants had been cleared of injury prior to the beginning of the investigation by the team's sports medicine staff. Prior to the first testing session, each participant provided informed written consent as approved by the university's institutional review board.

Procedures

During each testing session, participants performed three maximal effort CMJ trials using a portable force platform (Accupower, AMTI, Watertown, MA, USA). Each trial was performed with a dowel rod placed across the participants back. Verbal instructions were given prior to each trial for the participant to "jump as high as possible while maintaining contact with the dowel on their back". Participants were allowed to use a self-selected foot position and countermovement depth during each trial. Trials were separated by a minimum of 20 seconds. All testing sessions followed the same procedures, with all testing occurring prior to the on-field training session for the day. Testing was the first physical activity that each participant partook in on the testing day.

Playing time data was obtained from the official season statistics page of the team's website. Group assignments were based off a percentage of total minutes played over the competitive season. Each participant's minutes played was divided by the total minutes available, participants were placed into either the below 50% (n = 13, 70.32 ± 7.88 kg, 168.53 ± 8.49 cm, 278.71 ± 218.98 minutes played) or above 50% group (n = 9, 65.74 ± 7.31kg, 169.23 ± 7.79 cm, 1136.75 ± 172.86 minutes played).

Data Analysis

Raw vertical ground reaction forces sampled at 1000 Hz, and exported from the data acquisition software of the force platform. Each trial was then analyzed using a customized Microsoft Excel spreadsheet.13,14 The spreadsheet was modelled using the methods described previously by Chavda et al.15 and the phases of the CMJ force-time curve were defined similar to McMahon et al.16 Mean net force and duration were calculated for each phase. Additionally, jump height, TTT, RSImod, and countermovement depth were calculated.

Statistical Analysis

Data normality was first determined using Shaprio-Wilk's test. A two x three (playing time x testing session) repeated measures analysis of variance was used to determine if differences were present. If a significant effect was found, a Fisher's least significant difference post-hoc analysis was then performed. Effect sizes were calculated as partial eta squared. Effect sizes were interpreted as small (0.01), moderate (0.06), and large (0.14). Pearson product moment correlations were calculated between minutes played throughout the year and CMJ variables from the preseason testing session. All statistical analysis were performed using SPSS statistical software (v28.0, IBM, Chicago, IL, USA).

RESULTS

All results are presented as means and standard deviations. A significant main effect for seasonal change in propulsive mean force was found (f (2,40) = 4.36, p = 0.02, η^2 = 0.18). Significant differences were seen between preseason and midseason testing in propulsive mean force (510.63 ± 79.44 N vs 549.97 ± 93.35 N, p = 0.04). Additionally, there was a significant difference between preseason and post-season testing in propulsive mean force (510.63 ± 79.44 N vs 548.74 ± 96.12 N, p = 0.01). No other significant differences were present across the testing sessions or between groups (Table 1). Though not significant moderate effect sizes were seen for every variable of interest (0.06 – 0.11) outside of countermovement depth and braking duration. No significant correlations were observed between playing time and CMJ variables (Table 2).

DISCUSSION

The main findings of the current investigation are that playing time over a competitive season does not impact changes in countermovement jump performance. This is supported by no significant interactions between groups for any of the variables of interest. Additionally, this is supported by the lack of significant relationships between the number of minutes played in a competitive season and the CMJ metrics used in this investigation.

Previous investigations have found conflicting evidence of seasonal changes in CMJ performance over a competitive season.[5,8,9] Many of these investigations have used jump height alone to quantify jump performance.[8,9] Recent literature has suggested a move away from using only jump height as a standalone metric of jump performance.[2] This is primarily due to the underlying mechanics changing while maintaining jump height. Donahue et al.[13] demonstrated this between female athletes of different sports backgrounds and their ability to obtain similar jump heights by using various strategies (time vs force-driven propulsive impulse). Thus, the current investigation used several additional metrics outside of jump

Table 1. Group Comparisons Across the Competitive Season

	Pre		Mid		Post		Interaction		Time		Group	
	Below	Above	Below	Above	Below	Above	p	η^2	p	η^2	p	η^2
Peak Braking Force (N)	752.44 ± 187.75	661.93 ± 151.10	775.15 ± 182.36	688 ± 123.43	750.15 ± 148.88	674.93 ± 203.64	0.93	0.00	0.48	0.04	0.25	0.07
Mean Braking Force (N)	384.39 ± 133.23	312.89 ± 90.00	406.26 ± 127.88	316.79 ± 74.26	380.38 ± 108.11	335.34 ± 116.13	0.35	0.05	0.69	0.02	0.16	0.09
Peak Propulsive Force (N)	818.67 ± 161.64	738.19 ± 77.74	835.21 ± 178.48	772.52 ± 100.72	848.88 ± 145.73	794.99 ± 129.39	0.77	0.01	0.08	0.12	0.28	0.06
Mean Propulsive Force (N)*	528.29 ± 95.95	492.95 ± 62.93	549.62 ± 111.67	550.3 ± 75.04	543.28 ± 91.14	554.18 ± 101.09	0.29	0.06	0.02	0.18	0.84	0.00
Braking Duration (ms)	194.89 ± 34.61	212.31 ± 48.39	189.59 ± 40.11	203.33 ± 46.62	195.73 ± 29.63	206.41 ± 46.99	0.89	0.01	0.58	0.03	0.39	0.04
Propulsive Duration (ms)	299.47 ± 43.51	267.25 ± 37.00	296.52 ± 47.46	275.08 ± 25.92	298.35 ± 43.78	281.33 ± 44.19	0.56	0.03	0.66	0.02	0.18	0.09
Time To Takeoff (ms)	884.83 ± 94.46	847.95 ± 81.00	862.54 ± 106.98	898.04 ± 71.38	869.45 ± 81.31	912.33 ± 196.24	0.12	0.10	0.51	0.03	0.74	0.01
Jump Height (cm)	0.23 ± 0.03	0.24 ± 0.02	0.25 ± 0.04	0.24 ± 0.03	0.25 ± 0.03	0.25 ± 0.03	0.11	0.11	0.12	0.10	0.85	0.00
RSImod	0.27 ± 0.05	0.28 ± 0.01	0.30 ± 0.06	0.27 ± 0.04	0.29 ± 0.05	0.29 ± 0.05	0.08	0.12	0.39	0.05	0.67	0.01
Countermovement Depth (cm)	0.31 ± 0.06	0.29 ± 0.03	0.32 ± 0.07	0.28 ± 0.03	0.32 ± 0.08	0.28 ± 0.04	0.59	0.03	0.95	0.00	0.18	0.09

* = significant main effect for time

height to possibly identify changes in jump strategy during the competitive season. As such, propulsive mean force significantly increased from pre to mid and post-testing. This contrasts with findings previously reported within collegiate baseball, where a non-significant moderate reduction in propulsive mean force was seen between preseason and midseason testing.[17] However, in a sample of male collegiate basketball athletes, a significant increase in propulsive force from the preseason to the beginning of the competitive season was seen, similar to the present study's findings.[7] Ishida et al.[5] showed a non-significant increase in peak force from the beginning of the season to the midseason testing (d = 1.22). This supports the current study's findings, where increases in propulsive force were seen. It should also be noted that the increase in force was accompanied by a stable or non-significant increase in propulsive duration. This would not be an indication of a change in the force-time strategy being used during the CMJ. Typically, a shift in the strategy being used would result in an increase in force and reduction in time to obtain a similar net impulse and jump height. In the present study the increase in both force and propulsive duration resulted in a moderate non-significant increase in jump height (Table 1). Though the sample size is relatively small, a post hoc power analysis of the interaction effect and time effect for jump height produced a beta level of 0.95 and 0.92 respectively.

When comparing studies that examined changes in physical performance measures across competitive seasons, many factors can directly impact results. Each sample will experience different fatigue levels based on the team's travel schedule, training regime (sport-specific and physical preparation), nutrition, sleep schedule, and outside stresses of the sport itself. Thus, comparing previous investigations becomes difficult. However, this investigation highlights specifically the influence of playing time during the competitive season on changes in CMJ performance. This is a potentially important factor for practitioners and researchers to consider when monitoring longitudinal shift in performance.

Previous investigations have examined changes in CMJ performance between starters and nonstarters across various team sports.[18,19] Specifically, in collegiate soccer athletes, no significant differences were found between starters and nonstarters in CMJ height, sprint speeds, or intermittent running tests.[19] Thus, the findings of no group differences in any of the variables of the current investigation are supported by these previous findings. Interestingly, the group below 50% had greater values in both peak and mean braking force and peak propulsive force. This finding would also partially explain the lack of significant and, at times, negative relationships seen between CMJ force-time metrics and playing time within the current study. It is also interesting to note that the strength of the relationship decreased when comparing preseason and postseason values (Table 2). This reduction in the strength of the relationship from post season testing and the minutes played over the course of the season can be attributed to a narrowing of the difference between the two groups. All four-force variables showed non-significant improvement over the course of the season for the above 50% group, while the below 50% group remained stable. While no relationship was determined to reach statistical significance, this could largely be attributed to the relatively small sample size used in the analysis as well as the large between subject variability for minutes played (590.73 ± 467.03 minutes).

Regarding the change seen for the specific variables of interest, propulsive mean force in the above 50% group increased to a greater extent than that of the below 50% group. This greater increase in the above 50% group could, in part, be a product of individual changes that were experienced. Donahue et al.[14] showed that a small number of individuals with significant performance shifts could drive group-level changes in TTT, and RSImod. As such, future investigations should examine the individual change in CMJ performance over the season.

It is important to also note how the group assignment was determined within this study. Previous investigations have used starters and nonstarters to define group assignments when evaluating CMJ performance in soccer. However, starting roles may change during a competitive season due to on-field performance, injuries, and skill sets within the team. Thus, the approach was used in this investigation to examine

Table 2. Pearson Product Correlations Between CMJ Performance and Minutes Played

	Pre		Post	
	r	p	r	p
Peak Braking Force (N)	-0.32	0.14	-0.21	0.35
Mean Braking Force (N)	-0.26	0.25	-0.15	0.52
Peak Propulsive Force (N)	-0.38	0.08	-0.24	0.28
Mean Propulsive Force (N)	-0.31	0.16	-0.10	0.65
Braking Duration (ms)	0.20	0.37	0.11	0.64
Propulsive Duration (ms)	-0.15	0.51	-0.07	0.77
Time to Takeoff (ms)	-0.14	0.53	0.23	0.31
Jump Height (cm)	-0.09	0.70	-0.09	0.69
RSImod	-0.02	0.92	-0.17	0.44
Countermovement Depth (cm)	-0.16	0.47	-0.13	0.56

the role of the team not as starters and nonstarters but rather as the total amount of time played during the season. Of the players below 50%, 6 started at least four matches over the season. One individual started 9 of 14 games they played but only played 41.2 % (520 of 1260) of the available minutes within those matches and 36.1% of the minutes over the season. As the substitution rules in NCAA collegiate soccer allow for reentry into a match, a starter's role does not necessarily mean an individual will play a large portion of minutes. As such, further investigation is needed to determine how minutes played are used as a grouping factor in soccer and other team sports.

This study is not without limitations. The small sample size is a limitation of the study, but to ensure that similar fatigue outside of playing time was imparted to each participant, one team over one season was used in this analysis. Another limitation of this study is the generalizability of across NCAA Division I womens soccer. As mentioned previously, each team and individual will experience different stresses that could impact performance, which makes translating this study to similar population groups difficult. However, this investigation sought to use playing time as a means to classify individual members of a team to examine changes in CMJ performance. Based on that premise, this investigation demonstrated that similar trends in CMJ performance were seen regardless of playing time. Thus, in collegiate settings, the additional loads/stresses placed on all individuals may create smaller performance differences than in other competitive settings.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest concerning this manuscript's research, authorship, and/or publication.

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