Laidlaw Scholar Research Attachment Report

MENSTRUAL CYCLE PHASE AND BIOMECHANICS IN FEMALE FOOTBALLERS: A PILOT STUDY

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Introduction

The popularity of women's football has been increasing over the years, with the Union of European Football Associations (UEFA) aiming to double the number of women and girls playing football to 2.5 million registered female players in its Women's Football Strategy 2019-2024.[1] There is also a significant growth in the standard of elite women's football, with increased demands on players, highlighted through the most recent FIFA physical analysis report.[2] While overall injury incidence is similar between male and female football players, there is a greater share of severe injuries in females.[3, 4] Females experience a greater incidence of ankle and knee ligament issues, with female athletes sustaining anterior cruciate ligament (ACL) injuries up to eight times as often as their male counterparts.[4, 5] The substantial counts of severe injuries affecting high-profile players and the rising professionalism of women's football highlight the need to better understand female athletes' unique risk factors.

While being primary reproductive hormones in females, oestrogen and progesterone also have non-reproductive functions, affecting musculoskeletal tissue such as muscle, tendon, and bone[6] and there is existing research showing that hormonal cycles may challenge homeostasis and affect readiness to perform.[7] However, efforts to explain mechanisms that link certain menstrual phases with increased injury risk are inconclusive. A recent systematic review showed that the ovulatory phase, with a peak estradiol level, is associated with a higher risk of injury through increased joint laxity, strength and poor use of neuromuscular control due to influences on the central nervous system.[8] There are other proposed but inconsistent or even contradictory mechanisms, showing greater ACL injury incidence in the early follicular or late-luteal phases.[9, 10]

Many hypotheses suggest that poor biomechanics movements, such as knee valgus, pronated foot placement, etc., may increase the risk of sports-related injuries. For example, acceleration into a valgus position and poor muscular control cause shear force and excessive rotary laxity that can result in meniscus tears and injury to the ACL.[11] Yet, there is currently minimal research examining the biomechanics of movement patterns in relation to injury in female footballers. Part of the lack of evidence is due to crude subjective assessments of functional movements (i.e. binary good vs. poor assessment) or inhibitive costs of sensitive measures of biomechanics movements,[12] making large-scale field studies impossible. The existing evidence has also focused primarily on male athletes or cohorts recovering from ACL reconstruction surgery.[13] In summary, no large-scale research has examined sensitive measures of the biomechanics of movement patterns in relation to injury risk in female footballers. There is a clear need for a biomechanics study design that is low-cost and scalable (for future expansion into a larger cohort).

OpenCap, a recently developed open-source platform for computing movement dynamics, provides a low-cost, portable and easy-to-use data collection tool.[12] It utilises videos captured on users' smartphones to cloud-compute movement dynamics and kinematics. While typical motion capture setup requires equipment like cameras, force plates, reflective markers, EMG electrodes and a fixed laboratory environment, OpenCap can be set up with two smartphones and supporting tripods. This saves both time and cost to procure specialized hardware, software and expertise.[12] Unlike motion capture technology, OpenCap is not susceptible to between-experimenter marker placement errors.[14] This software enables a more consistent and accurate longitudinal comparison of participants' biomechanics performance across different phases of their period. With its low-cost and portable nature, OpenCap is a good tool to pilot for a larger scale, practical fieldwork data collection and to put into more diverse clinical research applications in the future.

As part of a larger project aiming to understand the relationship between the menstrual cycle, biomechanics and injury risk in female football players, the aim of this pilot study is to investigate how biomechanics movements change across the menstrual cycle. Given timeline constraints (e.g. data collection continued beyond the summer research visit), this report focuses on the first data collection time point. Therefore, the key aim of this report is report is to examine the three biomechanics parameters from the double leg squat - hip adduction, hip flexion and knee – and the total number of errors from the Landing Error Scoring System[15] jump-landing test differ based on previous weight-based movement experience. The discussion session elaborates next steps to expand the analysis onto a more diverse set of parameters and the full range of time points, making comparisons between different phases possible.

Methods

This study was approved by the UCL Research Ethics Committee (REC Project ID number: 25759/001) in June 2023. Participants underwent a three-part study, consisting of a baseline questionnaire, biomechanics testing battery and menstrual cycle tracking. Data were collected both online and in person at the football club from July to August 2023.

Study participants

There were 20 participants recruited for this study. Participants were all female football players from a single team in the 2023-24 Football Association (FA) Women's National League (WNL) Division One. Inclusion criteria were being over 18 years of age, and eumenorrheic (i.e. having had at least 10 periods in the past year). However, participants who are currently using hormonal contraceptives will only be included in the baseline factor analysis but not the cross-menstrual phase analysis. We recruited participants via email, text message and existing player networks. All participants signed an informed consent form before taking part in this study. All participants were compensated with an option to enter a draw for a single prize consisting of a £30 gift card and to receive a personalised biomechanics report.

Data Collection

Baseline Questionnaire

After providing informed consent through the online form, participants reported their personal characteristics, including weight, height and age, football and training background, menstrual history and past injuries. Questions related to menstrual history asked for the participant's number of days of their bleeding phase and the entire cycle, their period regularity as well as any usage of contraceptives. These were used to identify eumenorrheic women, allowing examination of further data by the following status: eumenorrheic (i.e. having had at least 10 periods in the past year), on hormonal contraceptives or with irregular periods. See Appendix A for the baseline questionnaire.

Biomechanics

Figure 1 shows the set-up for data collection. The testing battery consisted of three tasks. The first two tasks were double-leg squats (DLS) and single-leg squats (SLS). Participants were asked to cross their arms across the shoulders following standard protocol).[16] Each squat task (double, and single on the left and right sides) was attempted once, each consisting of 3 repetitions. The jump-landing task followed the Landing Error Scoring System (LESS) protocol, which involved both vertical and horizontal movements by having participants jump from a 30-cm (12-inch) elevated surface to a distance of half of their height away from the surface. Participants were asked to rebound immediately for a maximum vertical jump on landing.[15] One practice attempt (1 repetition for SLS per side or DLS and 1 trial for the jump-landing tasks) was allowed before the formal testing. Jump-landing trials and squat (SLS or DLS) attempts (3 repetitions as a unit) that were unsuccessful or unable to be processed by OpenCap (indicated by a red dot next to the recording on the web application) would then be re-attempted. Squat tasks were chosen as previous research has shown the association between the performance of athletes in such SLS and DLS tests with their lower extremity injury risk. LESS is chosen as it is a validated clinical assessment tool for jump-landing tasks, in particular, ACL injuries.[15, 17]

Figure 1. Set-up for data collection with OpenCap using two smartphones

Left: Outdoors set-up at the football field during a data collection session in July
Right: Indoors set-up at the Institute of Sports Health and Exercise during the testing of OpenCap

This study used OpenCap, an open-source, cloud-based software that processes videos to visualise motion data and compute biomechanics such as joint angles. It utilises an open-source pose estimation algorithm OpenPose[18] and neural networks to map the anatomical key points in a three-dimensional space. OpenCap autodetects and auto-scores individual errors (e.g. knee valgus, trunk flexion, foot position, etc.) and estimates joint angles, joint loads, muscle activation and other parameters.[12] The kinematic data,[19] biomechanics parameters and 3D body anatomical marker keypoint coordinates,[12] downloaded from the OpenCap web application were then also used to perform an automated scoring of the LESS with Python script. Two iOS devices (iPhone 13 Pro MLT83ZA/A and iPhone 11 MWLY2B/A, Apple Inc., Cupertino, CA, USA), both installed with the then-latest operating system version iOS 16.5.1 (Apple Inc., Cupertino, CA, USA) was used to record and upload videos of the trials onto OpenCap web application. The calibration checkerboard was printed on A4 paper from a standard printer.[12] More information regarding OpenCap can be found in Appendix B.

Menstrual cycle

The menstrual cycle is monitored by self-reported menses through the baseline questionnaire and ovulation tracking tests. The ovulation tracking is self-administered by players at home, using urinary hormone-tracking ovulation test kits (Clearblue Advanced Ovulation Test, Swiss Precision Diagnostics GmbH, Geneva, Switzerland). The test kits identify a fertility window by tracking estrone-3-glucuronide (E3G) and luteinising hormones (LH).[20] Ovulation can be predicted based on the trends of fertility hormones E3G and LH as research has shown that oestrogen peaks indicate forthcoming ovulation and that an LH surge precedes ovulation.[21, 22] The test kit shows "high fertility" when there is a rise in oestrogen levels and "peak fertility" when the LH surge is detected, which also indicates the end of a participant's ovulation testing cycle.

In participants whose average cycle length is greater than or equal to 24 days (i.e. having 15 or fewer periods) in the past year, ovulation testing began 7 days (i.e. Day 8, "D8") after Day 1 ("D1") of her next menstrual cycle and ended on the day with "peak fertility" results. D1 of a participant's cycle is estimated from the last reported menstrual bleeding based on the baseline questionnaire data or subsequent responses to the testing day questionnaire that also collects fatigue data (see Appendix C). In participants whose average cycle length is less than 24 days (i.e. having 16 or more periods) in the past year, testing began on Day 7 ("D7") instead. Participants reported their daily test results up till the day of getting "peak fertility" results, which corresponded to when they ovulate through either email, a Qualtrics questionnaire or a designated WhatsApp portal.

Key Variables

Based on players' baseline questionnaire responses, we regrouped those with "substantial experience (i.e. regular personal training)" and "fair bit of experience with a qualified personal trainer/coach" as with a *high level of experience* in weight-based movements; and those with "some experience but only in a football team setting" and "some experience but on my own" as with *low level of experience* in weight-based movements. Peak values of each biomechanics parameter (hip adduction, hip flexion and knee angle) were extracted by the findpeaks function in the pracma[23] package in R. The peak values across the three repetitions are averaged for the right and left sides, then the absolute differences between sides was calculated.

Statistical Analysis

Descriptive baseline data are shown as mean (± SD) and median (min, max) for continuous data and frequency (n, %) for categorical data. Shapiro-Wilk tests for normality were performed on the output biomechanics parameters (hip adduction, hip flexion and knee angle). The distribution of the data was also visualised by examining the respective histograms. As the biomechanics parameters were not normally distributed, we performed the Kruskal–Wallis one-way analysis of variance by ranks to look for any individual pair of significant differences in the right and left mean peak values and the imbalances, i.e. the difference of mean peak values (9 variables in total) across the two strength-based movement experience groups. Statistical analysis was performed in R Statistical Software[24] with the dplyr[25] (v1.12), ggplot2[26] (v3.4.2) and pracma[23] (v2.4.2) packages. An alpha level of .05 was used for all statistical tests.

Results

Baseline characteristics

A total of 20 players participated in the study. The participants had a mean age of 25.5 years (SD = 4.51), a mean height of 166 cm (SD = 5.96) and a mean weight of 65.5 kg (SD = 9.42). They were predominantly of a white ethnic background (75%) and were right-leg dominant (90%). The mean length of their bleeding phase and the whole menstrual cycle was 5.00 days (SD = 1.08) and 28.3 days (SD = 2.70), respectively. At baseline, 13 individuals reported having high levels of weight-based movement experience (*n* = 4 with “substantial experience (i.e. regular personal training)”, *n* = 9 with “fair bit of experience with a qualified personal trainer/coach”) and 7 individuals reported a low level of experience (*n* = 5 with “some experience but only in a football team setting”, *n* = 2 with “some experience but on my own”). Further descriptive statistics for the total sample and stratification by weight-based movement experience at baseline are presented in Table 1.

Table 1. Baseline characteristics of study participants stratified by weight-based movement experience

	Total sample *N* = 20	High levels of weight-based movement experience *n* = 13	Low levels of weight-based movement experience *n* = 7
Age			
Mean (SD)	**25.5 (4.51)**	**25.2 (5.21)**	**25.9 (3.13)**
Median [Min, Max]	**25.0 [18.0, 36.0]**	**25.0 [18.0, 36.0]**	**25.0 [22.0, 32.0]**
Ethnicity			
Black, Asian and minority ethnic	**5 (25.0%)**	**4 (30.8%)**	**1 (14.3%)**
White	**15 (75.0%)**	**9 (69.2%)**	**6 (85.7%)**
Height, cm			
Mean (SD)	**166 (5.96)**	**166 (6.63)**	**166 (4.96)**
Median [Min, Max]	**166 [153, 178]**	**166 [153, 178]**	**167 [160, 174]**
Weight, kg			
Mean (SD)	**65.5 (9.42)**	**67.2 (10.7)**	**62.3 (5.71)**
Median [Min, Max]	**63.5 [54.0, 99.0]**	**64.0 [58.0, 99.0]**	**62.0 [54.0, 71.0]**
Dominant leg			
Right	**18 (90.0%)**	**12 (92.3%)**	**6 (85.7%)**
Left	**2 (10.0%)**	**1 (7.7%)**	**1 (14.3%)**
First organized football experience, age			
Mean (SD)	**7.70 (2.23)**	**7.46 (2.18)**	**8.14 (2.41)**
Median [Min, Max]	**8.00 [4.00, 12.0]**	**8.00 [4.00, 10.0]**	**7.00 [6.00, 12.0]**
Squad with which majority games played last season			
First team, FA WNL Division One	**17 (85.0%)**	**11 (84.6%)**	**6 (85.7%)**
Others	**3 (15.0%)**	**2 (15.4%)**	**1 (14.3%)**
Regular gym-goer, at least once per week			
Yes	**17 (85.0%)**	**13 (100%)**	**4 (57.1%)**
No	**3 (15.0%)**	**0 (0%)**	**3 (42.9%)**
Regular gym experience, years			
Mean (SD)	**5.25 (4.79)**	**7.08 (4.91)**	**1.86 (1.95)**
Median [Min, Max]	**4.00 [0, 16.0]**	**5.00 [2.00, 16.0]**	**1.00 [0, 5.00]**
Strength-based training, times per week			
More than once	**16 (80.0%)**	**13 (100%)**	**3 (42.9%)**
Less than once	**4 (20.0%)**	**0 (0%)**	**4 (57.1%)**
Short-term injuries			

Yes	**7 (35.0%)**	**4 (30.8%)**	**3 (42.9%)**
No	**13 (65.0%)**	**9 (69.2%)**	**4 (57.1%)**
Severe injuries			
Yes	**5 (25.0%)**	**3 (23.1%)**	**2 (28.6%)**
No	**15 (75.0%)**	**10 (76.9%)**	**5 (71.4%)**
Hormonal contraceptive usage			
Yes	**2 (10.0%)**	**2 (15.4%)**	**0 (0%)**
No	**18 (90.0%)**	**11 (84.6%)**	**7 (100%)**
Length of bleeding phase, days			
Mean (SD)	**5.00 (1.08)**	**4.92 (1.26)**	**5.14 (0.690)**
Median [Min, Max]	**5.00 [2.00, 6.00]**	**5.00 [2.00, 6.00]**	**5.00 [4.00, 6.00]**
Length of cycles, days			
Mean (SD)	**28.3 (2.70)**	**28.7 (2.14)**	**27.6 (3.60)**
Median [Min, Max]	**28.0 [23.0, 34.0]**	**29.0 [25.0, 32.0]**	**27.0 [23.0, 34.0]**
Regular periods			
Yes	**18 (90.0%)**	**12 (92.3%)**	**6 (85.7%)**
No	**2 (10.0%)**	**1 (7.7%)**	**1 (14.3%)**

Biomechanics performance

Hip and knee biomechanics variables

In the full sample, the ranges of left knee angle, hip flexion and hip adduction mean peak values were 83.2°-118°, 66.8°-119° and 8.88°-27.7°, respectively; while those of the right side were 83.2°-117 °, 66.0°-118° and 7.79°-27.0° respectively (see Table 2). The imbalances (i.e. absolute differences in mean peak knee angle, hip flexion and hip adduction values) were 1.67° (SD = 1.32), 2.91° (SD = 2.24) and 5.12° (SD = 3.84) respectively. The histograms with left and right mean peak values overlayed can be found in Figure 2. Further descriptive statistics for separate left/right mean peak values and mean peak value differences can be found in Table 2.

Figure 2. Distribution of left (red) / right (black) mean peak hip flexion, hip adduction and knee angle values and their differences.

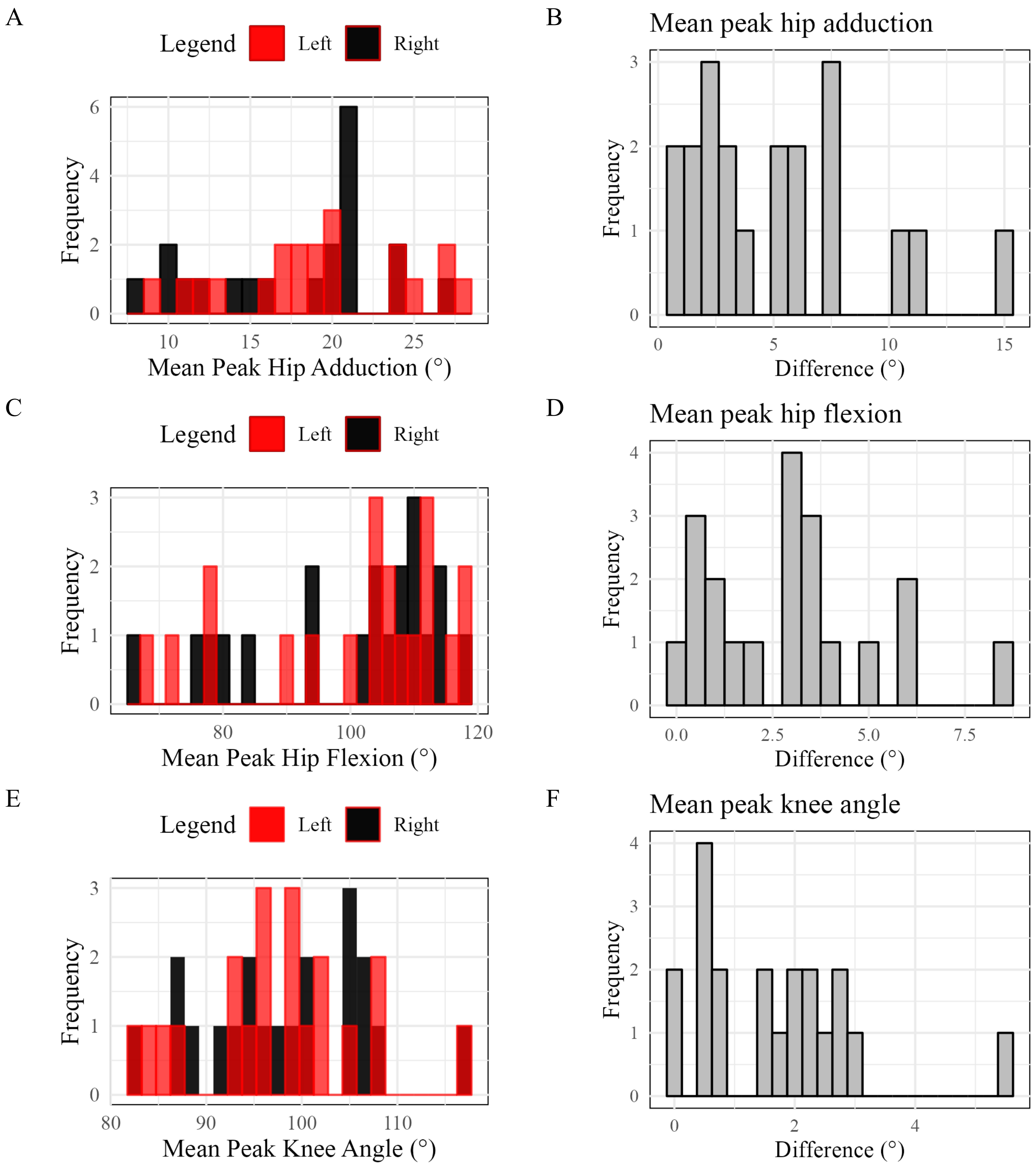
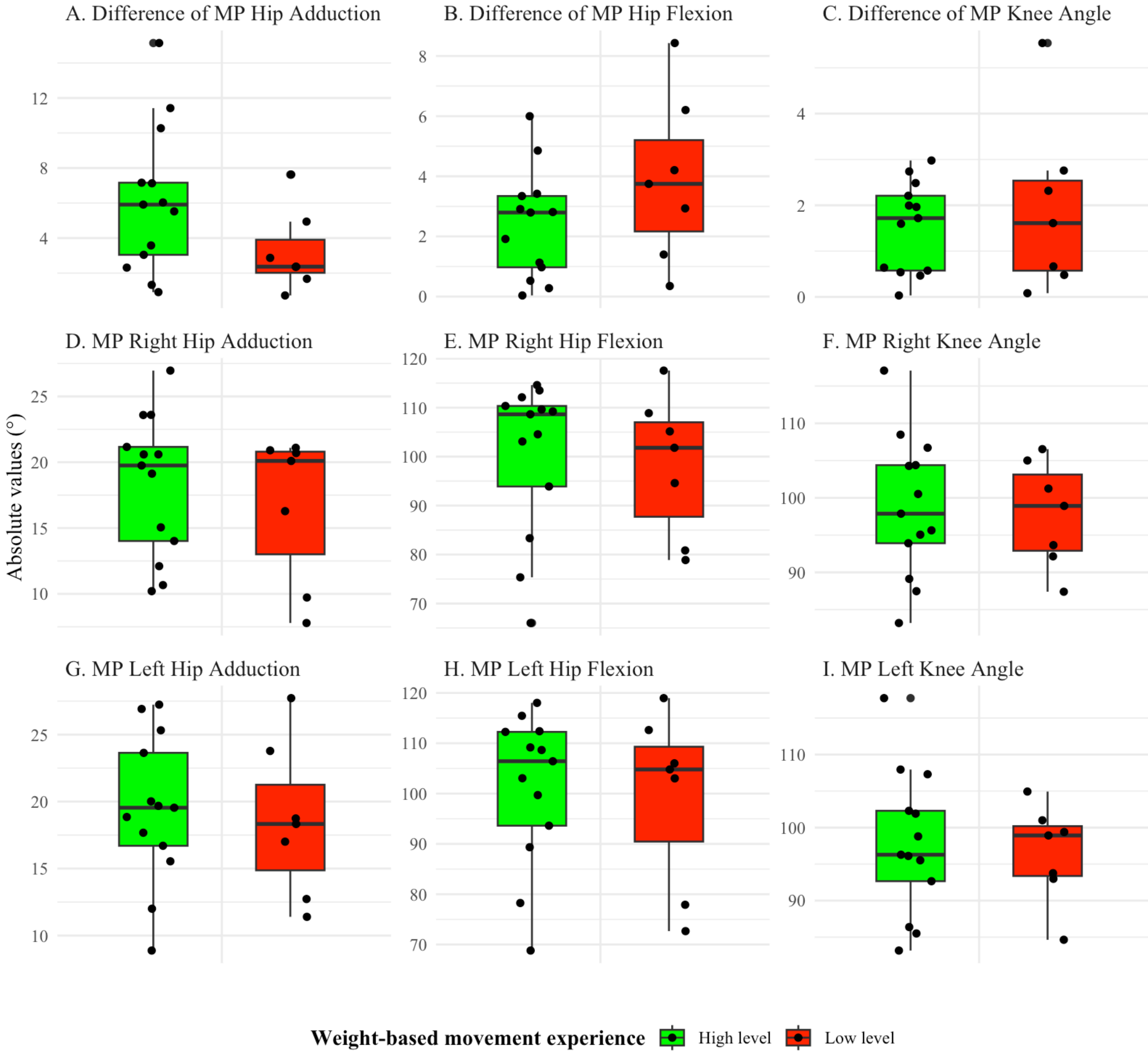


Table 2. Biomechanics performance (mean peaks and their differences) stratified by weight-based movement experience

	Total sample $N = 20$	High levels of weight-based movement experience $n = 13$	Low levels of weight-based movement experience $n = 7$	p value from Kruskal–Wallis test
Knee angle, °				
Mean peak, right				
Mean (SD)	98.4 (8.50)	98.8 (9.44)	97.8 (7.06)	0.78
Median [Min, Max]	98.4 [83.2, 117]	97.9 [83.2, 117]	98.9 [87.4, 107]	
Mean peak, left				
Mean (SD)	97.4 (8.69)	97.8 (9.83)	96.5 (6.66)	0.84
Median [Min, Max]	97.5 [83.2, 118]	96.3 [83.2, 118]	98.9 [84.6, 105]	
Mean peak differences				
Mean (SD)	1.67 (1.32)	1.53 (0.976)	1.92 (1.87)	0.78
Median [Min, Max]	1.66 [0.0319, 5.54]	1.72 [0.0319, 2.98]	1.61 [0.0813, 5.54]	
Hip flexion, °				
Mean peak, right				
Mean (SD)	99.6 (15.0)	100 (15.8)	98.2 (14.4)	0.55
Median [Min, Max]	105 [66.0, 118]	109 [66.0, 115]	102 [78.9, 118]	
Mean peak, left				
Mean (SD)	101 (15.4)	101 (14.9)	99.4 (17.4)	0.84
Median [Min, Max]	105 [68.8, 119]	106 [68.8, 118]	105 [72.7, 119]	
Mean peak differences				
Mean (SD)	2.91 (2.24)	2.38 (1.80)	3.89 (2.76)	0.14
Median [Min, Max]	2.86 [0.0363, 8.43]	2.79 [0.0363, 6.00]	3.75 [0.350, 8.43]	
Hip adduction, °				
Mean peak, right				
Mean (SD)	17.7 (5.37)	18.3 (5.35)	16.7 (5.67)	0.61
Median [Min, Max]	19.9 [7.79, 27.0]	19.8 [10.2, 27.0]	20.1 [7.79, 21.1]	
Mean peak, left				
Mean (SD)	19.1 (5.45)	19.4 (5.49)	18.5 (5.76)	0.66
Median [Min, Max]	18.8 [8.88, 27.7]	19.5 [8.88, 27.2]	18.3 [11.4, 27.7]	
Mean peak differences				
Mean (SD)	5.12 (3.84)	6.14 (4.18)	3.22 (2.33)	0.12
Median [Min, Max]	4.26 [0.724, 15.1]	5.91 [0.915, 15.1]	2.37 [0.724, 7.63]	

We found that the more experienced group had slightly greater individual left or right mean peak values but these were not statistically significant. Figure 3 provides stratified box-whisker plots for all nine biomechanics parameters Table 2 provides the means (SD), medians (min, max) as well as the *p* values obtained from the non-parametric Kruskal-Wallis test.

Figure 3. Biomechanics variables between players who are more experienced (green) and less experienced (red) with weight-based movements.



Note: MP = Mean Peak

Landing Error Scoring System

There was a total of 44 recordings from the first session of 16 participants (*n* = 10 with high and *n* = 6 with low levels of weight-based movement experience) analysed by the OpenLESS system. Two participants did not conduct jump-landing tests due to injury, and two participants had trials that faced difficulties with processing and the auto-scoring of LESS and were thus not included. Each participant performed 3 jump-landing trials in a single continuous attempt, with 1 to 3 valid trials (M = 2.75, SD = 0.68, median = 3) per participant from those included in the final analysis (*n* = 16). Taking an average of each participant's trial(s), the mean number of errors was 3.65 (SD = 2.33) and the median was 3.17 (range = 0.00-8.00). Across the averaged trials, the mean total LESS error count was 3.23 (SD = 1.99) for the group with high level of experience with weight-based movements while that of the group with low level of such experience was 4.33 (SD = 2.88). Histograms of the distribution of all individual tests and individual participants averaged LESS scores can be found in Figure 4. Further descriptive statistics for LESS scores stratified by participants' weight-based movement experience can be found in Table 3.

Figure 4. Distribution of individual test and individual averaged LESS scores

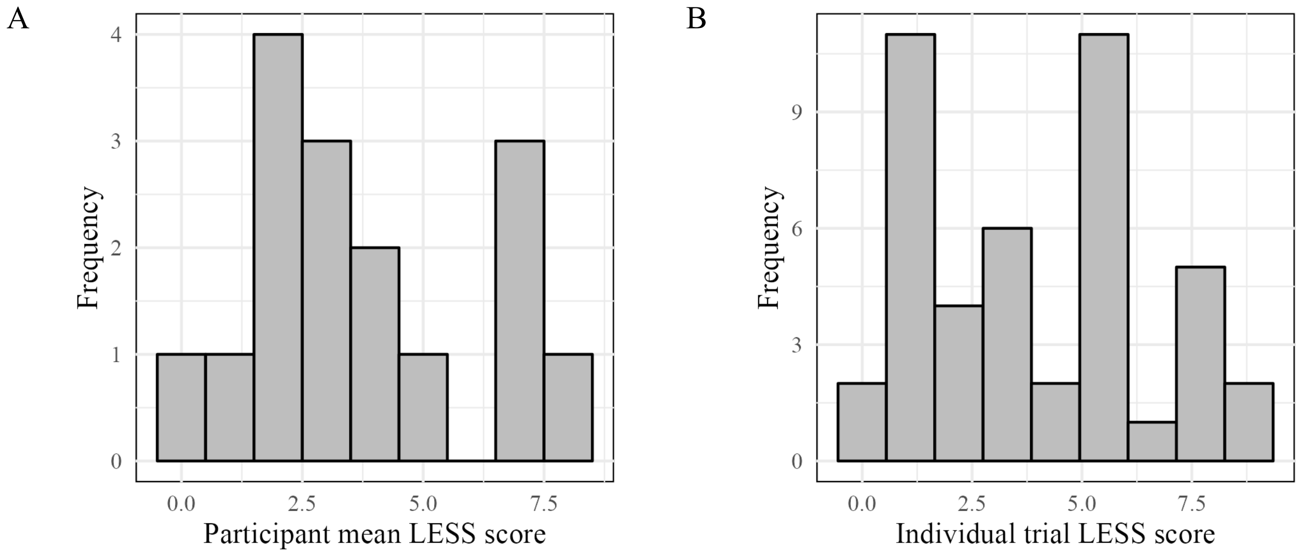
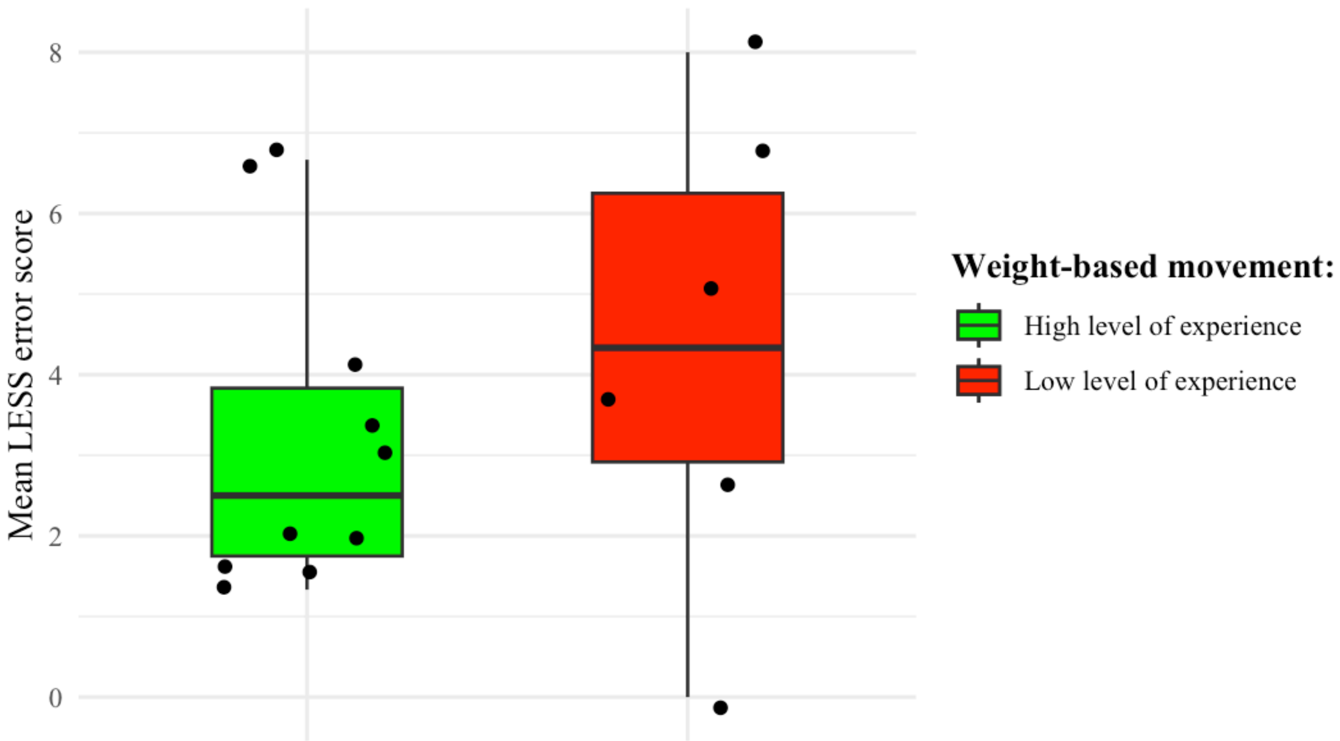


Table 3. Number of mean total LESS errors (per participant) stratified by weight-based movement experience at baseline

	Analysed sample *N* = 16	High level of weight-based movement experience *n* = 10	Low level of weight-based movement experience *n* = 6	*p* value from Kruskal–Wallis test
Mean LESS error score				
Mean (SD)	**3.65 (2.33)**	**3.23 (1.99)**	**4.33 (2.88)**	**0.33**
Median [Min, Max]	**3.17 [0, 8.00]**	**2.50 [1.33, 6.67]**	**4.33 [0, 8.00]**	

We observed a lower mean LESS error score in the group with more experience with weight-based movements (see Figure 5). However, we did not find statistically significant differences between such mean LESS error scores of the two groups of participants with the Kruskal–Wallis test by ranks (χ^2 = 0.961, df = 1, p = .33).

Figure 5. Mean LESS score stratified by weight-based movement experience



Discussion

Main Findings

We compared 9 variables derived from the three initial biomechanics parameters (right, left, asymmetry for each of hip adduction, hip flexion and knee angle) as well the mean number of LESS errors across the two groups of different weight-based movement experience at baseline. We observed non-significant differences between the groups, but the data showed a trend of higher individual left/right side mean peak values and lower imbalance between the mean peak values for the more experienced group. By using the LESS to analyse the jump-landing tasks, we found fewer errors for the more experienced group, although this was not statistically significant. This pilot study successfully piloted using OpenCap under field-work training conditions and showed that it is a low-cost and feasible tool to capture the biomechanics and movement patterns of athletes. A larger sample size is needed to further explore differences by weight-based movement experience and explore the key objectives of the main study (more detail below).

Comparison to other studies

Previous research showed similar results, with training programmes targeting pelvic and core strength in female football players and hip and knee musculature in female school students respectively resulting in improvements in biomechanical risk factors for ACL injuries.[27, 28] This pilot study's analysis was not significant but trending to show that greater exposure and experience to gym-related training may contribute to better biomechanics performance. This may be due to the current limited number of participants of n = 20 and n = 16 for hip/knee parameters and LESS analysis, respectively, that are underpowered to detect the sensitive changes. As the focus of this report is on the weight-based movement experience from the first week of testing, participants' menstrual phases were not considered in analyses. Therefore, this may partially explain the non-significant analyses; future analysis will explore the data collected across different phases in a menstrual cycle.

Mechanisms and implications

A possible reason for better biomechanics performance with greater gym training and exposure is due to improvements in strength and stability brought by physical activity, thus contributing to lowering injury risks.[29] For example, the capacity to generate force in ankle plantarflexors, quadriceps, hamstrings and gluteal muscles is increased by concurrent strength and endurance training in athletes.[30] Those who are more fit and familiar with performing physically demanding tasks can do so at a lower percentage of their maximum capacity which prevents fatigue that alters movement patterns and stresses the body.[31] A higher (i.e. worse) score on LESS implies a greater number of landing technique "errors"[15] counted during the jump-landing tasks. If the group having more experience with weight-based movements has a lower LESS score, this suggests that greater exposure to gym-related training with personalised programmes will help improve biomechanics performance. This suggests further benefits in injury risk reduction by implementing more gym sessions in the training of athletes.

Strength and limitations

This study has several strengths. We used OpenCap which can estimate kinematic, kinetic, and musculotendon parameters and generate a great volume of data with potential for analysis.[12] Even though in this report, we looked at 3 parameters from the DLS tests and the total LESS score only, future analysis can be expanded into a wider range of measures and musculoskeletal forces that are computed in OpenSim using the data collected from OpenCap, as well as the individual errors from the LESS score. We demonstrated the feasibility of using OpenCap in field-work level data collection and the portability of its set-up. There is a robust protocol developed for this study and makes it highly standardized, reproducible and replicable. Although not directly considered in the analysis in this report, this study also used urinary hormone ovulation test kits that, as described above, detect not only LH but oestrogen levels. These hormone detection kits which can identify the ovulation phase,[20] together with the participants' self-reported menses, enabled a more accurate estimated timeline of the four phases (bleeding, follicular, ovulation and luteal)[32] in a menstrual cycle.

There were however a few limitations in the study sample and set-up that must be acknowledged. Firstly, there is a limitation of our small sample of study participants. Despite the small sample size, this also demonstrated the feasibility of using OpenCap at a fieldwork setting and will allow expansion to collection from more teams and players in the future. There were also footwear differences across the players as they wore either training shoes or football boots during testing. Due to the varying timing of data (e.g. before training began, during a training session), it was not possible to standardise this and instead, players could select their preference. While OpenCap has been validated against gold standard measures computed with marker-based motion capture and force plates,[12] this study is still limited by OpenCap's internal accuracy. This will be improved in the future, as OpenCap releases new versions of deep learning models for anatomical markers prediction from video keypoints that is trained with data from more subjects and a more diverse set of tasks. It can be expected that the model will be more accurate for a wider range of movements.[33]

Future Plans

The next key aim is to widen the range of biomechanics parameters considered, with OpenCap automatically estimating up to 35 variables for each test from such as the pelvis, ankle, subtalar and metatarsophalangeal joints. We will also include the LESS binary errors and the kinematics that are being used for each construct within the LESS's operational definitions (e.g. ankle plantar flexion and lateral trunk flexion at contact).[15] Data collected from subsequent weeks, spanning over the full range of all four menstrual cycle phases will be used to explore whether there are changes across those phases. The analysis will be done in eumenorrheic women but data from those on contraceptives or with irregular periods will also be considered separately. There are ongoing plans to broaden the participating player base, expanding data collection to two more football teams.

Conclusion

By computing kinematics through videos captured through smartphone cameras at a fieldwork setting with local FA WNL teams, we were able to pilot data collection with OpenCap, an open-source, portable and low-cost tool. We explored the baseline differences in biomechanics parameters across two groups with different levels of experience with weight-based movements to find non-statistically significant differences. As the sample size expands, more parameters are investigated and the menstrual cycle phase are considered, potential implications may be important to inform changes in training plans to improve biomechanics performance for a reduced injury risk.

References

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Appendix A: Sample Baseline Questionnaire

Part 1: Introduction and Consent is excluded from this appendix.

Q12 **Part 2: About you**

Q13 How old are you?

____

Q14 What is your ethnic group? Choose one option that best describes your ethnic group or background. (Options are set based on Office for National Statistics guidelines)

- ○ English/Welsh/Scottish/Northern Irish/British (1)
- ○ Irish (2)
- ○ Gypsy or Irish Traveller (3)
- ○ Any other White background, please describe: (4) ________________
- ○ White and Black Caribbean (5)
- ○ White and Black African (6)
- ○ White and Asian (7)
- ○ Any other Mixed/Multiple ethnic background, please describe: (8) ________________
- ○ Indian (9)
- ○ Pakistani (10)
- ○ Bangladeshi (11)
- ○ Chinese (12)
- ○ Any other Asian background, please describe: (13) ________________
- ○ African (14)
- ○ Caribbean (15)
- ○ Any other Black/African/Caribbean background, please describe: (16) ________________
- ○ Arab (17)

◯ Any other ethnic group, please describe: (18)

____

Q15 What is your height? You can give this in centimetres or feet/inches.

____

Q67 What is your weight? You can give this in pounds or kilograms.

____

Q62 Which leg do you prefer to kick a ball with?

◯ Left leg (1)

◯ Right leg (2)

◯ No preference, I use both legs equally (3)

End of Block: Personal Particulars

Start of Block: Football & Training Background

Q16 **Part 3: Football & Training Background**

*

Q17 How old were you when you started playing organised football?

____

Q18 In the last season, with which squad did you play the majority of the games?

○ First team, FA WNL Division One (1)

○ Reserve team, FA WNL Division One (2)

○ Others, please specify the league and squad you were in: (3)
____

Q58 Do you go to the gym one or more times per a week?

○ Yes (1)

○ No (2)

○ Other, please describe: (3) ____

Display This Question:

If regular gym or not = Yes

Or regular gym or not = Other, please describe:

Q57 How many years have you been regularly going to the gym? *You can give partial years (e.g. 1.5 years = 18 months) or estimate this as best you can (e.g ~5 years)*

____

Q19 Thinking about the last six months, how often do you do strength-based training (with weights or body weight)?

- ◯ More than 4 times/week (1)
- ◯ 2-3 times/week (2)
- ◯ 1 time/week (3)
- ◯ 1-2 times/**month** (4)
- ◯ Less than 1 time/**month** (5)
- ◯ Never (6)

Q60 What experience do you have with doing weight-based movements (e.g. squats, deadlifts, etc)

- ◯ No experience (1)
- ◯ Some experience but only *on my own* (2)
- ◯ Some experience but only *in a football team setting* (3)
- ◯ Fair bit of experience with *a qualified personal trainer/coach (4)*
- ◯ Substantial experience *(i.e. regular personal training)* (5)

Q64 Do you notice any imbalance on one leg or the other when doing single-leg movements? *This can be either your left or right leg, or no difference. Please tell us about this.*

____

Q65 Have you had any short-term injuries in the **last three months** that could impact your performances on squats, jumps or landings? Please tell us more.

____

Q66 Have you had any severe injuries that could impact your performances on squats, jumps or landings *(e.g. ACL injury)*? Please tell us more.

____

End of Block: Football & Training Background

Start of Block: Menstrual History

Q21 **Part 4: Menstrual History**

Q26 Are you currently using hormonal contraception?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Currently using hormonal contraception? = Yes

Q27 Which type of hormonal contraception do you use?

- ◯ Implant (1)
- ◯ Injection (2)
- ◯ Hormonal intrauterine device (IUD) e.g. Mirena coil (3)
- ◯ Non-hormonal copper coil (IUD) (4)
- ◯ Vaginal ring (5)
- ◯ Hormonal patch (6)
- ◯ Oral contraceptive pill (7)
- ◯ Others, please specify: (8) ____

Display This Question:

If Currently using hormonal contraception? = Yes

Q28 Note: If you are currently using hormonal contraception, you will not be asked to do the urinary ovulation test. As stated in the PIS, *you may still take part in the questionnaire and biomechanical assessments, although your data will be used as comparison only.*

Page Break

*

Q23 When was the first day of your last period? We will ask you to start using ovulation test kits based on this date and will calculate this for you. **Please use dd/mm/yyyy format.**

____

*

Q25 How many days does your period typically last (the bleeding phase of the menstrual cycle)? If you currently track your cycle, you can check this.

____

*

Q55 How many days is your typical menstrual cycle? The cycle starts the first day of a period and ends the day before the first day of the next period. This is typically between 23-35 days. If you use a menstrual cycle tracking app, you can check that for this information.

____

Q54 Do you have regular periods (i.e. the number of days between each period is relatively consistent)? It is normal to vary by a few days each time, irregular refers to more significant variation.

- ◯ Yes, my period is regular (1)
- ◯ No, I get my period irregularly (2)
- ◯ Others, please specify: (3) ____

*

Q24 In the **last year**, approximately how many periods have you had? If you use a menstrual cycle tracking app, you can check that for this information.

____

Q29 Could you tell us about your current understanding of when in your menstrual cycle you may be at biggest risk of injury? There is no right answer, but we want to understand current perceptions.

____

____

____

____

____

End of Block: Menstrual History

Appendix B: Test Protocol

Test Protocol

Title of Study: Menstrual cycle phase and injury risk in female footballers: a pilot study

UCL Research Ethics Committee Approval ID Number: 25759/001

Department: Institute of Sport and Exercise and Health

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Dr Jo Blodgett
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Last update: 25 July 2023[1]

[1] The document's page numbering has been slightly modified for the final report

Contents

1 Overview:

This protocol covers the materials, set-up, methodology and procedures for the pilot study with a football team in West London from July to August 2023. Data collection visits spanned four weeks from 11 July 2023, performed two times per week with around 10 players test per visit.

Address for data collection: Rosedale College, Wood End Green Road, Hayes, Middlesex, UB3 2SE

2 Background:

The pilot study is designed to test OpenCap and assess if biomechanical movement patterns differ within individuals across the menstrual cycle phase in a sub-elite football team.

The pilot study is part of a larger research project aiming to investigate associations between menstrual cycle phase and injury type across a full season in the English Football Association's top four divisions (96 clubs). The secondary aim of the project is to use the AI jump-landing and squat biomechanics screening tool in a subset of clubs and examine how these parameters are associated with injury risk– including interactions with the menstrual cycle phase.

3 Materials and tools

3.1 Baseline player questionnaire

3.1.1 A browser device with a network connection to access the Qualtrics questionnaire (phone, laptop, tablet)

3.1.2 Body weight scale and height measurement device for respondent's own measurement

3.2 Biomechanics measurement

OpenCap, an open-source, cloud-based software that calculates kinematics using videos from smartphones was used for measuring the biomechanics and movement patterns of participants. *Please see Note A for more technical details.*

3.2.1 A computer/browser device with a good network connection to access app.opencap.ai

3.2.2 At least two iOS devices with cellular/Wi-Fi network connection.
- All iPhones, iPads and iPods released after 2018 are supported
- For live video recordings, to be uploaded to the OpenCap web app

3.2.3 At least two tripods with phone holders
- For mounting and supporting the iOS devices

3.2.4 One printed checkerboard on A4 paper
- Printed on at least A4 paper with squares at least 35mm, and a white border around all sides
- Must not be covered with a reflective surface or laminated
- For calibration of the video feeds from the iOS devices

3.2.5 Cardboard/plastic stand for the calibration checkerboard

3.2.6 A sturdy box or stool with a height of 12 inches (30cm)

3.2.7 Marking tape/sports tape

3.2.8 Face covering (e.g. face masks or mask scarfs)

3.3 Ovulation tracking

3.3.1 Urinary ovulation detection kits

- Clearblue Advanced Digital Ovulation Test[1] sourced online (or at pharmacies)
- A testing kit with eight test sticks and one test per participant (for testing from day 7/8 onwards)
- The ovulation test kits identify a fertility window by tracking estrone-3-glucuronide (E3G) and luteinising hormones (LH). Ovulation date is predicted based on the trends of fertility hormones E3G and LH as research has shown that oestrogen peaks indicate forthcoming ovulation and that an LH surge precedes ovulation.[2, 3] The test kit shows "high fertility" when there is a rise in oestrogen levels and "peak fertility" when the LH surge is detected.

4 Set-up and test procedures

4.1 Informed consent

4.1.1 The participant shall read the *Participant Information Sheet* and give consent to taking part in the test [online].

4.1.2 The participant should note that they are free to withdraw their consent any time without giving a reason, but their data could only be removed up till the submission of summary-level data due to the planned publication of a paper in an academic journal.

4.1.3 Consent is recorded electronically through the following online questionnaire.

4.2 Baseline player questionnaire

4.2.1 The participant shall complete the online baseline player questionnaire ('baseline questionnaire') taking around 5-10 minutes.

4.2.2 The questionnaire asks for personal demographics such as age, football and training background, menstrual history, menstrual cycle-related symptoms, injury history, etc. Anthropometric measures including height and weight was measured by participants on their own.

4.2.3 Participants can choose to either provide their contact details, i.e. email address or phone number or choose their own five-digit personal numerical identifier (PNI) for self-identification and follow-up purposes. Such identifiers are pseudonymised with a three-digit subject numerical identifier (SNI) and only the SNI will be used to identify them within the research environment, including but not limited to when using OpenCap to store testing battery recordings. Note: Participants can either quote their provided contact details or the PNI to identify themselves with researchers. However, they need to provide contact details at first (instead of choosing a PNI) if they want to receive a copy of their personalised report after the pilot study.

4.2.4 Groups were assigned based on participant availability in advance. For example, two separate groups can be created for two testing days per week. *Refer to Note B for template of emails of the grouping notification and reminders to attend the on-site training.*

4.3 OpenCap software set-up

4.3.1 Preparing an iOS device for the test requires:

- Stable mobile/Wi-Fi network connection (a “Device no longer connected to the server, verify your internet connection” warning will appear on screen if not)
- Prerequisite application *TestFlight*, which can be installed from App Store
- *OpenCap* beta, accessible by installing its mobile app or scanning the QR code

4.3.2 Scanning the QR code on the computer, using the *OpenCap* app to pair the devices with the same web session.

4.4 Camera set-up and calibration

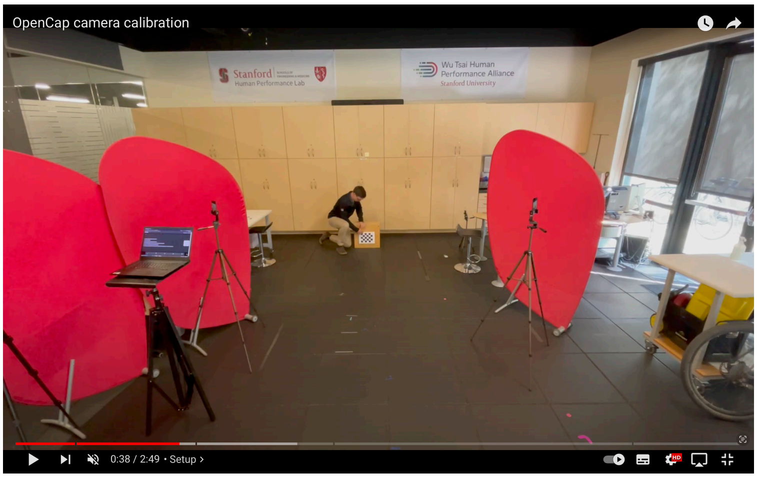
4.4.1 Use the rear-facing (on the side opposite the touchscreen) camera for recording

4.4.2 Maximise spread between cameras but minimize occlusion

- Stationary activities: ±45° from normal
- Gait activities: ±30° from normal for longer (deeper) capture volume, potentially add a third camera to remedy occlusion

4.4.3 Avoid sagittal views as it leads to confusion of the software when limbs overlap.

4.4.4 Wipe or clean the camera lens or adjust the angle to avoid any smudge/fingerprint on the lens or artefact introduced by direct sunlight that affects the video clarity.



Screenshot shows the setup demonstration by OpenCap team[4]

4.4.5 Place the checkerboard perpendicular to the ground, with the long size down.

4.4.6 The checkerboard should be within 5m from the cameras, at the centre of the desired capture volume while being visible by all cameras. Note: it is optional but helpful to use some objects to mark the perimeter of the capture volume to remind participants to stay inside it. *Refer to the following photo for reference.*

On-site set up showing one of the phones and markers on the ground.
Photo taken on 11 July 2023 (Tuesday).

4.4.7 Do not move the camera anymore after calibration but the printed checkerboard can be removed after the calibration stage. Note: in most of the data collection in this pilot, the checkerboard setup was left inside the capture volume for convenience when a recalibration is required.

On-site set-up showing the whole capture volume and calibration checkerboard. Photo taken on 11 July 2023 (Tuesday)

4.5 Testing day questionnaire and registration

4.5.1 Ask the participant to fill in the testing day questionnaire consisting of short questions about fatigue and their latest period (if applicable).

- Participants should use their participant identifiers (PNI or contact information) instead of a name for confirming their attendance and setting up the OpenCap web app.
- Participants should be allowed to first fill in the form and begin their training, then return at a more appropriate time/during a break to avoid significant distruption to their training routine.
- Collect the forms before starting the static (neutral pose) trial and keep them for upcoming processing or data entry for further analysis.

4.5.2 Input the participant details on the OpenCap web application before starting the static trial (neutral pose capture/calibration in the next section).

- Use the corresponding SNI from a separate dataset that links their participant identifiers to that SNI. *Refer to Note C for the naming standards of sessions and tests on OpenCap*.
- Select the "share no data publicly" option for data sharing with the research community, beyond the Stanford developers and leave the remaining settings on default.

4.6 Data collection

4.6.1 Make sure that the participant is fully visible within the capture volume throughout the testing battery. The box should also be equally represented in both phone cameras.

- Provide the participant with a face covering to wear before capturing or recording anything as the videos are visible (only) to the software development team for algorithm development[5] – having the face covering minimizes the extent of identification. Note: OpenCap is hosted by Stanford University, is HIPAA compliant, and complies with Stanford University requirements for Infrastructure-as-a-Service Solutions that involve high risk data, like videos. All data are encrypted in transit and at rest and can only be accessed by the OpenCap development team and the investigator. Authentication with a 20-character password and two-factor authentication is required to access data. [6]
- It might help to have the participant wear tight fitting clothing and contrasting colours between (e.g., black shoes on a black floor are not ideal; however initial testing showed that it still worked with black shoes + trousers + dark blue floor)
- The participant can enter the field of view after starting recording, but not re-enter after exiting

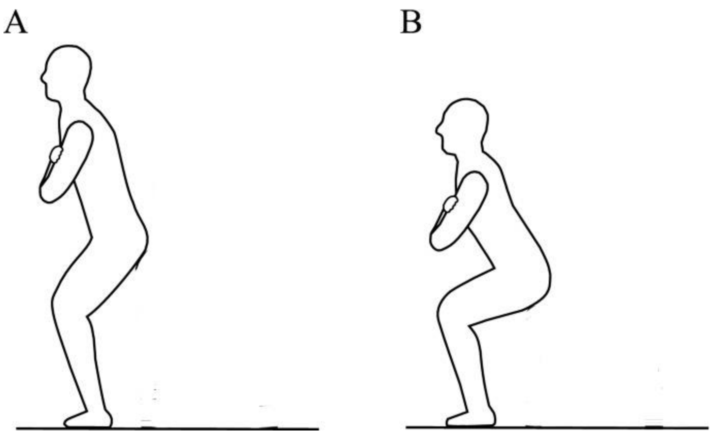
4.6.2 Record the neutral pose of the participant to scale the musculoskeletal model.

- Ensure that the entirety of the participant's body is visible by all (two) cameras.
- Stand in the pose shown in the web app: the participant's legs should be slightly apart, within shoulder width with hands slanted, forming an isosceles triangle towards the ground. The static trial should be captured with the subject facing forward.
- The participant should stand still during the recording process. There will be an on-screen notification telling when the participant can relax while it is processing and recognizing the recorded neutral pose.
- If the neutral pose fails to be recognized or processed, consider recalibrating with the checkerboard, or consult the OpenCap troubleshooting checklist.

4.6.3 The testing battery includes double leg squats (3 reps), single leg squats (3 reps/each side) [7] and a jump-landing task (Landing Error Scoring System[8]; 1 attempt). More detailed steps are laid out in the next part. Explain the tasks and allow the participant to practice **once**. Leave a one-second buffer between starting the recording and cueing the participant to start the movement.

4.6.4 Double leg squats (1 attempt consisting of 3 repetitions)

- Arms should be folded across the shoulder at all times
- Keep your feet flat on the floor and avoid lifting heels off the ground
- Aim at reaching a 90-degree squat, if not possible, still, try your best to squat deeper
- Stand back up, and repeat this motion for a total of 3 times



Drawing showing the double-leg squat task procedure[9]

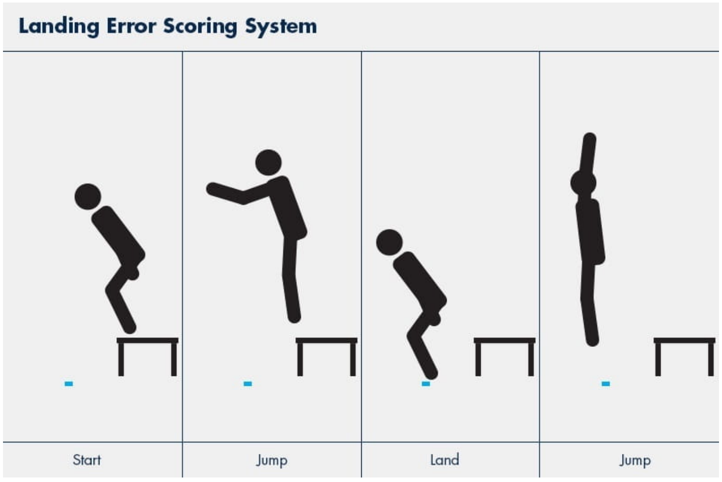
4.6.5 Single leg squat (1 attempt consisting of 3 repetitions per side)

- Arms should be folded across the shoulder at all times
- Stand on the right (left) foot only and hold the left (right) foot out, slightly in front of your torso
- Aim at reaching a 60-degree squat, if not possible, still, try your best to squat deeper
- Stand back up on your right (left) foot only
- Repeat 3 times and switch sides afterwards

4.6.6 Jump-landing task (Landing Error Scoring System[8]; 1 attempt)

- Stand on top of the 12-inch (30cm) stool/box. Note: confirm that the starting position on the box is fully visible in both cameras to avoid synchronization issues.
- Jump to a distance half of their height (taken from anthropometric measurement during the baseline questionnaire) away from the box. Rebound immediately to a maximum jump upon landing. Note: make sure that the cue is emphasized enough regarding the maximum height rebound jump and the 50% height landing location.
- Note: masking/sports tape can be used to mark different target landing zones for heights of approximately 150cm to 180cm (jump-landing distance of 75cm to 90cm).

- The attempt should consist of 3 successful trials of the above set of movements, recording each trial individually



Outline of the procedure to carry out a Landing Error Scoring System (LESS) jump-landing task[10]

4.6.7 Coloured dots next to trial names indicates the status of the trial: green (successfully processed), orange/yellow (being processed), and red (error in processing). Ask the participant to redo trials with a red dot. Note: there are times when processing takes a long time and the dot will remain yellow after a successful upload. Just proceed with caution once you have successfully uploaded the trial to avoid accidental deletion.

4.6.8 Download data only when all dots have turned green (or red). Click on the red dots to get insights into what went wrong. There is a specific session identifier for each individual session and every trial can be retrieved from the OpenCap web app in the future. Note: There are Python scripts available for download from https://github.com/stanfordnmbl/opencap-processing to download trials in bulk.

4.6.9 Repeat the testing battery for other participants without re-calibrating the cameras by pressing "New session same setup". Note: if there is a significant time for waiting between participants, a new session should be started nonetheless (without the neutral pose calibration stage) first to prevent the network from timing out. This also reduces the chance of the new session failing and having to recalibrate again starting from the initial checkerboard stage.

4.7 Ovulation tracking

4.7.1 In participants whose average cycle length is >23 days, testing should start on Day 8 (‘D8’) and end on the day with peak fertility results. In participants whose average cycle length is <24 days, testing should begin on Day 7 (‘D7’) instead. Day 1 (‘D1’) of the participant’s cycle is the first reported day of the most recent menstrual bleeding phase. This is calculated from the baseline questionnaire or (biomechanics) testing day questionnaire responses – the baseline period is used for calculating an expected test start date for everyone but when the first predicted ovulation window has passed, subsequent kit distributions should be planned based on self-reported ones via the testing day questionnaire.

4.7.2 Distribute the ovulation test kits ('test kits') containing one test holder and eight test sticks when the week of the biomechanics test visit immediately precedes their estimated date of D7/D8, unless known future unavailability required earlier arrangements. Explain and make sure participants understand the ovulation testing protocol. The starting date and other important points to note were printed on a test information slip (TIS) enclosed in the test kit envelope.

4.7.3 Send email/text reminders *(see Note B for templates)* to participants one day before their target start date (D7/D8) and also when there is non-compliance (i.e. forgetting to do the tests by noon or incorrect submissions) to urge them to submit at their earliest convenience.

4.7.4 Participants should read the instructions leaflet (a modified version is printed on the TIS) and/or the FAQ and video to ensure correct usage of the test kits. Important points to note are as follows:

- Do not test more than once per day.
- Always test using the first urine after one's longest sleep (I.e. first thing in the morning). Note: If it is not possible (e.g. they are given the kit the night of D8) or a participant missed it, they can still do it anytime throughout the day, although being less preferable.
- Throughout testing never hold the test with the absorbent tip pointing upwards.

4.7.5 Photo of the ovulation test kit results (low fertility–a clear circle, high fertility–a flashing smiley face, peak fertility–a static smiley face) should be uploaded to the designated portal (Qualtrics form, email or WhatsApp message) daily until the day with peak fertility. Participants should identify themselves with the 3-digit SNI printed on the TIS, instead of their contact information or the 5-digit PNI to avoid unnecessary identification. Note that low and high fertility results only display for 8 minutes so a photograph record should be taken as soon as possible. Note: Per the instructions leaflet, one can eject the test stick to have the results shown for another 2 minutes if they missed the results at first.

4.7.6 Used test sticks should be disposed of in accordance with instructions on the leaflet, but the test holder together with unused test sticks, if any, should be returned to experimenters at the next on-site testing date following peak fertility results.

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Note A: Technical Notes for OpenCap

This study uses OpenCap, an open-source, web-based software that processes (iOS) phone-captured videos on the cloud to visualise motion data and compute biomechanics such as joint angles. It uses open-source pose estimation algorithms like OpenPose[11] to extract 2D keypoints from the multi-view videos, and 3D keypoints are computed by triangulating the keypoint velocity cross-correlation synchronized 2D keypoints. This is further augmented into a more comprehensive 3D anatomical marker set using a recurrent neural network (two long short-term memory networks). Through computing marker trajectories, using inverse kinematics and a musculoskeletal model with biomechanical constraints, we can obtain 3D kinematics, which is then tracked by muscle-driven dynamic simulations to estimate 3D kinetics.

OpenCap algorithms can autodetect and auto-score individual errors (e.g. knee valgus, trunk flexion, foot position, etc.) and estimate joint angles, joint loads, muscle activation and other parameters[12]. After cloud analysis, the following types of data are downloadable: raw and synchronized videos, calibration images, marker data, and processed OpenSim data (OpenSim model and kinematic files). All kinematic data is stored in a .mot file and can be exported in OpenSim. There are utilities to batch download and/or export as .csv when using the Python scripts provided. (Links 1 and 2).

Note B: Sample reminder emails and text

Welcome email for group allocation and on-site testing reminder
Dear player, Thanks for signing up to our research about menstrual cycle and female footballer injury risks. You are assigned to the TUESDAY (18/7, 25/7, 1/8, 8/8) group. The first session of data collection will be tomorrow (18 July). Once you arrive, please come to our testing area to fill in a short form (with only 3 questions). Depending on your schedule and preference, you can just fill in the said form first and return to do the tests at a later appropriate time/break, or complete the test before training. I aim at finishing the set up process by roughly 19:15 so any time after that should work. For any enquiries, please feel free WhatsApp 07879467883 anytime (phone not monitored 24/7 but we will reply asap) or send us an email. Regards, [insert name]
Reminder email for kit distribution
Dear Player, Please be reminded that you will be given the the ovulation test kit with eight test sticks and one test holder at the testing session today. Please read the test information slip (TIS) enclosed in the envelope to find the testing start date and a 3-digit code to identify yourself when submitting results – do not use your name. Please remember that tests should be done as soon as possible in the morning. You can choose to upload your results via a Qualtrics form (link: https://qualtrics.ucl.ac.uk/jfe/form/SV_01YXWu6dPtt4ByC?Q), by replying to this email (research.football@ucl.ac.uk) or sending our research work phone a WhatsApp message (08789467883). Regards, [insert name]
Reminder email for shortly commencing ovulation testing period (1 day before D7/8)
Dear Player, Thank you for taking part in our study and doing the biomechanics test in the past weeks. This is a warm reminder that you should start doing your ovulation tests tomorrow, on the morning of [insert date]*. There are a total of 8 test sticks and 1 holder in your testing kit, with an information slip enclosed as well. Please read that sheet for more instructions. You can submit your results via Qualtrics (https://qualtrics.ucl.ac.uk/jfe/form/SV_01YXWu6dPtt4ByC?Q), email (research.football@ucl.ac.uk)

or whatsapp (07879467883). Do remember to do the test as soon as you wake up in the morning. Please let us know if you have any questions or difficulties. Once you reach peak ovulation ("a static smiley face") and have also submitted the results for that day, remember to return the unused sticks (if any) and the test holder to the research team on your next data collection. Regards, [insert name] *The paper information slip may contain another date but make sure that you follow the updated instructions
Reminder email for missed ovulation test results reporting or other non-compliance
Dear Player, This is a warm reminder for you to submit the ovulation testing results (Qualtrics/email/WhatsApp). Do note that even if you got the "peak fertility" results you should still send us a picture of that day's results. If you have already done so, please ignore this message. Regards, [insert name]

Note C: OpenCap session and trial naming standards

The following examples are based on a hypothetical participant with PNI = 099 and the test day being a Tuesday on the fifth week of data collection:

Name	Description
*neutral**	Static trial (neutral calibration pose)
099-w5tue-dlsx	Double leg squat
099-w5tue-slsr	Single leg squat with **right** foot on ground
099-w5tue-slsl	Single leg squat with **left** foot on ground
099-w5tue-less1	LESS jump no.1
099-w5tue-less2	LESS jump no. 2
099-w5tue-less3	LESS jump no. 3

*This is the default naming used by OpenCap and is not controlled by the researcher

The session name for this example is *099-w5tue*.

Appendix C: Sample Testing Day Questionnaire

Date:

Day of Week: Tuesday / Thursday

Week Number: 1 / 2 / 3 / 4 / 5

Contact/PNI (5-digit)	
Please rate how tired or fatigued your legs feel today **from 1 to 10)** *1=fresh & ready to run; 10=feel so heavy, can barely walk*	
Please circle: 1 2 3 4 5 6 7 8 9 10	
Have you started your period since the baseline questionnaire or the last testing day?	
Please circle: Yes / No **If yes, please tell us the date of the first day of your period:________________________**	
Any remarks	

Thank you for taking part in: Menstrual cycle phase and injury risk in female footballers: a pilot study *(UCL Research Ethics Committee Project ID number: 25759/001)*