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Scheduling of eccentric lower limb injury prevention exercises during the soccer micro-cycle: Which day of the week?

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Abstract

Scheduling eccentric-based injury prevention programs (IPP) during the common 6-day micro-cycle in Soccer is challenged by recovery and tapering phases. This study profiled muscle damage, neuromuscular performance, and perceptual responses to a lower-limb eccentric-based IPP administered 1 (MD+1) versus 3 days (MD+3) post-match. 18 semi-professional players were monitored daily during 3 in-season 6-day micro-cycles, including weekly competitive fixtures. Capillary creatine kinase concentration (CK), posterior lower limb isometric peak force (PF), counter-movement jump (CMJ) performance, and muscle soreness were assessed 24 h prior to match-day (baseline), and every 24 h up to 120 h post-match. The IPP consisted of lunges, single stiff leg dead-lifts, single leg-squats and Nordic hamstring exercises. Performing the IPP on MD+1 attenuated the decline in CK normally observed following match-play (CON: 142%; MD+3: 166%; small differences). When IPP was delivered on MD+3, CK was higher versus CON and MD+1 trials on both MD+4 (MD+3: 260%; CON: 146%; MD+1: 151%; moderate differences) and MD+5 (MD+3: 209%; CON: 125%; MD+1: 127%; small differences). Soreness ratings were not exacerbated when the IPP was delivered on MD+1, but when prescribed on MD+3, hamstring soreness ratings remained higher on MD+4 and MD+5 (small differences). No between trial differences were observed for PF and CMJ. Administering the IPP in the middle of the micro-cycle (MD+3) increased measures of muscle damage and soreness, which remained elevated on the day prior to the next match (MD+5). Accordingly, IPP should be scheduled early in the micro-cycle, to avoid compromising preparation for the following match.

Keywords: injury prevention, scheduling, muscle, soccer

Introduction

Soccer has a problem with injuries. Injury rates in both professional [1-3] and amateur soccer (9.6 injuries/1000h [1]) exceed those observed both in industrial occupational settings [4] and other outdoor sports [5]. The economic burden of injuries is substantial [6], and has also been shown to transcend to soccer performance outcomes, where teams with more injuries have been less successful on the pitch [7,8]. Whilst some soccer injuries are inevitable (i.e. trauma injuries), 58% of injuries occur without contact and are considered preventable [3]. The most common injury type are muscle strain injuries (31-37%), predominantly occurring in the hamstrings, adductors, quadriceps and calves [1-3]. Although injury prevention programs (IPP) are commonplace in high-level professional soccer teams, there is a lack of information about how to schedule these sessions in the context of a training week during the competitive season [9].

A survey of 44 'Premier League' teams from around the world identified that the adoption of IPP was ubiquitous, with an average of 5.1 ± 2.4 practitioners (doctors, physiotherapists, sport scientists) employed to administer the programs [9]. Eccentric exercises were ranked the most effective modality implemented within IPP [9]. The theoretical basis for the inclusion of eccentric strengthening exercises include the greater mechanical tension and strain exerted upon the muscle fibers [10], yielding increases in muscle fascicle length [11,12] that consequently increase muscle shortening velocity and force production at longer muscle lengths [10,12]. Whilst IPP consisting of eccentric exercises are warranted on the basis of the enhanced muscle function and architectural adaptations, the residual muscle fatigue and damage incurred [13] presents a scheduling dilemma for injury prevention specialists. This challenge is exacerbated in soccer, where competition schedules mandate a delicate balance between providing adequate recovery from competition and training, in combination with a suitable maintenance stimulus to prevent declines in muscle strength and lower limb power that have been documented over the course of a season [14-16].

According to the available literature, intense soccer training is not scheduled in the 24-48 h period post-match [17-19], to facilitate recovery of muscle function and damage. In micro-cycles consisting of one competitive match per week, the greatest volume of on-field training is typically scheduled in the middle of the training week, between 2-4 days prior to the match [19,20], with IPP most commonly delivered 48-72 h post-match [9]. However, considering the muscle damage and residual fatigue inflicted from eccentric exercise may persist for 48-72 hours [21-23], current IPP scheduling in the middle of the training week may impact upon subsequent physical match performance. Moreover, during congested fixture periods (2 or more matches per week) common to soccer, IPP are often sacrificed to prepare for, or compete in, the following match [9], which over-time may result in muscle de-training [14,15,24] and render the player more susceptible to injury [25]. To our knowledge, a dearth of evidence is available regarding the scheduling and subsequent recovery from an IPP session in relation to soccer matches [9].

The purpose of this study was to examine the acute impact of scheduling an eccentric-based lower-limb IPP on different days of the micro-cycle upon muscle function, damage, and soreness. Assessment of these muscle responses can inform the scheduling of IPP in soccer micro-cycles, and provide relevant insight to practitioners dealing with congested fixtures.

Materials and methods

Participants

Eighteen semi-professional outfield players (Age: 22.9 ± 4.5; Stature: 178.4 ± 8.7 cm; Body Mass: 74.5 ± 11.3 kg) were recruited from three teams competing in the 3rd and 4th tiers of the Australian Soccer pyramid during the 2015 season. These players typically undertake 2 field-based training sessions, perform in one or two competitive fixtures, and 1-3 gymnasium conditioning sessions (on an independent, self-selected basis) per in-season week. The study obtained ethical approval from the Western Sydney University human research committee, and each player provided written informed consent to participate.

Experimental Design

Within a cross-over design, players were randomized into three groups within each team (n=6) to ensure that the order of experimental trials could be counter-balanced and limit the impact of extraneous factors such as weather conditions, training and competition loads etc. Allocation was performed using a spreadsheet to reduce between group differences in controlled trials (Hopkins, 2010), using participant characteristics in the following priority order: team, peak posterior limb isometric force (see details below), positional role, age and body mass. Table 1 displays the characteristics of players in each group

Over a 3-week period, players undertook three experimental conditions in 6-day micro-cycles. The micro-cycles were selected on the basis that only one match was scheduled on weekends, and there were no expected changes to the routine training program that included two soccer training sessions each week. The 6-day micro-cycles commenced on match-day (MD), and outcome measures were tracked for the following 5-days, which included on-field training sessions scheduled 3 (MD+3) and 5 days (MD+5) post MD. During each micro-cycle, players training and match training loads were determined; and subjective, biochemical and performance recovery profiles were assessed 24 h prior to match-day (baseline), and 24 (MD+1), 48 (MD+2), 72 (MD+3), 96 (MD+4) and 120 h (MD+5) post-match.

The experimental design included a control micro-cycle (CON), in which the players training loads and recovery parameters were monitored without any intervention. The impact of scheduling was examined using two treatment trials in which an eccentric-based IPP focusing on the anterior and posterior thigh muscles was administered either ~24- (MD+ 1) or ~72-h (MD+3) post-match, immediately following the recordings of muscle performance, damage and recovery measures. We selected the scheduling in our two treatment trials based on the survey of McCall and colleagues [9], which demonstrated that whilst the majority (61%) of teams prescribed IPP between 48-72 h post-match, a notable proportion (16%) delivered an IPP within 24 h of the match, highlighting the uncertainty in professional practice.

The IPP was based on a program administered to elite level soccer players in a premier level European club, and consisted of 4 exercises depicted in figure 1; lunges, single stiff-legged deadlift with 6 kg kettle-bell, single leg eccentric squats (all 4 x 5 repetitions on each limb) and Nordic hamstring exercises (NHE) performed on a Bosu-ball (4 x 5 repetitions). The Bosu-ball was used for the NHE to accentuate the eccentric stimulus at extended muscle lengths, the joint position which corresponds with the mechanism of hamstring injury [26] and positioning in which the greatest NHE-induced strength gains are observed [12]. These exercises were selected because injuries to the hamstring and quadriceps are amongst the most prevalent in soccer [1-3], and that eccentric exercises are considered the most important feature of IPP by soccer specialists [9]. The IPP was performed under direct supervision of both a chartered physiotherapist (MW) and a sport scientist (RL) to ensure appropriate and consistent exercise techniques. Players had been familiarized with the IPP program following two training sessions in the 2-weeks preceding the study.

Outcome Measures

On the day prior to the match, and each day of the micro-cycle (excluding match-day), players attended a training ground to perform the battery of measures. Upon arrival, players warmed-up by running around a marked area on the training pitch for 5-minutes at 10 km/h (running speed standardized via a metronome). Upon completion, a capillary blood sample was drawn to determine plasma creatine kinase, which was used as an indirect estimate of muscle damage [27]. Next, players were fitted with a knee brace to undertake the assessment of posterior lower-limb isometric peak force. During a subsequent 4-min rest interval players recorded their subjective evaluations of any training load incurred over the previous 24 hours, and ratings of perceived muscle soreness. Finally, players performed the maximal counter-movement jump assessments. Players were familiarized with the outcome measure procedures on two occasions prior to data collection.

Creatine Kinase

Duplicate capillary blood samples were drawn from the fingertip and collected in heparinzed capillary tubes. 30 μl samples were immediately transferred onto reagent strips and the concentration of creatine kinase in the plasma was measured via Reflectance photometry (Reflotron IV, Boehringer Mannheim, Germany). The spectrometer was calibrated prior to each day using manufacturer supplied calibration strips. Where duplicate samples were either dubious or markedly different, additional samples were collected. The mean of two acceptable CK recordings was used for subsequent analysis (3.5% coefficient of variation; measurement range: 24.4-1400 $U{\cdot}L^{-1}$).

Isometric Muscle Strength

Posterior lower limb isometric peak force was measured on the dominant limb at 30° of knee flexion (0° = full knee extension) according to the methods adopted in previous soccer studies [21,28]. We adopted an isometric modality that is sensitive to neuromuscular fatigue induced by soccer match-play [21,28], and deemed feasible for daily monitoring to limit the impact of the maximum contractions upon the time-course of muscle function recovery. Knee flexion angle was sustained throughout the contraction using a knee brace that was fixed according to an inherent goniometer (Orthopaedic Appliances Pty Ltd, Australia). The heel of the dominant leg was placed on a 1000hz piezoelectric force platform (Kistler Instruments Pty Ltd, Australia) wired to a data acquisition system and attached to a plinth, with the non-dominant leg fully extended below the plinth (See Figure 2). Players were instructed to push their dominant heel into the force platform "as fast and as forcefully as possible" during three maximal 3 s contractions, separated by a 2-min rest period. Force data was smoothed with a sliding 200 ms window and the peak force (N) was recorded for analysis, having corrected for passive limb-mass. The typical error (expressed as a percentage co-efficient of variation) established from the three baseline (MD-1) recordings of isometric peak force was 8.2 % (90% confidence intervals [CI]: 6.7 to 11.2%).

Counter-movement Jump

The counter-movement jump is a commonly used tool to track neuromuscular recovery following soccer match-play [21,29]. Players performed two maximal counter-movement jumps (CMJ; hands placed on hips for the duration of the attempt), interceded by 2 minutes of passive recovery. The speed and depth of the countermovement phase were self-selected. Players performed the CMJ on a force platform (Precision Calibration Systems, Sydney, Australia), with force signal sampled at 1000Hz. The analogue to digital converter signal was calibrated prior to each day using a known mass, and the signal was zeroed in between each participant to avoid drift. The vertical force trace was collected (Powerlab 16/35, ADI instruments, Australia; 16-bit analogue to digital conversion) and smoothed by a digital low pass filter cut off at 50 Hz. The flight-time:contraction-time ratio was recorded according to previously outlined procedures [30], and the jump height (cm) estimated from time in flight [31]. The baseline coefficients of variation for CMJ height and flight-time:contraction-time ratio were 5.8% (CI: 4.8-7.9%) and 9.5% (CI: 7.7-12.7%), respectively.

Perceived Muscle Soreness

Daily ratings of perceived soreness in the hamstring and quadricep muscle groups were reported at rest. Players used a 100 mm visual analogue scale superimposed with the following verbal anchors: 0 = "absolutely no soreness", and 100 = "the most muscle soreness that they could possibly bear" [32].

Monitoring Variables

External Load

During matches, players wore a 10Hz GPS device (MinimaX S4, Catapult, Australia) affixed in a neoprene under-garment worn beneath their training/playing jersey. Players wore the same device and undergarment throughout the study to attenuate within-subject error. Doppler velocity data was pre-processed using the manufacturers 'Intelligent Motion Filter' and the minimum effort duration was set at 0.2 secs (Catapult Sprint, version 5.1.7, Catapult Sports, Australia). GPS data were extracted and further processed using R (version 3.01). Instantaneous observations of velocity and acceleration were discarded when the number of satellites informing the receiver was less than 6, and/or the horizontal dilution of precision (HDOP) was less than 1.25. The average proportion of data discarded during match files was 0.19 ± 0.21% of total playing time. All match observations therefore met the inclusion criteria, whereby extracted instantaneous data accounted for <3% of the total session duration. Players' total distance covered (TDC) and that covered at high- (HSR; > 15.0 $km{\cdot}h^{-1}$) and sprinting (SPR; > 23.0 $km{\cdot}h^{-1}$) running speeds were computed for each session.

Internal Load

The internal load was calculated using the session-RPE method [33], recorded 10 minutes after all training and matches during each micro-cycle. Players were also asked to retrospectively rate exertion and provide training duration(s) for any additional conditioning sessions performed outside of the team environment. These ratings were collected on a daily basis during the recovery profiling assessments for the previous 24-hour period. Recent observations suggest that sessional RPE ratings are robust measures even when collected retrospectively [34].

Statistics

For statistical analysis, outcome measures were expressed as change scores from the relevant micro-cycle baseline measure, and subsequently log-transformed to reduce non-uniformity error. Linear mixed models (IBM SPSS version 23.0, Armonk, NY) were used to examine the impact of scheduling upon the recovery time-course of muscle function, soreness and damage markers. The experimental trial and measurement day were entered into the model as fixed factors, and within-player variance was modeled as a random factor. In addition, sRPE and baseline measures of the relevant dependent variable were imputed as covariates in the model. Baseline recordings accounted for week-to-week changes, and sRPE adjusted for variations in internal training load both within and between micro-cycles for each individual player. P-values generated from least-squared difference post hoc tests, in combination with back-transformed estimated marginal mean effect statistics, were imputed into a spreadsheet [35] to derive magnitude-based inferences. The magnitude of the effect was classified as small, moderate, or large according to standardized fractions (0.2, 0.6, and 1.2) of the pooled between-subject standard deviation, calculated from measures collected 24 h post-match (MD+1) in the each trial. We elected to use MD+1 data to anchor standardized thresholds considering the large between-subject variation in responses to soccer match-play, and to avoid type II error. Inferences were determined from the disposition of the 90% confidence interval for the mean difference in reference to the standardized thresholds (*likely* = >75%; *very-likely* = > 95%; *most-likely* > 99.5%), but regarded as unclear if the confidence intervals overlapped both positive and negative thresholds by 5% [36]. Data are reported as the back-transformed estimated marginal means (adjusted for sRPE and relevant baseline measures) with corresponding 90% intervals.

Results

Compliance

17 players undertook all 3 micro-cycles and fully complied to the IPP. One player completed one micro-cycle, before withdrawing due to a contact injury sustained during a match.

Match Loads

Table 2 presents external and internal load data collected during the three competitive matches, according to the experimental trial. Match-day external load measures (TDC, HSR) were *likely* lower in the MD + 3 trial (small-moderate effects), however no internal load (sRPE) differences were identified between experimental conditions. The matches were also played in similar ambient temperature (CON: 18.3 + 1.5; MD+1: 18.5 + 2.4; MD+3: 19.2 + 2.9) and relative humidity (CON: 44.1 + 18.8%; MD+1: 42.3 + 18.0%; MD+3: 39.6 + 17.1%).

Muscle Damage

Creatine Kinase responses to the study can be observed in Figure 3. CK was 256% (CI: 225-292%) of baseline 24 hours post-match, with no between trial differences observed. Expressed as percentage change from baseline, performing the IPP 24 h after the match (MD+1) attenuated the decline in CK (197%; CI: 166-233%) at MD+2 (likely small effects) versus CON (142%; CI: 120-170%) and MD+3 (166%; CI: 140-196%). Administering the IPP 72 h following the match (MD+3) increased CK versus CON and MD+1 on both MD+4 (MD+3: 260%; CI: 219-310%; CON: 146%; CI: 121-176%; MD+1: 151%; CI: 127-180%; likely moderate effects) and MD+5 (MD+3: 209%; CI: 176-248%; CON: 125%; CI: 105 to 150%; MD+1: 127%; CI: 106 to 151%; likely to very-likely small effects).

Muscle Soreness

Soreness ratings (VAS 0-100) of the hamstring and quadricep muscle groups are presented in panes A and B, respectively, of Figure 4. Hamstring soreness increased 4.8-fold following match play, with no between trial differences, and returned to baseline after 72 hours in CON. Hamstring soreness following the match was not exacerbated by undertaking the IPP on the following day (MD+1), as observed over the subsequent 72 hours. Alternatively, when the IPP was administered on MD+3, hamstring soreness remained higher on MD+4

(26.9; CI: 20.3-33.4 AU) and MD+5 (22.5; CI: 16.2-28.9 AU) versus CON (MD+4: 7.0; CI: 0.2-13.7 AU; MD+5: 9.5; CI: 3.1-16.0 AU) and MD+1 trials (MD+4: 8.2; CI: 1.9-14.6 AU; MD+5: 7.1; CI: 0.8-13.4 AU; likely to very-likely small effects).

Quadriceps soreness also increased (+16.2; 90%CI: 11.8-20.5 AU) 24 h post matches, and returned to baseline by MD+3 irrespective of the trial. Scheduling of the IPP on either MD+1 or MD+3 had no effect upon quadriceps soreness across the micro-cycle.

Performance Measures

Changes in performance measures according to both the micro-cycle and experimental trial are presented in Figure 4. Posterior lower limb strength (panel A) was lower at baseline in CON versus MD+3 (likely small difference), however no other between trial differences were observed during the micro-cycle when adjusted for both baseline data and sRPE. Posterior lower-limb strength also did not change across the micro-cycle, irrespective of the experimental trial.

Flight time:contraction time ratio (panel B) did not differ either across the micro-cycle or between experimental trials. CMJ height was 3.7% lower versus baseline at 24 h post-match (likely small effect; panel C), and performance returned to baseline on MD+2. There were no differences between the experimental trials in CMJ performance.

Discussion

In this study we examined the impact of IPP scheduling within 6-day micro-cycles upon muscle function, soreness, and creatine kinase as an indirect measure of damage. Administering the eccentric-based IPP 24 hours following matches slowed the rate of creatine kinase decay, but did not exacerbate soreness beyond the typical recovery time-course. In contrast, delivering the IPP in the middle of the micro-cycle (MD+3) increased measures of soreness and damage, which remained elevated on the day prior to the following match (MD+5). IPP scheduling had no impact upon the muscle function measures adopted in this study. To our knowledge, this is the first study to examine the impact of IPP scheduling during a typical micro-cycle in soccer, and our preliminary findings infer that administering eccentric-based exercises in the middle of the training week may negatively impact upon preparation for the following match. Moreover, delivery early in the micro-cycle ensures that the training stimulus is not sacrificed during congested fixtures periods in which matches are played every 3-4 days.

Surveys of current industry practice suggest that IPP are commonly scheduled 48-72 hours following a match, and that eccentric-based exercises are considered the most effective modality [9]. When we administered an eccentric-based IPP 72 hours following match-play

(MD+3), robust CK and hamstring muscle soreness responses were observed (Figures 3 and 4), and remained elevated 24 h prior to the next match in 6-day micro-cycles. Although acute muscle function was not impaired following the eccentric IPP in this study (Figure 5), higher residual values of CK prior to team-sport training and competitive matches have been associated with reduced explosive running [37] and technical performance ratings [38]. Whereas, self-reported muscle soreness collected pre-training or pre-match have a trivial association with external load parameters [39,40], and to the authors knowledge there is no published literature evaluating the impact of soreness ratings on subsequent non-contact injury risk. Notwithstanding, collectively these observations would suggest that scheduling IPP in the middle of the micro-cycle may compromise performance in the following match, however further work may be necessary to confirm whether repeated high-intensity actions that better reflect the nature of soccer activity are unhindered following eccentric IPP.

Although training load studies have implied that the greatest volume of both on-field [19,20] and IPP training [9] is performed in the middle of the micro-cycle, following approximately 24-48 h post-match recovery [17-19], 7 of the 44 teams surveyed by McCall and colleagues [9] reported delivering an IPP within 24 h post-match. When IPP was scheduled on MD+1 in the current study, CK decay was slowed 48 h post-match, but returned to baseline after 72 h, and the time-course of muscle function and soreness recovery post-match was not affected. These observations to some degree are supported by previous work, which showed that prescribing an upper-body strength training session 24 h following a bout of damaging lower-limb eccentric actions [13] did not adversely impact recovery kinetics (hamstring strength, CK, muscle soreness). Whilst training structures in micro-cycles consisting of weekly competition schedules typically comprise of recovery and regenerative strategies, the inclusion of additional training 24 h post-match may optimize the limited time available for training, and offset the seasonal losses in strength and power in team-sports [14-16]. Whilst a potentially attractive solution to training prescription in congested competition schedules, further work is necessary to determine both the acute and chronic responses to administering an IPP during the typical muscle regenerative phase of the weekly soccer micro-cycle in which muscle function may be compromised.

The increase in creatine kinase observed 24 h post match in this study (256% vs. 98-300%), together with the decay recorded at 48 (142% vs. 45-300%) and 72 h (138% vs. 90-202%) in the control trial, was comparable to previous research [21-23,41]. Furthermore, the response magnitudes for soreness recorded in our control trial far exceeded those reported previously in elite cohorts [21,22,42] at 24 and 48 h post-match. Despite the robust CK and soreness responses observed, the muscle function measures adopted in our study were generally not sensitive to soccer match-play. Only peak counter-movement jump height was reduced 24 hours post-match, with no change documented in FT:CT ratio, or the isometric assessment of posterior lower-limb peak force. Our data on lower-limb power and strength are in contrast with other work documenting the recovery time-course of neuromuscular function following team-sports match play [21,29]. Given the equivalent internal responses to soccer match-play we observed when contrasting to previous work, it is difficult to reconcile this disparity. However, because we were not able to influence team selection in our study, players were at times selected as substitutes or were early withdrawals from the game, which to an extent reflects the low external loads reported herein. Accordingly, the impairment of neuromuscular function likely had a high degree of variability in our study, which may explain the lack of differences observed.

Of note was that the IPP induced the same acute CK magnitude response versus match-play, when delivered on MD+3. This was surprising considering that the players were familiar with the IPP, but may reflect the lower training status of our semi-professional cohort. For example, the mean baseline isometric peak strength recorded in this study was ~20-30% lower than that reported for the same procedure in professional players [21,28]. It is also noteworthy that individuals with a strength training history recover muscle function and CK responses back to baseline quicker than their untrained counterparts [43]. It may be the case that professional players routinely exposed to eccentric muscle actions during both IPP and soccer activity have a blunted response and faster CK decay following IPP. This may be due to structural reinforcement of muscle fibers, or the addition of sarcomeres in series which renders the fascicles more resistant to stretch, potentially reducing mechanical disruption and microscopic trauma [44]. The semi-professional cohort examined in this study had a mixed strength-training history, but were familiar with lower-limb eccentric exercises, and were exposed to the eccentric nature of soccer activity between 3-4 times per week, with a particularly rigorous soreness and CK response to matches. Hence, whilst generalization of the current findings to professional programs is speculative, we would caution against administering eccentric-based IPP in the middle of the micro-cycle in professional team-sports.

The major limiting factor of the current study was the administration of a standardized IPP that did not take into consideration the differing training histories and capacities of the individual players. We recognize that in applied practice athletes may undertake tailored IPP, but we considered standardization necessary given the cross-over design adopted, and the challenges in prescribing individualized eccentric training intensity and volume. In contrast, we were unable to standardize the match stimulus given our preference for an ecologically natured study, and with the exception of load monitoring could not access the players on match-day to ascertain measures of muscle function, damage and soreness immediately pre- and post matches. An examination of physical match performance following the IPP delivery at MD+1 or MD+3 may have provided further insight on the impact of IPP scheduling, however we omitted this analysis considering the high-degree of between-match variation in high-speed running and sprinting [45]. Interpretation of CK derived from blood samples as an indicator of muscle damage is confounded by its unknown origin, and can often be explained by blunt force traumas in sporting settings where collisions are commonplace [46]. Finally, generalizability of the current findings should be tempered considering the semi-professional cohort adopted, whose training history, micro-cycle schedules, and capacity may influence the acute muscle responses following the eccentric-IPP, and may not directly translate into professional practice.

In summary, scheduling an eccentric-based injury prevention program in the middle of a 6-day micro-cycle left residual impairments in muscle soreness and damage on the day prior to the next match. Alternatively, administering the program 24 hours post-match had limited impact on recovery kinetics. The results would suggest that delivering eccentric injury prevention exercises earlier in the micro-cycle does not impact on subsequent match preparation, and that this strategy may avoid in-season detraining which renders the player more susceptible to injury, particularly considering that IPP are often sacrificed during congested fixture schedules involving 2 or 3 matches per week.

Perspectives

The incidence and location of injuries in Soccer is well established [1-3], and substantial resources have been allocated to injury prevention [9]. However, scheduling of eccentric-based injury prevention programs is challenged by fixture congestion, and the inherent need to recover from, and prepare for, competitive matches. The insights from this study provide some preliminary evidence to guide sports medicine professional practice, however further work is warranted considering the multitude of factors governing the scheduling of injury prevention programs. Further knowledge generation in the area of injury prevention scheduling will assist both Soccer teams and their governing associations in reducing the high burden of injury, and may inform fixture-scheduling policy.

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Tables

Table 1: Mean (SD) participant characteristics and order of counter-balanced trials.

Group	Peak Force (N)	Body Mass (kg)	Positional Roles	Age (yrs)	Order of counter-balanced trials		
					Week 1	Week 2	Week 3
A	241.0 (49.2)	82.0 (7.6)	2*LAT, 1*CD, 1* CM, 2*ATT	23.0 (2.1)	CON	MD+3	MD+1
B	252.3 (66.7)	74.6 (14.3)	2 * LAT, 3 * CD, 1*ATT	24.5 (7.0)	MD+1	CON	MD+3
C	244.7 (33.8)	66.9 (4.6)	2*LAT, 1* CD, 3*CM	21.2 (3.1)	MD+3	MD+1	CON

LAT=lateral defender/midfielder; CD=central defender; CM=central midfielder; ATT=attacker; CON=control trial; MD+1=IPP administered on MD+1; MD+3=IPP administered on MD+3.

Table 2: External and Internal Load measures from competitive matches

	Control	MD + 1	MD + 3
Total Distance (m)	8500 [M] (7580-9420)	7900 [S] (7060-8740)	6839 (5947-7730)
High-Speed Running ($m; > 15.0\ km{\cdot}h^{-1}$)	1108 [S] (944-1272)	1011 (862-1161)	895 (736-1054)
Sprinting ($m; > 23.0\ km{\cdot}h^{-1}$)	166 (127-206)	133 (97-169)	123 (85-161)
Game Time (mins)	85 [S] (75-95)	79 (70-88)	70 (61-80)
sRPE (AU)	503 (443-563)	476 (415-536)	487 (426-547)

[S] Denotes likely small difference vs. MD + 3; [M] Denotes likely moderate difference vs. MD + 3.

Figure Legends

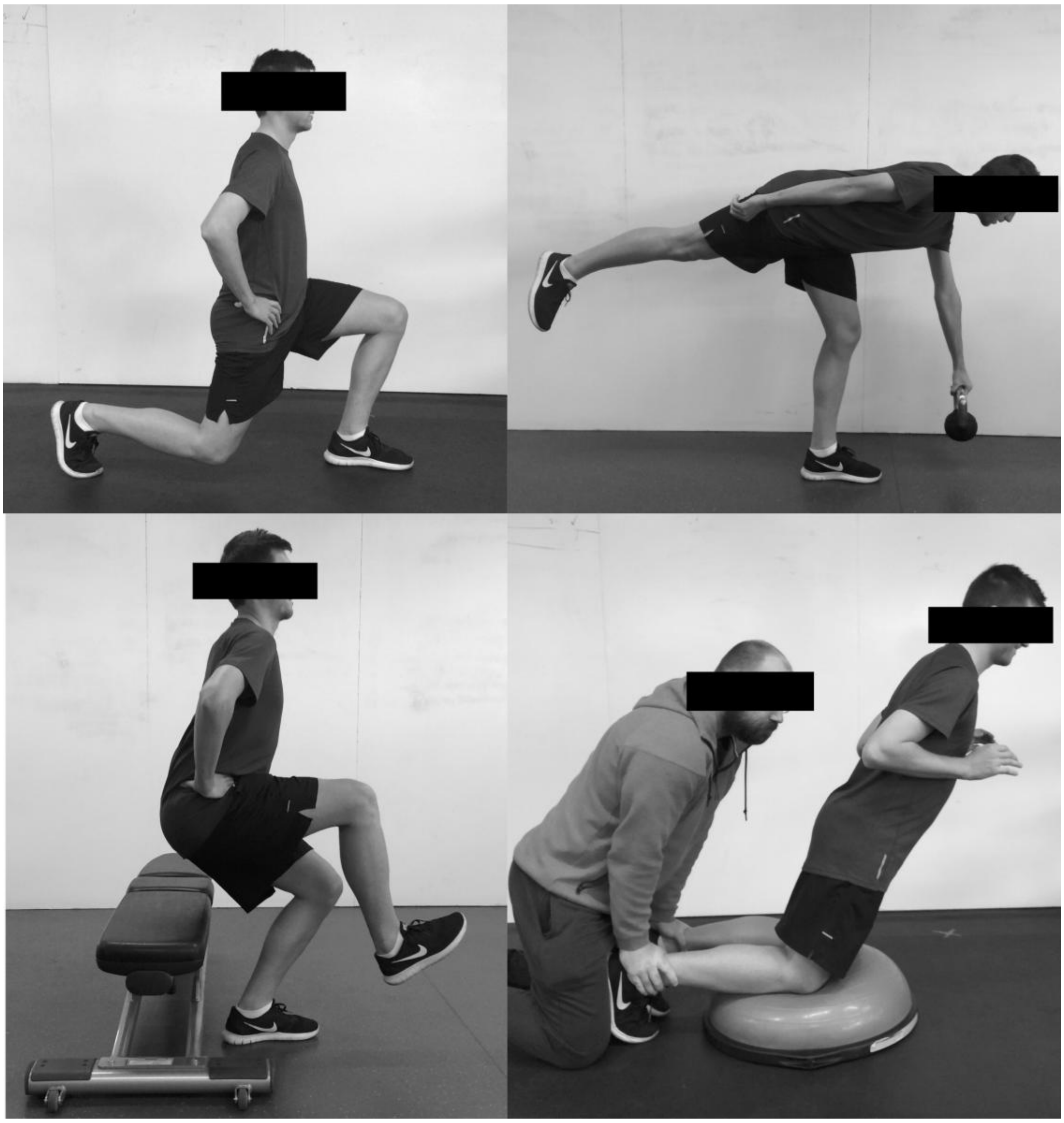
Figure 1: Injury prevention program exercises; including lunges (top left panel), single stiff-leg deadlift with 6 kg kettle-bell (top right panel), single leg eccentric squats (bottom left panel) and Nordic hamstring exercises performed on a Bosu-ball (bottom right panel).

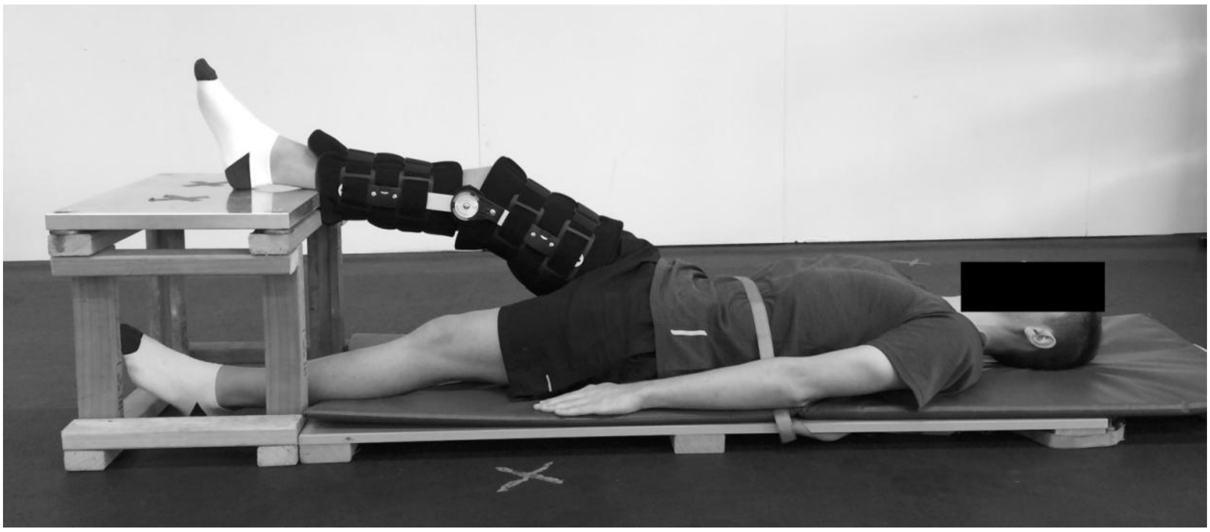
Figure 2: Posterior lower-limb isometric peak force assessment.

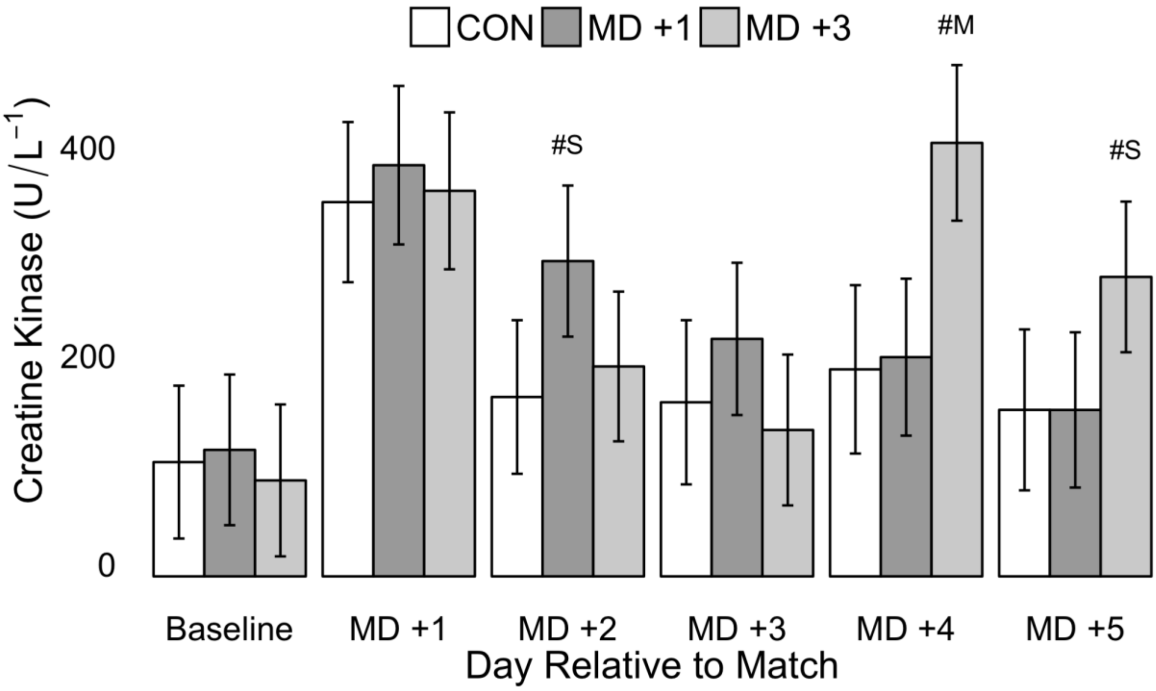
Figure 3: Creatine Kinase concentration (estimated marginal mean ± 90% confidence intervals). # Denotes very-likely difference versus CON and MD+1 trials; * Denotes likely difference versus CON and MD+1 trials; ^{S} Denotes likely small effect size.

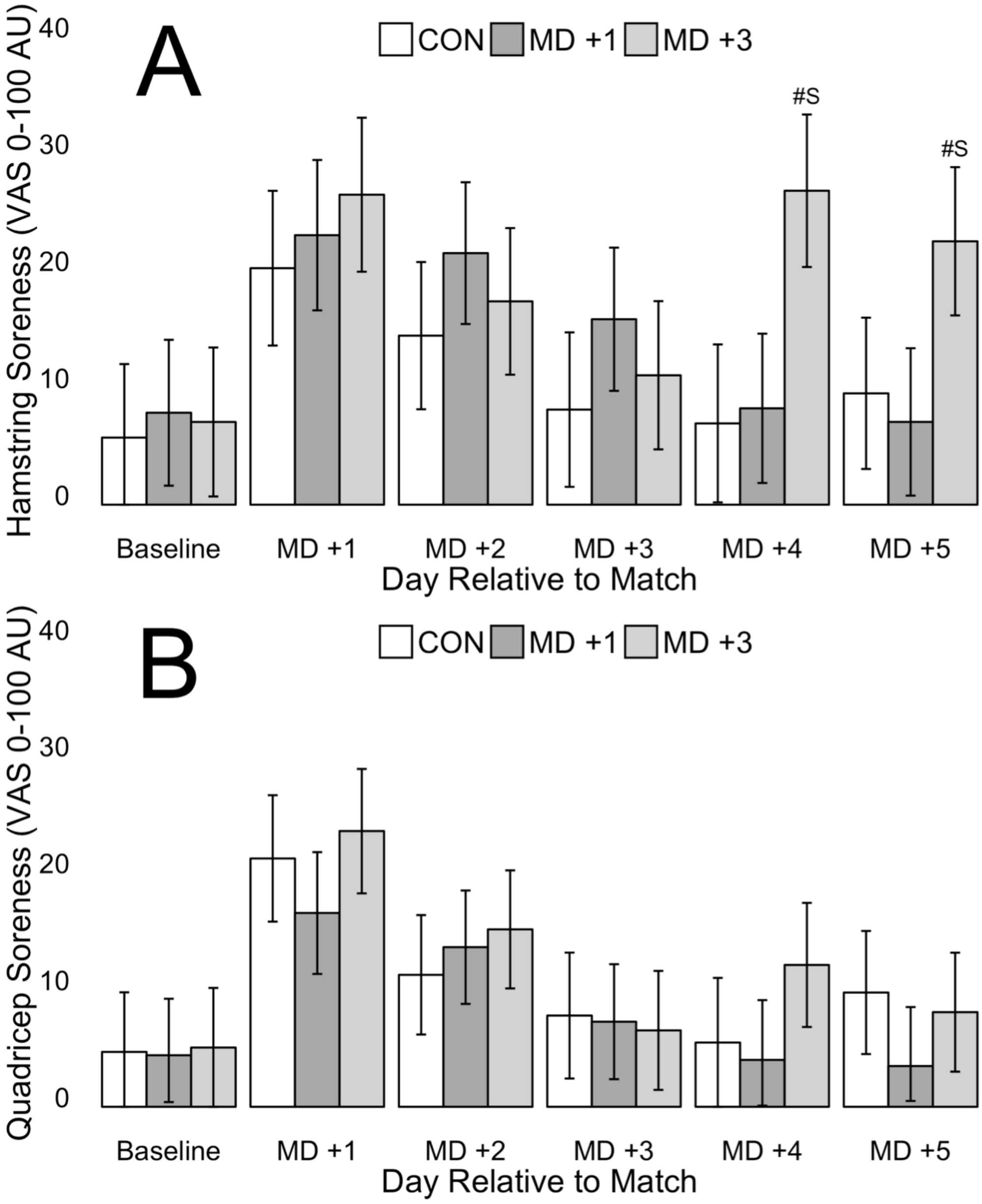
Figure 4: Hamstring (A) and Quadricep (B) soreness ratings (estimated marginal mean ± 90% confidence intervals). # Denotes difference versus CON and MD+1 trials; ^{S} Denotes likely small effect size.

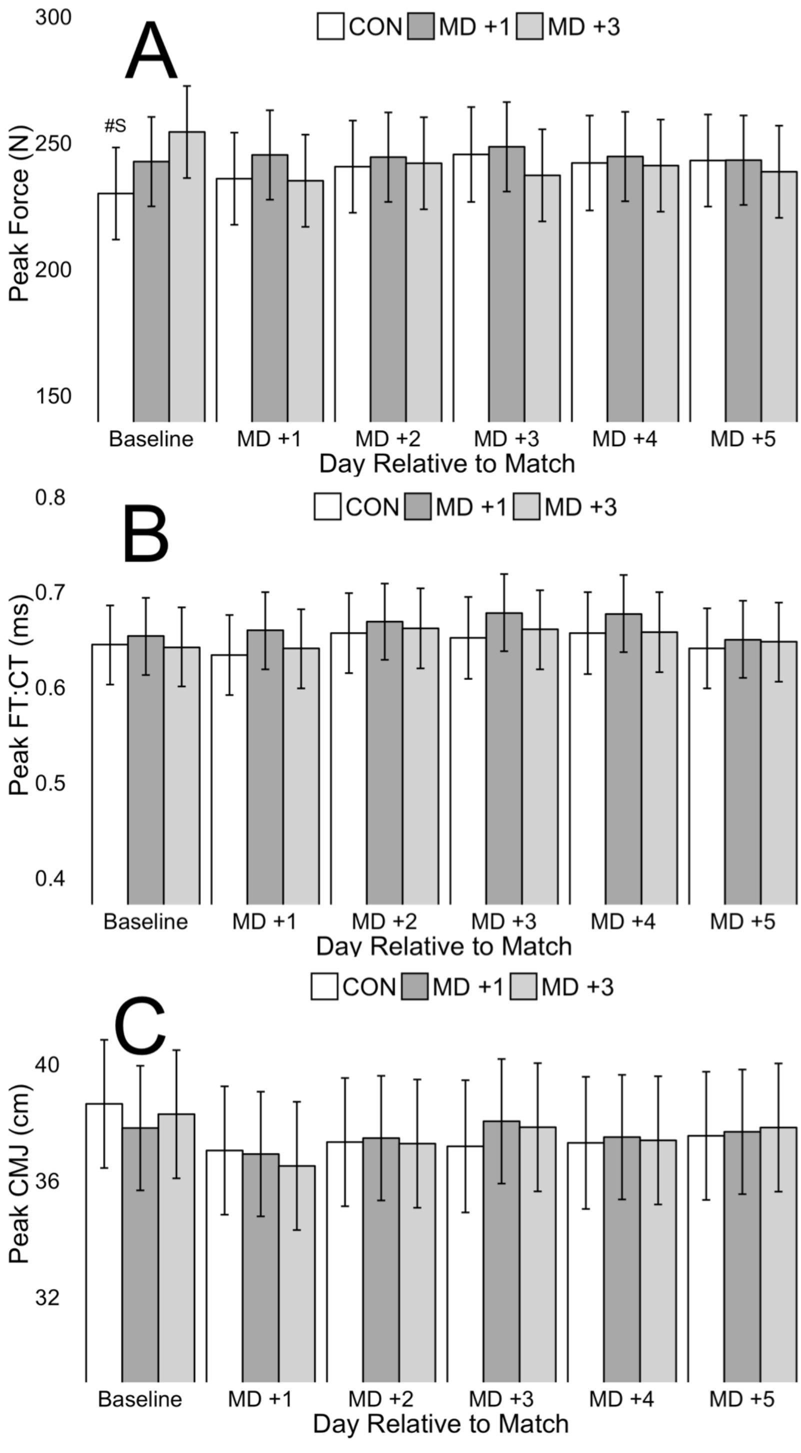
Figure 5. Posterior lower-limb strength (A), flight time:contraction time ratio (B), and counter-movement jump (B) responses to the micro-cycle. # Denotes difference versus MD+3; ^{S} Denotes likely small effect size.






CON
MD +1
MD +3
#M
#S
#S
Creatine Kinase (U/L^{-1})
400
200
0
Baseline
MD +1
MD +2
MD +3
MD +4
MD +5
Day Relative to Match


A
CON
MD +1
MD +3
Hamstring Soreness (VAS 0-100 AU)
40
30
20
10
0
#S
#S
Baseline
MD +1
MD +2
MD +3
MD +4
MD +5
Day Relative to Match
B
CON
MD +1
MD +3
Quadricep Soreness (VAS 0-100 AU)
40
30
20
10
0
Baseline
MD +1
MD +2
MD +3
MD +4
MD +5
Day Relative to Match


A
CON MD +1 MD +3
Peak Force (N)
300
250
200
150
#S
Baseline MD +1 MD +2 MD +3 MD +4 MD +5
Day Relative to Match
B
CON MD +1 MD +3
Peak FT:CT (ms)
0.8
0.7
0.6
0.5
0.4
Baseline MD +1 MD +2 MD +3 MD +4 MD +5
Day Relative to Match
C
CON MD +1 MD +3
Peak CMJ (cm)
40
36
32
Baseline MD +1 MD +2 MD +3 MD +4 MD +5
Day Relative to Match