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*Original Research*

# Reduced Injury Prevalence in Soccer Athletes Following GPS Guided Acclimatization

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ABSTRACT

***International Journal of Exercise Science 14(7): 1070-1077, 2021.*** GPS technology has been used to retrospectively correlate injury risk to changes in training load, however the use of GPS technology to plan and monitor training load over an acclimatization period to prevent musculoskeletal injury remains unexplored. This article reports the utility of GPS technology to help develop and monitor incremental increases in training load while transitioning from off-season to in season to reduce musculoskeletal injury. A series of daily minimum standards were established based on observed training loads in year 1 to gradually acclimate soccer athletes over a 5-week period prior to competition season in year 2. Daily check-ins with GPS data were used to ensure athletes met the standards to safely reach the expected training load of a competitive season. Following the 5-week GPS guided training program a lower overall prevalence of injury (Year 1: 92.6% (95%CI = 75.7-100) vs. Year 2: 55.2% (95%CI = 35.7-73.6)) ($p$ = .002) and overall injury rate (Year 1: 8.1/1000 exposure hours (95%CI = 5.2-12) vs 4.6/1000 exposure hours (95%CI = 2.7-7.5) in year 2 ($p$ = .08)) was observed. The observed reduction in injury prevalence and incidence demonstrates how GPS data can be used to proactively design and monitor preventative chronic training load acclimatization programs.

KEY WORDS: Soccer injury, GPS, musculoskeletal injury, acclimatization

## INTRODUCTION

The risk of musculoskeletal injury associated with soccer participation ranges from 2.33-7.4/ 1,000 athletic-exposures (2, 10, 14, 20). Players' training load over the short and long-term has been associated with injury incidence (9). While higher chronic training loads (average across 4 week period) are associated with increased musculoskeletal injury in soccer players, (9, 18) dramatic spikes in training load over a short term (one week/day to the next) may result in even higher injury risk (6, 19, 27).

As high as 40% of injuries occur during the preseason and training camp period where training loads are increased at the quickest rate (11, 28), moreover those with the highest increase in training load are at the greatest risk of injury during these periods (28). In contrast incremental increases in training load to reach a desired chronic workload can result in positive outcomes, such as fewer injuries and reduced perceived exertion (4, 19, 22, 29). Training load should therefore be carefully planned and monitored when designing a periodization plan to manage both acute and chronic workloads while transitioning across a season.

Global position systems (GPS) are commonly used to track external training loads in soccer athletes (7, 8, 29). Common suggested applications include monitoring external workloads (7), identifying injury risk (26), and improving performance (1, 3, 17). While injury risk has been retrospectively correlated with training loads using GPS, no research has investigated GPS as a proactive tool to guide and monitor incremental increases in training load. In theory, the use of objective GPS data to plan and monitor players' training load would allow teams to avoid acute spikes in workload balancing out the acute to chronic workload ratio, especially during transition points in across a season(off season, pre-season training camp, competition season), thereby reducing musculoskeletal injury risk (24).

The purpose of this study was to determine if the use of GPS technology to develop and monitor an acclimatization program for summer workouts leading up to training camp prior to the competitive season would decrease the prevalence and incidence rate of injury throughout a collegiate female soccer season. It was hypothesized that a GPS-guided summer acclimatization training program would result in lower prevalence and incidence rate of musculoskeletal injuries during a competitive season.

## METHODS

*Participants*

A power analysis conducted based on previously observed reductions in musculoskeletal injuries across two seasons determined that a minimum of 23 athletes would be needed for a power of 0.80 and an alpha = 0.05. 27 (year 1) and 29 (year 2) division 1 collegiate soccer players participated. Five left the team after year 1, and seven joined the team in year 2. No participants had a musculoskeletal injury at the start of the training program or had surgery in the previous 6 months. All participants signed an approved institutional review board consent form prior to starting the GPS-guided training program in year 2. This research was carried out fully in accordance to the ethical standards of the international Journal of Exercise Science. (25)

*Protocol*

Injury prevalence and incidence rate were compared across two consecutive collegiate soccer seasons. Prior to year 1, athletes completed a 5-week conditioning program. GPS was not used to monitor training loads during the summer acclimatization period in year 1. Instead, total estimated distance and intensity was recorded for each workout in a training log that was analyzed for the purpose of comparison in this article. These records included approximate millage estimates based on the strength and conditioning coaches report and revealed that a total of 11 sessions were completed and total distances for each were: Week 1: 16,000 meters; week 2: 22,000m; week 3: 12,000m; week 4: 20,000m; week 5: 18,000. It is important to note that little context for intensity and duration for each workout was documented. Moreover, little consistency was observed in the progressive nature of the exercise program.

GPS data collection started midway through the competition season year 1 during practices and games to analyze average intensity, duration and volume of individual training sessions. These data were used to design a 5-week GPS-guided training load acclimatization program prior to training camp leading up to competition season in year 2. The program was designed to gradually acclimate athletes from the off-season period (dead period between spring and fall) to the expected workload anticipated for a fall competition season.

*Measuring/monitoring training load:* Training load was measured using a GPS with a sampling rate of 10Hz (Titan 1; Integrated bionics, Houston, TX, USA). GPS workload variables were taken directly from Integrated Bionics (Titan Sync) software. Variables used to develop and track the training program included 1) total distance (m), 2) total time moving at > 1m/s (active time), and 3) GPS load, a proprietary value using arbitrary units that accounts for the intensity and duration of effort. The data from fall and spring of year 1 were used to identify an estimated expected load for the competitive season in year 2. Throughout the summer acclimatization program GPS data was uploaded daily and reviewed to insure the minimum daily training standards for distance, active time and load were being met during each workout.

*GPS guided summer training program:* GPS data from 60 practices and 15 games from fall competition season and spring (training season) year 1 were analyzed to estimate the expected training load for week 1 of training camp. That load was estimated at: total distance 23,000-26,00 m, active time: 150-200 min and GPS load: 500-850. A minimum daily standard based on a 3x weekly schedule was established to gradually acclimate players to the expected training load over 5 weeks (Table 1). GPS data were used to quantify the training load while the athletes performed common conditioning drills such as maximum aerobic speed (MAS) and wind sprints. For example, a 5- minute MAS conditioning drill requiring players to complete continuous 60m runs in under 15 seconds with 15 seconds of rest between each repetition yielded approximately 600m of total distance, 2.5-3 min of active time, and a GPS load of 15 AU. See Table 2 for a sample week 1 workout. Workouts occurred 3/week and each daily minimum standard was approximately 33% of the desired acute workload for that week.

**Table 1.** Daily minimum standard and results from summer training program in year 2

| | Daily minimum standard | | | Actual measured daily value † | | |
|---|---|---|---|---|---|---|
| | Total Distance (m) | Total Active Time (min) | Total GPS Load (AU) | Average Distance (m) | Average Active Time (m) | Average GPS Load (AU) ‡ |
| Week 1 | 4000 | 30 | 80 | 4137 ± 160 | 33 ± 4 | 84 ± 5 |
| Week 2 | 5000 | 35 | 95 | 5337 ± 180 | 38 ± 2 | 98 ± 8 |
| Week 3* | 6500 | 40 | 125 | 6882 ± 230 | 45 ± 3 | 131 ± 11 |
| Week 4 | 7500 | 50 | 140 | 7423 ± 159 | 53 ± 4 | 145 ± 13 |
| Week 5 | 8500 | 60 | 165 | 8567 ± 204 | 62 ± 2 | 162 ± 18 |

* Only completed 2 training sessions due to weather concerns with an extremely high heat index. † Means and standard deviations are reported. ‡AU = Arbitrary Units

**Table 2**. Sample Training load week 1

| | Distance (m) | Time (sec) | Reps | Sets | Distance/ set | *Total Distance (m) | *Total active time (min) | *GPS Load (AU) |
|---|---|---|---|---|---|---|---|---|
| Warm up | 200 | 80 | 1 | 1 | 200 | 200 | 3 | 3 |
| Warm up | 200 | 70 | 1 | 1 | 200 | 200 | 2 | 2 |
| MAS | 60 | 17 | 5 min | 3 | 525 | 1600 | 9 | 35 |
| MAS | 60 | 15 | 5 min | 2 | 600 | 1200 | 7 | 30 |
| Sprints | 40 | 7 | 5 | 1 | 120 | 200 | 1 | 5 |
| Sprints | 100 | 16 | 4 | 1 | 100 | 400 | 4 | 10 |
| Cool Down | 200 | 80 | 1 | 1 | 200 | 200 | 5 | 4 |
| Totals | | | | | | 4000 | 31.5 | 89 |

*Approximate values given for example purposes only

*Injury Surveillance:* Musculoskeletal injuries affecting player's participation during fall camp and the fall competitive season in each year were analyzed. Exposure data was taken from team practice and game logs. It must be noted that while game logs offered an exact amount of exposure time per- athlete, training sessions provide only the number of minutes and each player who participated was given the same exposure time. An Athletic Trainer who was not involved with the research project classified each musculoskeletal injury as season-ending, time-loss, or time-limiting. Time-loss injury was defined as any injury that inhibited the athlete's ability to participate. A time-limiting injury was characterized by an injury that limited the athlete's participation but did not restrict them from participation. Only primary injuries were classified as a new injury and no recurrent injury or secondary injury to the same body part was subsequently counted. However, time limited and time loss periods needn't have been on subsequent days and some athletes fluctuated from "out" to "limited" to "full play" and back to "limited" status following as a result of one primary injury.

*Statistical Analysis*

Descriptive statistics are reported as mean and standard deviation for continuous variables, and count and percentage for categorical variables. Measures of total injury, time-limited and time-loss prevalence were calculated as the number of each injury type divided by the total number of players. Incidence rates of total injury, time-limited and time-loss injuries were calculated by dividing the number of each injury type per 1000 exposure hours. Prevalence and incidence rates were compared using exact binomial and Poisson tests, respectively, as only primary injuries from each individual athlete were recorded allowing us to assume each injury as independent from other injuries (reported with 95% confidence intervals and exact p values). Statistical significance was set as $\alpha = 0.05$.

## RESULTS

Demographic data are presented in Table 3. No differences were found in demographic data, previous musculoskeletal injury, or previous season ending injury between cohorts.

**Table 3.** Demographic data by player season.

| | Year 1<br>Mean (SD) | Year 2<br>Mean (SD) | *p*-value | 95% CI<br>Lower | <br>Upper |
|---|---|---|---|---|---|
| Age | 19.7 (1.4) | 19.7 (1.5) | .709 | -.74 | 0.89 |
| Weight | 60.9 (11.7) | 63.4 (8.4) | .342 | -18.57 | 6.57 |
| Soccer history (yrs) | 13.9 (3.1) | 13.5 (4.2) | .684 | -1.65 | 2.50 |
| # season ending injury / year soccer participation | 0.1 (0.4) | .17 (0.3) | .987 | -.22 | 0.22 |
| # time-loss injury / year of soccer participation | 1.2 (0.8) | 1.4 (0.7) | .661 | -1.34 | 1.12 |

*GPS guided training program:* Except for week 3 when one of the sessions was cancelled, 27 of the 29 athletes completed 3 workouts a week for a total of 14 workouts. Two athletes completed only 12 and 11 workouts, respectively, and were asked to make up the workouts. Table 1 shows the average daily workload for each of the 5 weeks. The acute training load met or exceeded its respective week's daily minimum standard on all 5 weeks.

*Reducing injury risk:* Injury prevalence and injury incidence per 1000 exposure hours are reported in Table 4. Compared to year 1, year 2 when the 5-week GPS-guided training program was implemented had a lower overall prevalence of injury (Year 1: 92.6% (95%CI = 75.7-100) vs. Year 2: 55.2% (95%CI = 35.7-73.6)) ($p$ = .002). While the differences in the overall injury incidence rate and the rate of time-loss injury in year 2 compared to year 1 were non-significant a reduction was observed. The overall injury rate was 8.1/1000 exposure hours (95%CI = 5.2-12) in year 1 and 4.6/1000 exposure hours (95%CI = 2.7-7.5) in year 2 ($p$ = .08). The rate of time-loss injury was 3.6 per 1000 exposure hours (95%CI = 1.8-6.4) in year 1 and 1.4 per 1000 exposure hours (95%CI = 0.5-3.4) in year 2 ($p$ = .08).

## DISCUSSION

Despite the increasing number of researchers utilizing GPS technology to correlate injury risk to changes in training load (12, 13, 21, 22), utility of GPS technology to plan and monitor training load to prevent musculoskeletal injury remains unexplored (21, 22). In support of our hypothesis, the GPS-guided training acclimatization program resulted in a 50% reduction in injury prevalence and reduction (although non-significant) in injury incidence rate. This result may be explained by an increased tolerance to acute aerobic workloads in year 2 following the development of adequate chronic aerobic work capacity prior to the competitive season.

In support of the findings of the present study previous research suggests that athletes who undergo incremental increases in aerobic training are better capable of tolerating a sudden change in training load (15, 16). Moreover, the use of external load variables to dictate training has been shown to target and influence neuromuscular factors which may also in turn decrease injury susceptibility. Elite soccer players who keep their training load to within 100-125% of their respective chronic training load have a lower injury rate compared to those who let their training load exceed 150% their chronic training load (21, 22). These results suggest that athletes who are safely acclimated to a chronic workload that is sufficient to account for the demands of their respective position, competition level and playing style may be at a decreased likelihood of musculoskeletal injury. This idea is consistent with a study on elite youth football players that

**Table 4.** Comparison of exposure and injury data between 2018 and 2019

| Measures | Year 1 (*n* = 27) | (95% CI) | Year 2 (*n* = 29) | (95% CI) | *p* value |
|---|---|---|---|---|---|
| Total number of practice/games | 77 | | 85 | | |
| Mean length of practice/games (min) | 89 | | 84 | | |
| Total athlete exposure time (hours) | 3084 | | 3451 | | |
| Number of time-loss injury | 11 | | 5 | | |
| Number of time-limiting injury | 14 | | 11 | | |
| Total number of injuries | 25 | | 16 | | |
| Number of lost days | 134 | | 60 | | |
| Number of limited participation days | 132 | | 104 | | |
| Number of season ending injuries | 4 | | 1 | | |
| Overall Injury Prevalence | 92.6 | (75.7, 100) | 55.2 | (35.7, 73.6) | *0.002** |
| Time-loss Injury Prevalence | 40.7 | (22.4, 61.2) | 17.2 | (5.8, 35.8) | *0.53** |
| Time-limiting Injury Prevalence | 51.9 | (31.9, 71.3) | 37.9 | (20.7, 57.7) | *0.30** |
| Overall Injury Rate per 1000 Exposure Hours | 8.1 | (5.2, 12) | 4.6 | (2.7, 7.5) | 0.08 † |
| Time-loss Injury Rate per 1000 Exposure Hours | 3.6 | (1.8, 6.4) | 1.4 | (0.5, 3.4) | 0.08 † |
| Time-limiting Injury Rate per 1000 Exposure Hours | 4.5 | (2.5, 7.6) | 3.2 | (1.6, 5.7) | 0.38 † |

*Prevalence: P values and 95% CI based on exact binomial method. † p values and 95% CI based on exact poisson method.

reported the highest risk of non-contact injury when athletes suddenly experienced a high acute workload (5). Ehrman et al. also reported that injury rates among professional soccer players were highest in the weeks following training periods where loads exceed their chronic training capacity (12). Moreover, higher injury rates during competition vs. training sessions have been attributed to peaks in acute workload experienced during games compared to the predictable and controllable chronic workload of a training session (7, 23, 30).

While, previous research has demonstrated how training programs that incorporate incremental increases in training load to reach a desired chronic workload can result in positive outcomes (4, 19, 22, 29), no previous research has explored the utility of GPS technology to help design and monitor the progression of acclimatization programs. In the present study a daily check in utilizing data gathered from GPS allowed the conditioning staff to maintain and not exceed the minimum training standard established for each week during the acclimatization program during year 2. It also led to an observable week over week increase in training volume and intensity preparing athletes for the anticipated demands of the fall competitive season. The ideal conditioning program is likely dependent upon factors such as sex, team playing style, competition level, player position, playing environment and others (30). Use of GPS technology may allow teams and players to design and monitor individualized training programs based on their own respective GPS data.

In evaluating the effectiveness of the GPS guided summer acclimatization program in year 2 and the direct implication this had in reducing injury risk it is important to note a few limitations. The GPS training load was not collected during summer or a portion of fall year 1, which dramatically decreases the extent to which the decrease in injury rate can be directly attributed to the GPS guided acclimatization program. However, a review of previous preseason acclimatization records revealed significant variations in volume, intensity and duration of sessions which were improved with the implementation of the GPS monitoring protocol. Moreover, several factors such as roster changes, completion schedule, travel schedule, playing conditions, and coaching strategy may have also affected the fluctuations in injury seen between year 1 and year 2 and were not accounted for in the present study. Additional research is warranted to explore the appropriate applications of this principle based on the individual demands of specific teams, playing styles, player positions and completion level all of which have been suggested to alter musculoskeletal injury risk. Lastly, a single collegiate soccer team participated, and therefore the results may not apply equally to soccer teams of different playing styles, age, skill, and fitness levels.

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