Kent Academic Repository

Bacon, Christopher and Mauger, Alexis R. (2017) ***Prediction of overuse injuries in professional U18-U21 footballers using metrics of training distance and intensity.*** **Journal of Strength & Conditioning Research, 31 (11). pp. 3067-3076. ISSN 1064-8011.**

Downloaded from

https://kar.kent.ac.uk/59746/ The University of Kent's Academic Repository KAR

The version of record is available from

https://doi.org/10.1519/JSC.0000000000001744

This document version

Author's Accepted Manuscript

DOI for this version

Licence for this version

UNSPECIFIED

Additional information

Versions of research works

Versions of Record

If this version is the version of record, it is the same as the published version available on the publisher's web site. Cite as the published version.

Author Accepted Manuscripts

If this document is identified as the Author Accepted Manuscript it is the version after peer review but before type setting, copy editing or publisher branding. Cite as Surname, Initial. (Year) 'Title of article'. To be published in *Title of Journal* , Volume and issue numbers [peer-reviewed accepted version]. Available at: DOI or URL (Accessed: date).

Enquiries

If you have questions about this document contact ResearchSupport@kent.ac.uk. Please include the URL of the record in KAR. If you believe that your, or a third party's rights have been compromised through this document please see our Take Down policy (available from https://www.kent.ac.uk/guides/kar-the-kent-academic-repository#policies).

Prediction of overuse injuries in professional U18-U21 footballers using metrics of training distance and intensity.

Bacon, Christopher S; Mauger, Alexis R

This article can be accessed at the following link:

http://journals.lww.com/nsca-jscr/pages/articleviewer.aspx?year=9000&issue=00000&article=96214&type=abstract

doi: 10.1519/JSC.0000000000001744

ABSTRACT

The most common injury in professional football is an overuse injury to the lower limb. A significant external risk factor of this injury is the mismanagement of training and match loads. The aim of the current study was to examine the predictability of overuse injuries in professional youth soccer players using volume and intensity variables derived from Global Positioning Systems (GPS). A total of 41 players (Age – 17.8 yrs±1.1 yrs) training and match loads were assessed. These external loads were measured over two competitive seasons for every training session and match for each individual. A linear regression was used to test the predictability of the injury based on load, which were grouped using loading groups calculated from squad weekly averages. The load groupings assigned were: Low load = 1 SD below the squad mean score; Normal load = ±1 SD from the squad mean; High load = 1 SD above squad mean. The analysis demonstrated that total distance significantly predicted overuse injury incidence rates (F(1, 39) = 6.482, p = 0.015), whereas high speed running meters could not (F(1, 39) = 1.003, p = 0.323). This study demonstrated that distance covered in training and matches can impact on the incidence of overuse injury in youth soccer players. Coaches should seek to monitor player training loads and incorporate this metric into their decision making for protecting players from overuse injury.

Key words: Overuse Injury, GPS, External Loads, Total Distance, High Speed Running

INTRODUCTION

Overuse injuries account for approximately 34% of all injuries sustained in soccer and these occur throughout the competitive season (18,30,38). As this will directly impact on the quality of the team fielded, it is important to reduce the amount of overuse injuries in order to maximize the chances of the team's success (23). However, overuse injuries can be challenging to prevent due to the wide variety of causative factors, many of which are difficult to manage. Generally, injury occurrences are categorized by intrinsic (person related) and extrinsic (environment related) factors. Intrinsic factors that are purported to have an increased effect on injury occurrence include age, career duration and history of previous injury (12,17,32,35,38). The most prominent extrinsic risk factors causing overuse injuries are suggested to be excess levels of external training loads, high training to match ratio and playing on a hard surface with high friction (12,16,31). However, the consistent factor throughout the literature related to overuse injury appears the mismanagement of external load on the working muscles (36). This variable should be within complete control of the team's coaching staff, and so data is required to go beyond establishing a link between training load with overuse injury and instead attempt to quantify this relationship. It is important to note that although staff supervision in training can control part of the external load experienced in a regular season week, within competitive matches it can only be monitored through match data. Although certain aspects of training are more difficult to regulate (such as small-sided games), these elements of a session can be monitored in real-time in order to control the external load.

Most elite football clubs now use GPS (Global Positioning System) devices to monitor player external loads and distance covered during training and matches across a season (33). GPS units collate data into a system which has the potential to provide the user with detailed feedback regarding player over- and under-loading, and this could be used to help reduce overuse injuries. However, there is currently a lack of unity of procedures that elite club's follow in terms of data processing, inhibiting the quality of data (16) and meaning the system is only as good as the user. The most recognized method of data usage involves the comparison of each player's load for the session/match with the squad's average for that session. This metric is then used to inform the degree of risk of an overuse injury in the forthcoming sessions/matches for that player. The current method does not account for the internal load that is likely to vary across a squad of players. Using a squad average for player's external load can only be used for indicating a potential risk in terms of the external load that can be easily accounted for in training/matches. Currently the method allows the users to make modifications to easily managed external loads in order to alleviate potential high internal loads. Modifications in the player's training program can then help to mitigate this risk (25).

The competitive football season generally lasts in excess of 9 months, and it is important to take account the contributing effect of cumulative overloading to overuse injury (5). Some studies on Australian Football have taken this cumulative training and match load meters completed factor into account by monitoring the effect of 3-weekly cumulative loads on injury incidence rates (13). Colby et al. (13) showed a higher injury risk with increased load and this was elevated with higher intensities. The research also presented that the metrics of total distance (TD) and high speed running (HSR) were the most plausible measures to be used in terms of injury prediction, which supports other prior research by Castagna et al. (10). However, Australian Football has very different physiological demands to football, and greater amounts of physical contact between players (13,18). This likely increases the amount of injuries that are sustained in Australian Football compared to football (13,18), and limits the translation of the data between the two sports.

There is a significant body of the research which uses GPS to provide movement analysis in football (10). Indeed, Castagna et al. found players covered between 5098-7019 m in a match, with 15% being accounted for as high intensity distance (10). It was also shown that players fatigued over the course of the fixture by 3.8% in terms of their TD covered when compared to first half values (10). Castellano and Casamichana (11) has examined the relationship between heart rate and GPS to define fitness levels. Castellano and Casamichana (11) presented the average percentage of heart rate maximum players worked at in relation to their distances covered from various GPS derived variables. Whilst this information is interesting, there is a need to provide some application of this data. Brink et al. (6) suggests that quantification of the relationship between cumulative training and match load/intensity and overuse injury could be used to provide a framework for coaches to use in order to reduce overuse injury risk. However, when applying GPS as a measure of load the percentage error must be accounted for as this can range from 5-8% (14). Coutts and Duffield (14) demonstrated that the accuracy of GPS devices is within an acceptable margin of error for validity of results, but it was noted that measures of high intensity movements, such as HSR, have presented a potential error of 11.2-32.4%. Deficiencies in the accuracy of the models can be attributed to devices which are less then 10 Hz in processing power (14,15). Accounting for this, data from appropriate GPS devices could provide a basis for individual training norms for each player in a squad to be calculated and allow a more intelligent means of guiding training prescription (6). Consequently, the aim of this investigation was to monitor youth player training loads/intensities in a professional football club using GPS, and to subsequently calculate the capacity of this data to predict overuse injury. It was hypothesized that TD would predict overuse injury incidence rates and that HSR would not be able to significantly predict overuse injury incidence rates.

METHODS

Approach to the Problem

Both 2012-13 and 2013-14 season's data were collated into a single data set for analysis. Player weekly averages of TD and HSR within the 40-week time period were calculated. The calculation used did not include weeks of training that were affected by injury (i.e. where a player was returning from injury and training load/intensity was reduced). GPS (StatSports, Viper Pod, NI) data was acquired for every training session and match that each individual player was involved in across the seasons. From this, the metrics used in the current study were TD (volume of training) and HSR (intensity of training), used in a similar study by Colby et al. (13). These metrics were used to represent external loads from training and competitive matches. Injuries were collected from an injury audit with diagnosis and recording into this dataset completed by a qualified physiotherapist. It is worth noting that there was an increase in injuries between the seasons which can be potentially attributed to internal changes in the club - an increase in coaching hours, an increase in the number of players and a change in coaching staff at the club. This data was collected for two seasons in the Barclays U21/U18 Premier Leagues from 2012-13 and 2013-14. Data was collated for the 40 weeks of the competitive season in each year for both training sessions and matches. The relationship between overuse injuries and external loads was explored using a method similar to Colby et al. (14). Weekly training loads were assigned certain loading groups dependent on the amount completed and then assessed to see the relationship to injury incidence rate.

Subjects

Over two seasons, data was collected from forty-one youth soccer players (n = 18 in 2012/13 season, height: 175.2 cm ± 4.5 cm, body mass: 72.4 kg ± 3.1 kg, age: 18.7 yrs ± 1.2 yrs; n = 23 in 2013/14 season, height: 181.3 cm ± 6.1 cm, body mass: 74.9 kg ± 8.7 kg, age: 17.0 yrs ± 1.1 yrs). All players were on a full-time training program (6 training sessions a week) and had either signed a youth scholarship contract with the club or had signed a professional contract. All of the data obtained from the professional football club was from pre-existing datasets which included both the GPS metric measurements and the injury audit data. Access to data was granted with the consent from the professional football club. All data was analyzed in an untraceable and anonymized format. Ethical approval for the use of existing datasets was obtained from the University Research Ethics Committee.

Procedures

The squad average and standard deviation (SD) was calculated for both TD and HSR along with player weekly averages of the same variables. The SD was used to assign player groupings dependent upon their weekly average (for TD or HSR) compared to the rest of the squad. The groupings assigned were as follows: Low load = 1 SD below the squad mean score ($x \leq 19404.30$ m for TD, $x \leq 538.17$ m HSR); Normal load = ±1 SD from the squad mean ($19404.30 \text{ m} \leq x \leq 23700.62$ m for TD, $538.17 \text{ m} \leq x \leq 890.63$ m for HSR); High load = 1 SD above squad mean ($x \geq 23700.62$ m for TD, $x \geq 890.63$ m for HSR). A second analysis was completed to test the effect of cumulative weekly loads on injury incidence, in a similar manner to previous research (14). Cumulative player loads were calculated for 2, 3 and 4 week periods throughout the 40-week season, with players grouped according to SD and squad averages, as described previously. In line with this, injury incidence rates were calculated for each player in each season to allow comparison between load/intensity and overuse injury. Injury incidence rates were reported by calculating the total number of overuse injuries (diagnosed by a qualified physiotherapist) divided by the total ‘on-leg’ exposure time, and then reported as a figure per 1,000 training and match hours (20). Injury audits across the two seasons were collated and analyzed with an X^2 analysis used to compare the frequency of injuries between each season.

Statistical Analyses

Statistical analyses were conducted using IBM SPSS 19 (SPSS Inc., Chicago, IL). Statistical assumptions were checked using similar methods to Colby et al. (13) and Hulin et al. (27), and were deemed plausible in all instances. HSR and TD data were collected from all training sessions and matches that occurred during both seasons. The injury audit analysis contained detailed breakdown of injury sites, injury types, contact or non-contact injuries, activity when injury occurred and the severity of each injury. To ensure appropriateness of combining both seasons’ data, a limits of agreement analysis (2) was performed on data from youth players who had data across both seasons. A Pearson’s correlation test, in addition to the limits of agreement analysis, was run on the two seasons to test the correlation between the two, in order to ensure that when combining the dataset neither season would skew the data. Correlations were performed on; TD, HSR, Total Number of Injuries and Average Injury Incidence Rate. A between groups one-way ANOVA was run to test the differences between playing position and the variables; TD weekly average, HSR weekly average, whole season total distance average, whole season high speed running meters average and average injury incidence rate. Players were categorized based on the position they had played in for the majority of the competitive matches and according to positions previously described (8). The categories were as follows: central defenders, wide defenders, central midfielders, wide midfielders and forwards. Linear regression was used to test the predictive capacity of HSR and TD groupings (Low, Normal and High) on injury incidence rates. Odds ratios were used to assess the effect of cumulative weekly loads (2, 3 and 4 week) on injury risk, using procedures as previously described (13,34). The reference for the odds ratio was set as the Normal group (± 1SD of the squad mean). Significance was accepted at $P \leq 0.05$ with data expressed as means ± SD.

RESULTS

Injury Audit Analysis

In total there were 85 reported injuries in the cohort of players measured over the course of the 2012-13 and 2013-14 seasons (Table 1). The majority of injuries sustained were located at the ankle (n = 26, 3.23 IIR, 30.59%) with no difference observed between the two seasons. Overall there was a significant number of overuse injuries to the players involved (n = 16, 1.99 IIR, 18.82%) when compared to the other injury types recorded over the time period. Within this injury type there was a significant difference between the seasons for muscle strains ($X^2 = 7.514$, $p = 0.023$) with a substantial increase in the 2013-14 season (n = 11, 2.64 IIR, 19.64%) when compared to the 2012-13 season (n = 1, 0.26 IIR, 3.45%). Contact and non-contact injuries presented a difference overall with the data showing more of the injuries were non-contact (n = 44, 5.46 IIR, 51.76%). There was a significant difference in the total number of injuries sustained from training between each season ($X^2 = 11.402$, $p = 0.010$), although overall there were more injuries occurring in match scenarios (n = 47, 5.84, 55.29%) than in training sessions (n = 30, 3.72 IIR, 35.29%). The majority of the injuries sustained were low in severity (n = 34, 4.22 IIR, 40.00%), with a significant difference between the two seasons in low severity injuries, with the 2013-14 season (n = 23, 5.53 IIR, 41.07%) recording more than the 2012-13 season (n = 10, 2.57 IIR, 34.48%).

Please insert Table. 1. here

Season vs. Season Analysis

There was a positive correlation between the two seasons for the total number of injuries (r = 0.382, n = 41, p = 0.014), and injury incidence rates (r = 0.371, n = 41, p = 0.017), although both r values were relatively small. There was no correlation between the two seasons for TD or HSR (TD, p = 0.093; HSR, p = 0.914).

Please insert Table. 2. here

Limits of agreement analysis revealed good agreement for TD across the two seasons (limits = 4636.32 to -4786.19, mean = -74.94) (Figure 1). The regression performed on the same data also showed that data for both seasons worth for TDs were not significantly different (t = 0.673, p = 0.515), therefore demonstrating agreement between the datasets (p > 0.05). HSR also showed good agreement (Figure 2). The regression completed on this variable confirmed there was no significant difference in the seasons data (t = -1.932, p = 0.079). It was shown that there was agreement between the datasets, with no proportional bias between the datasets (p > 0.05).

Please insert Figure. 1. and Figure. 2. here

Effect of Position

Table 3 demonstrates the positional mean ± SD based on the two seasons analyzed, in addition to the squad's descriptive data for the variables detailed. The ANOVA displayed a significant difference between the positions for the variables; HSR weekly average (f = 4.565, df = 4, p = 0.004) and whole season HSR total average (f = 8.178, df = 4, p < 0.001). For whole season HSR total average, the multiple comparisons analysis displayed differences between: central defenders and wide midfielders

($p < 0.001$); central midfielders and wide midfielders ($p < 0.001$); forwards and wide midfielders ($p = 0.030$); wide defenders and wide midfielders ($p = 0.048$).

Please insert Table. 3. here

Cumulative Weekly Load Analysis

When comparing high load groups to the reference normal group, there was close to significant levels of increased risk of overuse injury for; TD - High Load Group (OR = 0.670, 95% CI = 0.395 – 1.137, $p = 0.137$) and HSR - High Load Group (OR = 0.580, 95% CI = 0.330 – 1.021, $p = 0.059$) for 2 week cumulative loads. The cumulative loads of 3 weekly and 4 weekly loadings showed no significant differences.

Please insert Table. 4. here

Overuse Injury Prediction Regression

A simple linear regression was used to predict overuse injury incidence rates based on TD and HSR, when players were assigned to the Low, Normal and High groups (Table 5). A significant regression equation was found in only the TD variable, ($F(1, 39) = 6.482$, $p = 0.015$, $R^2 = 0.143$). Player's predicted injury incidence rate was able to be significantly calculated by using their TD loading group. Injury incidence rate per 1000 hours is decreased by -5.835 times when moving upward from one TD loading group to the next. Thus, being in a higher TD loading group lowered the risk of an overuse injury occurring. HSR loading groups were also analyzed using the same method with no significant regression calculation found ($F(1, 39) = 1.003$, $p = 0.323$).

Please insert Table. 5. here

DISCUSSION

This is the first study to use training and match loads, derived from GPS data, to predict overuse injury risk in youth soccer players. The primary finding of the study was that overuse injury incidence rates were decreased in youth soccer players who completed a higher weekly TD in training and matches. It is important to note that these findings are based on average distances and intensities of the team from which this data was derived and so these findings are likely specific only to these players. However, Colby et al. (13) has also shown a similar result that an increase in weekly TD can lead to an increased risk of injury. Intensity of training and matches (expressed as HSR) had no effect on overuse injury incidence rates. This finding could be potentially due to the percentage error margin GPS devices display when measuring high intensity bursts of speed (14). Despite this, the methods of analysis used in this study could provide a framework on which other clubs can assess similar relationships within their squads, and use this specific data to reduce risk of injury.

Although the results from the current study were unable to directly predict the occurrence of overuse injuries, they do help to indicate the likelihood of these injuries occurring depending upon training and match loads. However, predicting overuse injuries represents a significant challenge primarily because of the numerous risk factors that contribute to this type of injury (25). The regression model used in the current study predicts that the overuse injury incidence rate reduced by nearly 6 times when the individual’s TD is increased to that of players who achieve a high TD in relation to this squad. Because high or low TD is relative to the squad of youth soccer players in this study, this finding should not be generically interpreted as a higher loading reducing injury risk. Rather, it is hoped that the methods outlined in this study can be used by other coaches and teams to assess their own squad’s competitive season loadings. By doing so, they can look to plan and modify training in individual players who are at risk of overuse injury as a result of too high or too low intensity or load. This relates to research by Gabbett (21) and Hulin et al. (27), where they examined the ratio of acute to chronic workloads and the ability to predict injuries. Within this research both Gabbett (21) and Hulin et al. (27) indicated that an increased risk of injury related to a sudden increase in workload ratio. Additionally, they agree that training needs to be ‘smarter not harder’ in order to keep a the risk of injury from mismanagement of loads reduced (21,27).

The findings in the present study can also potentially relate to literature focusing on the relationship between overtraining and overreaching injuries. Existing research states that overreaching injuries can be caused by an imbalance in the ratio of bouts of high intensity/load exercise to the amount of recovery time between these bouts (29). Overreaching is an acute condition which can lead to chronic overtraining due to a substantial period of mismanagement of external training loads (36). The present research agrees with the existing research to the extent that significant cumulative loading through overscheduling fixtures and training can cause a substantial increase to the risk of injury. Cumulative weekly load analysis demonstrated that significant external loads over the course of a micro/meso cycle start to increase injury risk. Although the results were not statistically significant, this may have been due to the players involved being managed correctly. However, strong indications (TD - High Load Group ($p = 0.137$); HSR - High Load Group ($p = 0.059$), for 2 week cumulative loads) were found supporting existing research around overtraining and overreaching injuries, respectively.

This is especially the case in athletes at the younger ages of the experience spectrum to reduce the chance of major overuse traumas later in their careers (5). Therefore, the important factor to take from the analysis of the current research to the previous research is that training loads seem to display reasonable association to injury risk. Monitoring athletes training load longitudinally will allow early detection of overreaching to in turn reduce the risk of an overtraining injury (7). The present research did not directly measure overreaching or overtraining symptoms, but additional metrics could be integrated could assess this. Doing so would help further explore the relationship between overreaching/training and injury. However, the findings of the current study show promise that GPS derived external loads, especially the TD metric, can be analyzed against injury incidence rates within professional sports over a longitudinal format.

GPS metrics have previously been used to demonstrate a link between injury risk and cumulative weekly loads in Australian Football (13,20,34). These studies show that high 3 weekly cumulative loads present a significantly elevated risk of injury. The current study suggests that in youth football players, 2 weekly loads came closest to significantly increasing risk of injury (HSR meters – 2 Weekly Cumulative Load, p = 0.059). In addition to the effect of cumulative load, the research on Australian Football indicates that the intensity of training and matches present a strong risk of injury (13,20,34). The current study does not support this finding, with no effect of intensity found on overuse injury incidence rates. An initial reason for this difference could be due to the sample age used in the present study compared to previous others; present research – 17.8 ± 1.1 yrs, Australian Football research average – 23.7 ± 3.4 yrs (13,20,34). This age difference in the samples will also indicate a difference in years of training experience which has been shown to influence overuse injury incidence rates (36). Additionally, the difference in the physical and physiological demands of the sport may explain this result (26). These factors may also be responsible for the observed greater injury incidence in Australian Football. Indeed, Colby et al. (13) presented figures of 297 injuries (n = 46 players) recorded in the space of 1 season compared to the total of 85 (n = 41 players) recorded over the course of two seasons found in this research. Additionally, movement analysis has shown that the proportion of a match scenario in soccer spent at high intensities is higher (9) when compared to Australian Football (22).

The data from the current study suggest that playing position should be taken into account when assessing play training loads. It was shown that wide midfielders experience significantly increased levels of HSR meters and TD meters throughout the season, and so a ‘one-size fits all’ approach to player loading should not be used in a squad. Rather, training sessions need to reflect these differences and ensure that each individual playing position is conditioned correctly to reduce overuse injury risk. Within the squad analyzed for the current study, it appears as though training has potentially been prescribed successfully as the injury incidence rate of the wide midfielders was the lowest out of the positions analyzed (2.15 ± 2.49 IIR). Conversely, it was found that central midfielders had the highest injury incidence rate (per 1000hrs) of all the positions with 14.22 ± 15.46 IIR. This may demonstrate the physical demands of this position, which is supported by existing research based on position specific movement analysis (3).

The present study has also examined the prevalence of different injuries within professional football to evidence the impact of minor avoidable injuries (See Table 1.). Over the two season period measured, the most common form of injuries were overuse injuries (n = 16, 1.99 IIR, 18.82%) and muscle sprains (n = 16, 1.99 IIR, 18.82%). This finding is similar to previous research that has also reported injury audits within professional football (1,12,19). Therefore, the findings in the current study further demonstrates that a large majority of injuries sustained by a team are avoidable, which is an important point to address in order to help maintain the team's performance (24). Additionally, the current study demonstrated that 51.76% of all injuries sustained were non-contact indicating that even with the sport being primarily contact based, injuries are just as likely to occur from non-contact actions. The main location site for a significant number of the injuries were to the ankle region (n = 26, 3.23 IIR, 30.59%). This is similar to previous findings showing the relatively high frequency of ankle injuries in football injury audits (24). It is also evident that a common trend appears in terms of when the injuries took place, which this research found was in a match scenario (n = 47, 5.84 IIR, 55.29%). The injury audit analysis has also established that the majority of injuries sustained are of minor level of severity (≤ 7 Days Missed). However, it is important to note that even such minor severity injuries can still play a significant part in a team's performance, as they can still result in a player missing an important fixture (24).

It should be recognized that all team sport-based GPS units present a level of error in measurement. The standard percentage error for GPS units normally lies between 5-8% (14,15). To help overcome this in the current study, each GPS unit was assigned to a single player. This helped ensure that all data error associated to the individual unit remained with individual players. In addition, all devices were placed at the same location (top of the body on the trapezius) on each player and recording during each session/match to help overcome inaccuracies as a result of differing placement (37). Future research should look to examine a variety of GPS metrics, such as force loads (i.e. measures of exerted power and momentum) which could also play a part in overuse injuries (13). Further prediction models that include physiological or functional parameters such as heart rate variability, creatine kinase levels and maximal force production should also be explored (4). Incorporating physiological markers of overuse injuries to existing GPS derived metrics could potentially increase the statistical power of an injury prediction model, allowing it to be more viable for use in the elite environment.

PRACTICAL APPLICATIONS

The present findings provide a potential new approach for professional football clubs in analyzing youth soccer player's GPS data. The present research shows that this cumulative approach has value, particularly when assessing player injury risk. Initially, data should be analyzed over the course of a season to provide individual player's training load baseline responses to training and matches (28). Consequently, individual player data can be compared to the norm of the squad, and adjusted accordingly. It is suggested that training sessions are not solely based on these loadings and instead only be used as a guidance tool. Coaches should also look to individualize training sessions based on playing positions, so that loads are specific to the position of the player.

REFERENCES

1. Arnason, A. Risk Factors for Injuries in Football. *Am J Sports Med* 32: 5S–16, 2004.

2. Bland, JM and Altman, DG. Statistical Methods for Assessing Agreement Between Two Methods of Clinical Measurement. *Lancet* 327: 307–310, 1986.

3. Bloomfield, J, Polman, R, and O'Donoghue, P. Physical demands of different positions in FA Premier League soccer. *J Sport Sci Med* 6: 63–70, 2007.

4. Brancaccio, P, Maffulli, N, and Limongelli, FM. Creatine kinase monitoring in sport medicine. Br. Med. Bull. 81-82: 209–230, 2007.

5. Brenner, JS. Overuse injuries, overtraining, and burnout in child and adolescent athletes. *Pediatrics* 119: 1242–1245, 2007.

6. Brink, MS, Nederhof, E, Visscher, C, Schmikli, SL, and Lemmink, KAPM. Monitoring Load, Recovery, and Performance in Young Elite Soccer Players. *J Strength Cond Res* 24: 597–603, 2010.

7. Brink, MS, Visscher, C, Coutts, AJ, and Lemmink, KAPM. Changes in perceived stress and recovery in overreached young elite soccer players. *Scand J Med Sci Sport* 22: 285–292, 2012.

8. Carling, C and Orhant, E. Variation in body composition in professional soccer players: interseasonal and intraseasonal changes and the effects of exposure time and player position. *J Strength Cond Res* 24: 1332–1339, 2010.

9. Castagna, C, D'Ottavio, S, and Abt, G. Activity Profile of Young Soccer Players During. *J Strength Cond Res* 17: 775–780, 2003.

10. Castagna, C, Manzi, V, Impellizzeri, F, Weston, M, and Carlos, J. Relationship between endurance field tests and match performance in young soccer players. *J Strength Cond Res* 24: 3227–3233, 2010.

11. Castellano, J and Casamichana, D. Heart rate and motion analysis by GPS in beach soccer. *J Sport Sci Med* 9: 98–103, 2010.

12. Chomiak, J, Junge, A, Peterson, L, and Dvorak, J. Severe injuries in football players. Influencing factors. *Am J Sports Med* 28: S58–S68, 2000.

13. Colby, M, Dawson, B, Heasman, J, Rogalski, B, and Gabbett, TJ. Accelerometer and GPS-derived running loads and injury risk in elite Australian footballers. *J Strength Cond Res* 28: 2244–52, 2014.

14. Coutts, AJ and Duffield, R. Validity and reliability of GPS devices for measuring movement demands of team sports. *J Sci Med Sport* 13: 133–135, 2010.

15. Ehrmann, FE, Duncan, CS, Sindhusake, D, Franzsen, WN, and Greene, DA. GPS and Injury Prevention in Professional Soccer. 2015.

16. Ekstrand, J, Gillquist, J, Möller, M, Oberg, B, and Liljedahl, SO. Incidence of soccer injuries and their relation to training and team success. *Am J Sports Med* 11: 63–67, 1983.

17. Ekstrand, J and Gillquist, J. Soccer injuries and their mechanisms: a prospective study. Med.

Sci. Sports Exerc. 15: 267–270, 1983.

18. Ekstrand, J, Hagglund, M, and Walden, M. Epidemiology of Muscle Injuries in Professional Football (Soccer). *Am J Sports Med* 1–7, 2011.

19. Engebretsen, AH. Football and injuries: Screening, risk factors and prevention. University of Oslo, Oslo, 2010.

20. Gabbett, TJ. The Development and Application of an Injury Prediction Model for Noncontact, Soft-Tissue Injuries in Elite Collision Sport Athletes. *J Strength Cond Res* 24: 2593–2603, 2010.

21. Gabbett, TJ. The training-injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med* 1–9, 2016.

22. Gray, AJ and Jenkins, DG. Match analysis and the physiological demands of Australian football. Sports Med. 40: 347–360, 2010.

23. Hägglund, M, Waldén, M, and Ekstrand, J. Injuries among male and female elite football players. *Scand J Med Sci Sport* 19: 819–827, 2009.

24. Hägglund, M, Waldén, M, Magnusson, H, Kristenson, K, Bengtsson, H, and Ekstrand, J. Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med* 47: 738–42, 2013.

25. Hawkins, D and Metheny, J. Overuse injuries in youth sports: biomechanical considerations. *Med Sci Sports Exerc* 33: 1701–7, 2001.

26. Hoskins, W, Pollard, H, Daff, C, Odell, A, Garbutt, P, McHardy, A, et al. Low back pain status in elite and semi-elite Australian football codes: a cross-sectional survey of football (soccer), Australian rules, rugby league, rugby union and non-athletic controls. *BMC Musculoskelet Disord* 10: 38, 2009.

27. Hulin, BT, Gabbett, TJ, Lawson, DW, Caputi, P, and Sampson, J a. The acute:chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. *Br J Sports Med* 33: 1–7, 2015.

28. Impellizzeri, FM, Rampinini, E, Coutts, AJ, Sassi, A, and Marcora, SM. Use of RPE-based training load in soccer. *Med Sci Sports Exerc* 36: 1042–1047, 2004.

29. Luke, A, Lazaro, RM, Bergeron, MF, Keyser, L, Benjamin, H, Brenner, J, et al. Sports-related injuries in youth athletes: is overscheduling a risk factor? *Clin J Sport Med* 21: 307–314, 2011.

30. Nielsen, AB and Yde, J. Epidemiology and traumatology of injuries in soccer. *AmJSports Med* 17: 803–807, 1989.

31. Orchard, JW. Is There a Relationship Between Ground and Climatic Conditions and Injuries in Football? *Sport Med* 32: 419–432, 2002.

32. Ostenberg, A and Roos, H. Injury risk factors in female European football. A prospective study of 123 players during one season. *Scand J Med Sci Sports* 10: 279–285, 2000.

33. Petersen, C, Pyne, D, Portus, M, and Dawson, B. Validity and reliability of GPS units to monitor cricket-specific movement patterns. *Int J Sports Physiol Perform* 4: 381–393, 2009.

34. Rogalski, B, Dawson, B, Heasman, J, and Gabbett, TJ. Training and game loads and injury risk in elite Australian footballers. *J Sci Med Sport* 16: 499–503, 2013.

35. Stølen, T, Chamari, K, Castagna, C, and Wisloff, U. Physiology of soccer: An update. Sport. Med. 35: 501–536, 2005.

36. Stubbe, JH, Van Beijsterveldt, AMMC, Van Der Knaap, S, Stege, J, Verhagen, EA, Van Mechelen, W, et al. Injuries in professional male soccer players in the Netherlands: A prospective cohort study. *J Athl Train* 50: 211–216, 2015.

37. Vaitl, C, Kunze, K, and Lukowicz, P. Does on-body location of a GPS receiver matter? *2010 Int Conf Body Sens Networks, BSN 2010* 219–221, 2010.

38. Wisloff, U, Helgrud, J, and Hoff, J. Strength and endurance of elite soccer players. Med. Sci. Sport. Exerc. 30: 462–467, 1998.

Acknowledgements

I would like to take this opportunity to thank Norwich City Football Club Academy for its assistance in this research. This also further extends to Dominic Walsh with his expertise and vital input from an applied point of view. Additionally, I would like to thank Barry Watters, StatSports, for his assistance in the research carried out.

Figure Legends

Fig. 1. Limits of Agreement for 2012-13 and 2013-14 Seasons for Total Distance (m)

Fig. 2. Limits of Agreement for 2012-13 and 2013-14 Seasons for High Speed Running (m)

Table Legends

Table. 1. Classification of Injuries in the 2012-13 and 2013-14 Season

Table. 2. 2012-13 Season vs. 2013-14 Season Correlation Analysis

Table. 3. Positional Breakdown between the seasons of 2012-13 and 2013-14 (n = 41)

Table. 4. Training and Match Load Metrics between the 2012-13 and 2013-14 seasons (n = 41)

Table. 5. Prediction of Overuse Injury Incidence Rates using Total Distance and High Speed Running from GPS

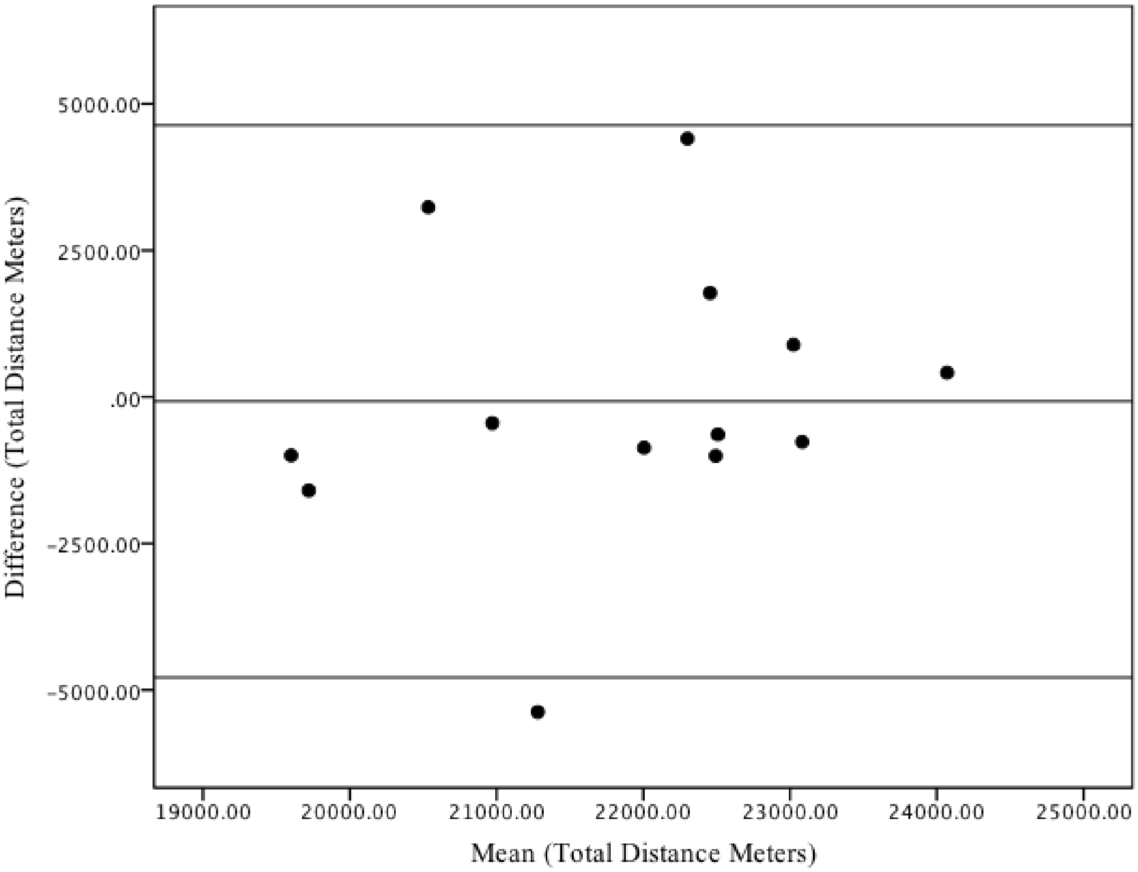

Figure 1. Limits of Agreement for 2012-13 and 2013-14 Seasons for Total Distance (m)

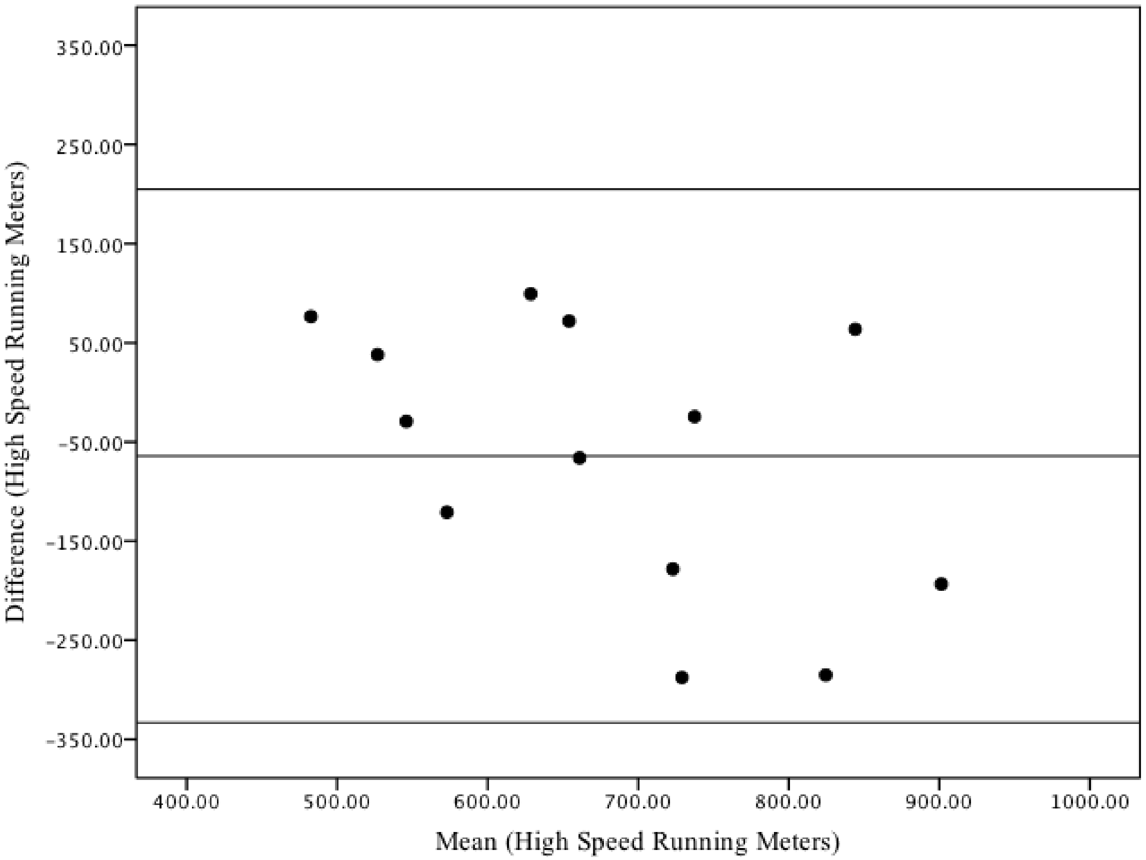

Figure 2. Limits of Agreement for 2012-13 and 2013-14 Seasons for High Speed Running (m)

Table 1. Classification of Injuries in the 2012-13 and 2013-14 Season

	Season 2012-13			Season 2013-14			Overall			Season vs Season	
		3893.8hrs			4161.0hrs			8054.8hrs			
	N	Injury Incidence Rate (Per 1000hrs)	%	N	Injury Incidence Rate (Per 1000hrs)	%	N	Injury Incidence Rate (Per 1000hrs)	%	X^2	P
	32	8.22	37.65%	56	13.46	65.88%	85	10.55	100.00%	45.642*	0.070**
Site											
Ankle	11	2.82	37.93%	15	3.60	26.79%	26	3.23	30.59%	1.847*	0.605**
Back	0	0.00	0.00%	2	0.48	3.57%	2	0.25	2.35%	2.392*	0.122**
Calf	0	0.00	0.00%	2	0.48	3.57%	2	0.25	2.35%	2.392*	0.122**
Foot	2	0.51	6.90%	4	0.96	7.14%	6	0.74	7.06%	1.793*	0.408**
Gluteal	1	0.26	3.45%	0	0.00	0.00%	1	0.12	1.18%	1.678*	0.195**
Groin	1	0.26	3.45%	2	0.48	3.57%	3	0.37	3.53%	0.150*	0.698**
Hamstring	0	0.00	0.00%	3	0.72	5.36%	3	0.37	3.53%	2.392*	0.302**
Hands	0	0.00	0.00%	2	0.48	3.57%	2	0.25	2.35%	1.176*	0.278**
Head/Neck	0	0.00	0.00%	3	0.72	5.36%	3	0.37	3.53%	3.653*	0.560**
Hip/Pelvis/Adductor	1	0.26	3.45%	10	2.40	17.86%	11	1.37	12.94%	4.089*	0.252**
Knee	4	1.03	13.79%	10	2.40	17.86%	14	1.74	16.47%	3.681*	0.159**
Other	2	0.51	6.90%	0	0.00	0.00%	2	0.25	2.35%	3.425*	0.064**
Quad/Thigh	4	1.03	13.79%	2	0.48	3.57%	6	0.74	7.06%	1.478*	0.224**
Upper Body	3	0.77	10.34%	1	0.24	1.79%	4	0.50	4.71%	3.969*	0.137**
Injury Type											
ATFL	1	0.26	3.45%	2	0.48	3.57%	3	0.37	3.53%	0.150*	0.698**
Bruising	2	0.51	6.90%	5	1.20	8.93%	7	0.87	8.24%	3.659*	0.161**
Contusion	6	1.54	20.69%	4	0.96	7.14%	10	1.24	11.76%	1.907*	0.385**
Fracture/Dislocation	1	0.26	3.45%	4	0.96	7.14%	5	0.62	5.88%	1.197*	0.550**
Impingement	0	0.00	0.00%	3	0.72	5.36%	3	0.37	3.53%	2.392*	0.302**
Irritation	1	0.26	3.45%	5	1.20	8.93%	6	0.74	7.06%	2.328*	0.127**
Muscle Sprain	11	2.82	37.93%	5	1.20	8.93%	16	1.99	18.82%	3.780*	0.151**
Muscle Strain	1	0.26	3.45%	11	2.64	19.64%	12	1.49	14.12%	7.514*	0.023†
Other	3	0.77	10.34%	4	0.96	7.14%	7	0.87	8.24%	1.234*	0.540**
Overload	3	0.77	10.34%	13	3.12	23.21%	16	1.99	18.82%	4.663*	0.198**
Contact or Non-Contact											
Contact	15	3.85	51.72%	21	5.05	37.50%	36	4.47	42.35%	2.451*	0.653**
Non-Contact	12	3.08	41.38%	32	7.69	57.14%	44	5.46	51.76%	7.555*	0.109**
N/A	2	0.51	6.90%	1	0.24	1.79%	3	0.37	3.53%	0.680*	0.410**
Unknown	0	0.00	0.00%	2	0.48	3.57%	2	0.25	2.35%	2.392*	0.122**
Activity											
Match	19	4.88	65.52%	28	6.73	50.00%	47	5.84	55.29%	5.333*	0.255**
Training	7	1.80	24.14%	23	5.53	41.07%	30	3.72	35.29%	11.402*	0.010†
Rehab	1	0.26	3.45%	1	0.24	1.79%	2	0.25	2.35%	0.032*	0.859**
Other	2	0.51	6.90%	4	0.96	7.14%	6	0.74	7.06%	0.326*	0.568**
Severity											

Low (≤ 7 Days Missed)	10	2.57	34.48%	23	5.53	41.07%	34	4.22	40.00%	11.351*	0.010†
Medium (≥ 8 Days Missed and ≤ 14 Days Missed)	9	2.31	31.03%	15	3.60	26.79%	23	2.86	27.06%	1.445*	0.695**
High (≥ 15 Days Missed)	10	2.57	34.48%	18	4.33	32.14%	28	3.48	32.94%	4.432*	0.218**

Mean injury incidence rate reported per 1,000 hours 'on-leg' training and match exposure (95% confidence interval) *Violated assumptions **No significant difference between seasons (P > 0.05) †Significant difference between seasons (P < 0.05)

Table 2. 2012-13 Season vs. 2013-14 Season Correlation Analysis

Statistic	Season vs. Season (Distance)	Season vs. Season (HSR)	Season vs. Season (Injuries)	Season vs. Season (Injury Incidence Rate)
Pearson Correlation	-0.266	0.017	0.382*	0.371*
Sig. (2-tailed)	0.093	0.914	0.014*	0.017*
R^2	0.071	0.000	0.146	0.138

*Significant Correlation (P < 0.05)

Table 3. Positional Breakdown between the seasons of 2012-13 and 2013-14 (n = 41)

Position	**Total Distance Weekly Average (m)**	**High Speed Running Weekly Average (m)**	**Whole Season Total Distance Average (m)**	**Whole Season High Speed Running Total Average (m)**	**Injury Incidence Rate (per 1000hrs)**
Central Defenders (n = 11)	21804.30 ± 1556.93	648.09 ± 136.30	760933.96 ± 98010.22	22328.06 ± 4783.54	10.02 ± 7.89
Wide Defenders (n = 9)	21665.77 ± 2558.58	751.68 ± 180.20	792227.28 ± 112516.40	27475.57 ± 7027.14	7.78 ± 4.44
Central Midfielders (n = 9)	21758.86 ± 2048.98	604.93 ± 83.52	722652.21 ± 223869.70	19502.94 ± 5124.87	14.22 ± 15.46
Wide Midfielders (n = 4)	22048.57 ± 982.18	952.36 ± 187.93	876445.14 ± 41207.99	37924.02 ± 7844.734	2.15 ± 2.49
Forwards (n = 8)	20598.46 ± 2976.82	767.81 ± 176.02	731448.03 ± 143052.00	26657.11 ± 5145.59	8.11 ± 7.16
Squad Average	21575.19	744.97	776741.32	26777.54	8.46
Standard Deviation	564.03	134.70	62063.78	7026.08	4.36

Table 4. Training and Match Load Metrics between the 2012-13 and 2013-14 seasons (n = 41)

	OR (Exp (B))	95% CI Lower	95% CI Upper	P
2 Week Cumulative Loads				
Total Distance – Normal Load (Reference)	1.000	-	-	-
Total Distance – Low Load	1.264	0.164	9.769	0.822
Total Distance – High Load	0.670	0.395	1.137	0.137
High Speed Running – Normal Load (Reference)	1.000	-	-	-
High Speed Running – Low Load	0.993	0.381	2.588	0.989
High Speed Running – High Load	0.580	0.330	1.021	0.059
3 Week Cumulative Loads				
Total Distance – Normal Load (Reference)	1.000	-	-	-
Total Distance – Low Load	0.688	0.290	1.635	0.397
Total Distance – High Load	0.953	0.442	2.054	0.903
High Speed Running – Normal Load (Reference)	1.000	-	-	-
High Speed Running – Low Load	0.506	0.212	1.206	0.124
High Speed Running – High Load	1.049	0.543	2.029	0.886
4 Week Cumulative Loads				
Total Distance – Normal Load (Reference)	1.000	-	-	-
Total Distance – Low Load	0.688	0.290	1.635	0.397
Total Distance – High Load	0.953	0.442	2.054	0.903
High Speed Running – Normal Load (Reference)	1.000	-	-	-
High Speed Running – Low Load	0.506	0.212	1.206	0.124
High Speed Running – High Load	1.049	0.543	2.029	0.886

OR = Odds Ratio, OR = 1.50 is indicative of a 50% increased risk and vice versa. For an OR to be significant, 95% confidence intervals (CIs) did not contain the null OR of 1.00.

Table 5. Prediction of Overuse Injury Incidence Rates using Total Distance and High Speed Running from GPS

	Total Number of Cases	**Total Injuries Sustained**	**Injury Incidence Rate (per 1000hrs)**	**F (df)**	**P**	**R^2**	**B**
Total Distance (Volume of Training Variable)				(1, 39) 6.482	0.015*	0.143	-5.835
Low Group	9	18	14.65				
Normal Group	26	42	8.93				
High Group	6	4	2.95				
High Speed Running (Intensity of Training Variable)				(1, 39) 1.003	0.323	0.025	-2.728
Low Group	5	10	11.29				
Normal Group	29	46	9.75				
High Group	7	8	6.08				

* Denotes Statistical Significance ($P < 0.05$)