

Combining Data From Injury Surveillance and Video Analysis Studies: An Evaluation of Three FIFA World Cups TM

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Received: 14 December 2013 Accepted: 2 January 2014 Published: 15 January 2014

Abstract

To analyze the playing actions and match circumstances which involve physical contact between players and lead to injuries in men's World Cup football. Design: Prospective injury surveillance and video analysis of matches in three FIFA World Cups.

Index terms— soccer, sporting injuries, epidemiology, video analysis.

1 Introduction

Football is one of the most popular sports in the world, but it also carries a significant risk of injuries. [7-16, 8] Therefore research on the epidemiology and prevention of football injuries is of major importance. In a four-step model for injury prevention in sports, van Mechelen, suggested that preventive measures should be based on knowledge of the etiology and the mechanisms of injuries. [9] Video analysis of injuries in football has been increasingly used for describing injury circumstances or investigating the mechanisms of injuries, [12,13,27] and for studying tackles. [15,26] In addition, video analysis has been used for assessing the accuracy of referees' decisions and assessing whether the laws of the game should be modified in order to prevent injuries. [22,23] The methods have, so far, been more useful for describing playing situations and athlete/opponent movements than evaluating joint biomechanics. [28] Andersen et al. described a video-based method, FIA (Football Incident Analysis), for analysing what were referred to as "injury risk incidents" using football-specific variables. [16] According to the FIA methodology, an injury risk incident referred to any situation in which the match was interrupted by the referee, a player was on the ground for more than 15 seconds, or a player appeared to be in pain or received on-pitch medical treatment. [14,16,18,23,29] Previous studies combining injury data, based on reports from the medical teams, and injury risk incident data, obtained by FIA, have shown that linking non-contact injuries with injury risk incidents is more difficult than linking contact injuries with injury risk incidents. [14,18] FIA, which was developed as a descriptive tool for analysing playing actions leading to injury risk incidents, has since been applied in several studies. [14,18,23,29] When using FIA, injury risk incidents are defined according to 19 variables, each with two or more categories related to playing actions preceding the incident. [16] To date, no clear patterns for the playing situations leading to injuries have been identified that link FIA incidents with resultant injuries; however, the injury risk associated with individual variables has not previously been studied.

Fuller et al. [15] performed video analysis of all tackles in three FIFA tournaments. They were able to identify certain tackle parameters that were associated with a higher risk of injury than others. [15] Their methods did not, however, take into account match events or the circumstances leading up to the tackles. Tscholl et al. [26] combined the FIA and the tackle analysis video methods and found that certain tackles were more frequently sanctioned by the referee than others. [26] However, they found that the factors leading to injury risk incidents (as defined in the FIA methodology) and the factors leading to injuries to be different, and thus, questioned whether equating injury risk incidents with the risk of injury was valid. [26] The playing actions leading to injury risk incidents, as defined in the FIA methodology, have not yet been analysed using video recordings in top-level international male football. As the injuries sustained during the three most recent men's FIFA World Cups, and the match circumstances in which these injuries occurred, have been extensively studied based on injury report

4 C) VIDEO ANALYSIS AND LINKING INJURIES WITH INJURY RISK INCIDENTS

46 data and match statistics, [1,4,7,30,32,39] performing an additional video analysis of the circumstances leading to
47 these injuries might add to the understanding of the circumstances and playing actions leading to football injuries
48 in top-level football. Such a study would also provide an insight into the benefits and limitations of the current
49 methods of video analysis and enable evaluation of whether current video analysis methodologies complement or
50 conflict with results from injury surveillance studies.

51 The aims of the present study were to:

52 1) analyze, using current video analysis methodologies, the playing actions and match circumstances that
53 involve physical contact between players and lead to injury in men's World Cup football and to 2) assess whether
54 the variables used for FIA have independent injury predictive value when compared to data obtained from injury
55 surveillance studies.

56 II.

57 2 Material and Methods

58 The study cohort consisted of complete video recordings of all 192 matches played during the 2002, 2006 and 2010
59 men's FIFA World Cups?, 441 injury reports of the match play injuries sustained during these three tournaments,
60 as well as match statistics for all the matches provided by FIFA's official website. [36] a) Definitions of injury
61 and injury risk incident An (FIFA) injury was defined as any physical complaint incurred during a match that
62 received medical attention from the team physician regardless of the consequences with respect to absence from
63 match play or training. [1][2][3][4]7 An (FIA) injury risk incident was defined as any situation in which the match
64 was interrupted by the referee, or a player was on the ground for more than 15 seconds, or the player appeared to
65 be in pain or received medical treatment (as defined in the FIA methodology). [14,16,18,23,29]A contact injury
66 was defined as any injury resulting from physical contact between players, and a contact injury risk incident, was
67 defined as an injury risk incident that resulted from physical contact between players.

68 3 b) Injury surveillance reporting

69 The post-match injury report forms, completed by team physicians, have been presented in previous studies of
70 FIFA tournaments. [1][2][3][4]7 Only contact injuries were included in the present study, as non-contact injuries
71 have previously been shown to be difficult to link with FIA injury risk incidents, [14,18] and as most injuries
72 in men's World Cup football result from contact between players. [1][2][3][4]7 The injury surveillance reporting
73 followed the consensus statement for injury definitions and data collection procedures for epidemiological studies
74 on football injuries. [20] Ethics approval for the injury surveillance study was obtained.

75 4 c) Video analysis and linking injuries with injury risk incidents

77 ? Ball possession (defence or attack). The number of playing positions was reduced to the four general categories,
78 in order to allow comparison of the results with those obtained from a previous study of injuries in FIFA World
79 Cup football. [30] All contact injury risk incidents were reviewed, using FIFA video recordings of all matches by
80 one author (LL), who was experienced in video analysis. In order to identify the contact injury risk incidents
81 associated with post-match injury reports, the details of each contact injury risk incident were compared to the
82 FIFA injury surveillance reporting data in terms of the time of incident, the player's shirt number, and the injury
83 type and location. The following eight established FIA variables (categories), [16] with some minor modifications,
84 were used in the analysis:

85 ? Degree of balance in opponents' defence (good, average, poor) **Modification: Some of the originally
86 proposed 14 categories were combined in order to avoid the previously described problem of having too few cases
87 in some categories. [16] ***Modification: the category "other" was added, as the player's attention was sometimes
88 directed elsewhere (e.g. coach/crowd//the pitch/ goal/ unknown etc.) ****Modification: the category "foul"
89 included the awarding of a yellow or red card, in order to simplify the analysis.

90 The main reason for combining some categories was to avoid a problem identified in previous studies; namely,
91 too many categories with small number of cases.

92 The variables "player's action with the ball", "player's movement intensity", "playing position" and the tackle
93 parameters (included in the present study) were considered to fully describe a player's actions, role, and the
94 contact mechanisms in the context of the present study. Therefore, the following original FIA variables, [16] were
95 excluded:? positioning ? player's role ? duel type ? ball winning situations ? player's movement direction ?
96 tackling type ? type of incident risk action

97 ? degree of individual ball control Similarly, "ball possession", "attack type" and "degree of balance in the
98 opponent's defence" (included in the present study) were thought to describe the team's actions and situations
99 sufficiently for the context of the present study; thus, the following team-related original FIA variables, [16] were
100 also excluded:

101 ? Team action before injury incident ? Attack effectiveness Additionally, the variable "localization on the
102 field" [16] was excluded, as the main focus of the present study was on match circumstances, playing actions and

103 tackle parameters, rather than the localization of the incident on the field. The playing actions included in the
104 present study were also not always directly related to a specific location on the field (e.g. "attack type").

105 **5 d) Added variables**

106 The following variables, previously shown to be associated with injury incidence in the 2002, 2006 and 2010 men's
107 FIFA World Cups were added to the analysis:

108 ? Current score (team in focus of the incident losing, drawing or winning). [30] ? Match period (minutes
109 0-15, 16-30, 31-45+, 46-60, 61-75, 76-90+ or extra time. [1,4,7,30] e) Tackle analysis A tackle was defined as any
110 event that occurred during the normal course of the match and involved physical contact between two or more
111 players while one or more of the players challenged for possession of the ball. [15,17,22,25,26] The contact injury
112 risk incidents that involved a tackle were also analyzed using the tackle parameters proposed by Fuller et al., [15]
113 with the addition of one new category within the tackle action parameter (*):

114 ? Tackle direction (front, side or behind)

115 ? Tackle mode (on feet, sliding in, vertical jump)

116 ? Tackle action (one-footed, two-footed, use of arm/hand, upper body contact, clash of heads, combination*)

117 * The new 'combination' category included tackles involving more than one simultaneous tackle action, as some
118 tackle incidents were found to involve several simultaneous actions that had the potential to cause an injury.

119 Tackle parameters associated with contact injury risk incidents involving a tackle, that were identified by
120 video analysis and which were also linked to a post-match reported injury, were compared with parameters
121 associated with injury risk incidents involving a tackle, identified by video analysis that could not be linked with
122 a post-match reported injury.

123 **6 f) Statistical analysis**

124 Ratios of the variable categories associated with contact injury risk incidents that were (a) linked with an injury
125 and (b) not linked with an injury were calculated, in order to assess the injury predictive value of each variable
126 category. Logistic multivariate regression models with robust estimate of variance were used to investigate
127 the variables related to the contact injury risk incidents. Comparisons between groups were made by the chi-
128 square test. The tackle parameters were not analysed in the same multivariate regression model with the other
129 variables, as they formed a separate and predetermined group. [15] As there were only three tackle parameters,
130 a multivariate regression analysis of them was not performed and comparisons between the categories of tackle
131 parameters were made by the chi-square test. The level of significance was set at p-values <0.05. Intra-observer
132 reliability was tested by reviewing and reanalysing 10% of the contact injury risk incidents (randomly chosen
133 from the three tournaments and including a re-analysis of 23 different teams): a minimum of 3 weeks was allowed
134 between the two assessments, in order to reduce potential learning bias. The agreement between the two sets of
135 results was determined by the kappa statistic (?). The level of agreement was defined as follows, poor:?=0.20;
136 The STATA 12.1, StataCorp LP (College Station, TX, USA) statistical package was used for the analyses.

137 **7 III.**

138 **8 Results**

139 The 192 matches resulted in 441 injuries being reported within the FIFA match-day injury surveillance system,
140 of which 304 were contact injuries: in addition, 671 contact injury risk incidents were identified from the video
141 recordings of these matches. One hundred and twenty-eight (42.1%) of the 304 reported contact injuries were
142 linked with a corresponding contact injury risk incident. The intra-rater reliability for the video analysis of
143 contact injury risk incidents was very good (?=0.88-0.98) for all variables and tackle parameters.

144 From the FIA video analysis, two variables were identified as independent predictors of injury; attack type
145 ($p<0.01$) and the involvement of foul play ($p<0.05$). Long attacks had the lowest ratio of contact injury risk
146 incidents linked with injuries compared to other contact injury risk incidents. The involvement of foul play in
147 the contact injury risk incidents was associated with a significantly smaller ratio of contact injury risk incidents
148 linkable with injuries/other contact injury risk incidents, compared with the contact injury risk incidents not
149 involving a foul. Table ?? summarizes the study results and the results of the regression analysis.

150 Table ???. The numbers of both the contact injury risk incidents that were not linkable with an injury and
151 those that were linked with an injury, as well as their relative proportions for all the categories of each variable.
152 Additionally, the results of the multivariate regression analysis, with the relative risk (OR*) for each category,
153 as well as the significance of differences in the relative risks between the categories of each variable.

154 **9 Descriptive data Results of multivariate regression analysis**

155 Variables 3) of these incidents were linkable with an injury recorded in the injury surveillance. Figure 1 shows
156 the percentages of contact injury risk incidents involving a tackle linkable with injuries (as defined in the FIFA
157 post-match injury surveillance) for the tackle parameters direction, mode and action. i.

15 DISCUSSION

10 Tackle direction

158 Most (n=346) incidents resulted from tackles from the side, while 144 tackles came from the front and 129 tackles from behind. The differences in the proportions of contact injury risk incidents involving a tackle linkable with 161 injuries compared with other contact injury risk incidents between the tackle direction categories (upper part of 162 Figure 1), were not statistically significant (p=0.055).

163 ii.

11 Tackle mode

164 The most common tackle mode in the incidents was on feet (n=328), followed by sliding in (n=176) and vertical 165 jump (n=115). There were no statistically significant differences in the proportions of contact injury risk incidents 166 involving a tackle linkable with injuries compared with other contact injury risk incidents involving a tackle 167 between the tackle mode categories (middle part of Figure 1). iii.

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170 13 Tackle action

171 Most contact injury risk incidents involving a tackle, involved one footed tackle action (n=234), followed by 172 two footed tackles (n=158), tackles involving use of the upper limb (n=67), tackles involving upper body 173 contact (n=62) and tackles involving a clash of heads (n=59). Thirty-nine incidents involved a combination, 174 and no dominant tackle action could be determined. Two-footed tackle actions, and tackle actions involving 175 use of upper limb, a clash of heads or a combination of several tackle actions were more frequently associated 176 with injuries than tackle actions involving upper body contact or one-footed tackle action. The differences 177 in the proportions of contact injury risk incidents involving a tackle linkable with injuries compared to other 178 contact injury risk incidents involving a tackle between the tackle action categories (lower part of Figure 1) were 179 statistically significant (p=0.013).

180 14 IV.

181 15 Discussion

182 The main finding of the present study was that there are major differences between the results obtained with the 183 FIA methodology, the tackle analysis methodology and the injury surveillance system. In particular, the present 184 study highlights some methodological issues concerning the definitions of some of the parameters used in the FIA 185 methodology, which may be useful for developing new video-based epidemiological research methods for future 186 studies of football injuries.

187 We were able to link only 42% of the contact injuries reported by team physicians with injury risk incidents, as 188 defined in the FIA methodology and involving player-to-player contact. This questions whether the definition of 189 an injury risk incident is appropriate for this type of epidemiological football injury study. In previous FIA studies, 190 it was possible to link 34-54% of all reported injuries with injury risk incidents for both contact and non-contact 191 injuries but with a tendency towards a higher identification percentage for contact injuries. [14,18] In these FIA 192 studies that combined medical data with video analysis of injury risk incidents, the injury definition used was 193 based on time loss, [14,16,18] may be a contributing factor for explaining the lower percentage of association 194 achieved, as time-loss injuries are generally more serious and the circumstances of injury onset may be more 195 visible in nature, and thus easier to detect and link to match events on video recordings. An investigation of 196 how injuries manifest themselves during matches could potentially provide useful information for a redefinition of 197 what constitutes an injury risk incident. This view is supported by a previous study, which also found differences 198 between the tackle mechanisms associated with injuries and those associated with FIA injury risk incidents. [26] 199 These authors also questioned the validity of the current FIA injury risk definition. [26] A concern related to 200 the low percentage of contact injuries recorded in the injury surveillance study that could be linked to contact 201 injury risk incidents is that there may be one or more common but unknown factors linking these injuries that 202 are not included in the FIA definition of an injury risk incident. It is thus difficult to consider the descriptive 203 data obtained by these definitions as representing a general overview of playing actions and match circumstances 204 leading to injuries. The present study considered all contact injuries as equal and did not differentiate between 205 injuries of different types or different locations.

206 Injury risk incidents refer to situations in which the match is interrupted by the referee, a player is on the ground 207 for more than 15 seconds, or the player appears to be in pain or receives medical treatment. [14,16,18,23,29] 208 However, these situations may have numerous other causes than an injury, such as player substitutions, off-sides 209 or when a player is purely timewasting. In the present study, some of these other situations were excluded, 210 as only injury risk incidents resulting from contact between players were included in the analysis. It could 211 also be questioned, whether apparent medical treatment (assessed on video recordings) should necessarily be 212 associated with a risk of injury. A previous study by Fuller et al. indicated that most on-pitch medical attentions 213 did not result in postmatch physicians' reports, and that the majority of postmatch physicians' reports were 214 not associated with on pitch medical attention. [17] Another concern with the FIA methodology is that the

215 total frequencies of the variables and categories during a match are not assessed, making it impossible to draw
216 conclusions with regards to the risk of injury associated with individual actions. Some factors, such as dribbling
217 or a short pass may be present in most injury risk incidents, but they may also be the most common playing
218 actions during a match; thus, an injury risk incident may result from only a small fraction of these actions. In
219 the present study, the relative risk of injury associated with the variables was assessed by comparing the ratios
220 of the number of contact injury risk incidents linked with contact injuries reported by team physicians to the
221 number of contact injury risk incidents not linked with injuries for the categories of each variable. Using this
222 approach, two variables were identified as independent predictors of injury; attack type and the involvement of
223 foul play. Meaning merely, that the presence of some categories of the variables 'attack type' and 'foul play',
224 during a contact injury risk incident, had an injury predictive value. Whether or not the variable itself has
225 an injury predictive value remains unclear, as not all injuries could be linked with incidents and as the total
226 frequencies of the variables were not recorded. However, the finding that the involvement of a foul in a contact
227 injury risk incident was associated with a lower percentage of linkable injuries than when a foul was not involved
228 seems somewhat counter-intuitive. A possible explanation for this result is that fouls usually result in the referee
229 interrupting the game, which is one of the criteria for an FIA injury risk incident. In the present study most of
230 the contact injury risk incidents involved a foul. However, player-to-player contact can cause injury irrespective
231 of the involvement of a foul, and thus some non-foul contact situations, not fulfilling the criteria for a FIA injury
232 risk incident, were almost certainly excluded. The results of the tackle analysis of the present study share similar
233 limitations, as the included tackles were chosen from the cohort of identified contact injury risk incidents, and
234 thus many other tackles (and possibly some injuries resulting from these tackles) were again most likely excluded.

235 The injury surveillance methodology may also present a source of bias, which could contribute to the
236 discrepancies observed between the data obtained by the different methodologies. The injury surveillance
237 reporting data consists of post-match injury reports, where all the players' complaints that required medical
238 attention during, or immediately after, the match should have been recorded. For the researcher aiming at
239 linking a post-match reported injury to an event on video material, the time (minute) of the injury reported on
240 the injury form may constitute the best lead to identifying the corresponding match event. However, in post-
241 match conditions, the reported time of injury may sometimes be an approximation, which complicates the video
242 analyst's work in identifying the injury event. This could contribute to the low percentage of injury reports that
243 were linked to an injury risk incident

244 The present study did not take into account the frequencies of the different criteria used in the injury risk
245 incident definition. Thus, we cannot draw conclusions on whether some of the criteria, for example when a player
246 is receiving on-pitch medical treatment, are more frequently linkable with a FIFA injury than others.

247 Importantly, only eight of the nineteen variables included in the original description of FIA [16], were included
248 in the present study. Therefore, we cannot draw conclusions about the relevance of the other variables previously
249 included in the FIA methodology.

250 What can we learn from the present study? The FIA video approach for investigating injury risk associated
251 with playing actions and match circumstances requires further development. The optimal method may be to focus
252 on a few well-defined playing actions, in order to assess their total frequencies during matches, and to assess the
253 injury risk associated with these actions. This approach was successfully applied by Fuller et al. in studies on
254 tackle parameters in football [15,17,22] and rugby union. [40] They identified some tackle parameters having a
255 greater propensity for causing injuries than others. [15,40] They concluded that an assessment of injury causation
256 factors should therefore, differentiate between initiating events with a high frequency of occurrence and a low
257 propensity for injury and those events with a low frequency of occurrence and a high propensity for injury. [15,40]
258 Also Drawer et al. stated that an effective risk management strategy begins with an estimation and evaluation
259 of the risks associated with the activity. [38] By comparing the number of contact injuries, based on post-match
260 injury reports [2], and the number of injuries that was linked with the tackles identified on video recordings in
261 one of the tournaments (2000 Olympics), included in the tackle analysis study by Fuller et al. [15], we find that
262 96% (98/102) of all the contact injuries were linkable with the tackles, further indicating that their methodology
263 was suitable. However, we do not know how reliable the linking of a match event, identified by a researcher from
264 video recordings, to an injury, reported by the team physician, really is. Fuller et al. identified 8572 tackles
265 from 123 matches, [15] giving an average of roughly 70 tackles per match (or more than one tackle every two
266 minutes). Thus, one player could potentially be involved in several tackles during the same match and within a
267 short time frame. Considering this, the reliable linking of an injury to a specific tackle may be debatable, as it
268 is based on the researcher's interpretation, especially when it comes to minimal and mild injuries.

269 V.

270 16 Conclusions

271 In conclusion, the limitations discussed above make comparison of the results obtained by these three
272 methodologies difficult to interpret and there is little evidence that the current definition of an injury risk
273 incident, as defined in the FIA methodology, is adequate for linking match events with injuries. Future studies
274 are needed that will provide more reliable methods for identifying injury causation events using video recordings:
275 this is difficult, but it remains the most important factor. One potentially valuable methodological revision would
276 be to include post-match reviews of video recordings of matches, in the presence of the injured player and/or the

16 CONCLUSIONS

277 team physician who made the post-match medical assessment of the injured player, as these individuals are best
278 suited to identify the injury events associated with an injury.

VI. ¹



1

Figure 1: Figure 1 :

279

¹Combining Data from Injury Surveillance and Video Analysis Studies: An Evaluation of Three FIFA World Cups TM

280 .1 Acknowledgments

281 The authors gratefully acknowledge F-MARC for providing the injury surveillance reporting data and video
282 material. We also greatly appreciate the co-operation of all team physicians who provided the injury data. a)
283 Contributorship statement JR coordinated the study, conducted the statistical analysis together with HK, and
284 drafted the manuscript. LL reviewed all the video recordings. JR, LL, LP, JK and MB participated in the
285 study design, through revision and by partly writing the research plan, as well as approving the final manuscript.
286 Author LP played a key role in the collection of injury data. JK, MB and LP participated in revision and writing
287 of the research plan, the first draft, and the final manuscript. CF participated through revision and writing of
288 the final version of the manuscript.

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