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Quantification of accelerometer derived impacts associated with competitive games in National Collegiate Athletic Association division I college football players

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QUANTIFICATION OF ACCELEROMETER DERIVED IMPACTS ASSOCIATED WITH COMPETITIVE GAMES IN NCAA DIVISION I COLLEGE FOOTBALL PLAYERS

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ABSTRACT

The aims of the present study were to 1) examine positional impact profiles of NCAA division I college football players using global positioning system (GPS) and integrated accelerometry (IA) technology, and 2) determine if positional differences in impact profiles during competition exist within offensive and defensive teams. Thirty-three NCAA Division I Football Bowl Subdivision players were monitored using GPS and IA (GPSports, Canberra, Australia) during 12 regular season games throughout the 2014 season. Individual player datasets (n = 294) were divided into offensive and defensive teams, and positional sub-groups. The intensity, number, and distribution of impact forces experienced by players during competition were recorded. Positional differences were found for the distribution of impacts within offensive and defensive teams. Wide receivers (WR) sustained more very light and light to moderate (5-6.5 G force) impacts than other position groups, while the running backs (RB) were involved in more severe

22   (>10 G force) impacts than all offensive position groups, with the exception of the

23   quarterbacks (QB) (p<0.05). The defensive back (DB) and linebacker (LB) groups were

24   subject to more very light (5.0-6.0 G force) impacts, and the defensive tackle (DT) group

25   sustained more heavy and very heavy (7.1-10 G force) impacts than other defensive

26   positions (p<0.05). Data from the present study provide novel quantification of positional

27   impact profiles related to the physical demands of college football games and highlight

28   the need for position-specific monitoring and training in the preparation for the impact

29   loads experienced during NCAA Division I football competition.

30

31   Key Words: Integrated Accelerometers, monitoring, American football

32

33   **INTRODUCTION**

34

35   American football is a field-based team-sport with competition characterized by

36   repeated short-duration, high-intensity, intermittent movement patterns involving

37   accelerations, decelerations, sprinting, and multi-directional running, followed by periods

38   of low-intensity recovery and tactical strategizing between plays (10,29).   In addition to

39   the running demands associated with American football, athletes are exposed to

40   frequent collisions and blunt force trauma associated with repeated contact with

41   opponents and the ground during tackling, blocking, and ball-carrying activities (25).

42   Previous research (10,24,29) has provided some insight into positional movement

43   profiles, including the quantification of high-intensity accelerations and decelerations

44   and sprint distances, along with a rudimentary understanding of exercise to rest ratios

45 performed during National Collegiate Athletic Association (NCAA) division I football

46 games. However, there is currently limited quantitative information describing the

47 number and intensity of impacts associated with competitive NCAA division I football

48 games. Due to the intense physical demands associated with American football

49 competition, a quantitative examination of position-specific impact profiles may provide

50 an increased understanding of the competitive demands for individuals participating in

51 NCAA division I football games, and novel insight for performance coaches seeking to

52 develop position-specific training and recovery strategies.

53

54 Advances in game analysis technologies, such as global positioning system (GPS) and

55 integrated accelerometry (IA), have provided a valid and reliable means of assessing

56 activity profiles (4,11,12,28) and an accurate measure of the impacts associated with

57 collisions in contact team-sports (3,5,18,21). The quantification of competitive

58 movement demands associated with American football (29) and collisions in team-sport

59 competition similar in nature to American football, including rugby league

60 (1,7,18,19,21,23), rugby sevens (9), Australian rules football (17,27,30), and rugby

61 union (5,20) have been reported. Nevertheless, the unique characteristics of American

62 football will dictate specific and distinct physical demands that require detailed

63 examination.

64

65 The development of GPS technology with IA have allowed the physiological demands of

66 practice and competition in contact team-sport to be quantified by the tracking of player

67 movement demands (1,7,18,21,29,32). Integrated triaxial accelerometers have proven

68   to be a reliable means of measuring physical activity across multiple players in team-

69   sport (2), and offer a valid tool for detecting the frequency and magnitude of impacts

70   and collisions associated with practice and competition in contact team-sport (6).

71   Impacts may differ in magnitude depending on the intensity of movement undertaken by

72   an athlete and commonly occur in collision sport as a result of decelerations, high-

73   intensity changes in direction, landing from jumps, falling to the ground, and collisions

74   and tackles inherit to collision sport similar to American football (18). While the use of

75   movement profiles collected from GPS and IA offers an assessment of athlete

76   movement during sport-specific activity, the use of impact data collected by GPS and IA

77   during competition and training may provide the most holistic assessment of volume

78   and intensity of exercise in comparison to the traditionally used movement metrics. As

79   such, the quantification of the impact profiles in NCAA division I college football may

80   add novel insight to the physical loading demands placed upon athletes during

81   competition.

82

83   Within American football, each position group has specific physiological and movement

84   demands associated with unique technical and tactical requirements (14). The

85   positional movement profile characteristics associated with NCAA division I football

86   games have been reported (29) and significant ($p < 0.05$) differences between positions

87   groups on offense and defense for high-intensity movement demands have been

88   established. Movement characteristics may provide a rudimentary understanding of the

89   physical demands associated with competition, however, these measures fail to

90   consider the physical demands associated with the contact nature of competitive

91   football games. American football competition presents a unique model to study

92   position-specific impact profiles that may be similar to other contact team-sports. The

93   characteristics of repeated collisions and the associated blunt force trauma resulting

94   from competition in Rugby League and Rugby Union players have been reported

95   (3,5,18,21), and significant (p<0.05) inter-positional differences in total impacts

96   experienced have been demonstrated during competition (20,26). However, uncertainty

97   exists regarding the intensity and frequency of position-specific impact profiles of NCAA

98   division I football players during competition. Despite the widespread inclusion of GPS

99   and IA technology in collegiate American football programs, there remains a paucity of

100   research regarding the characteristics of collisions experienced by players during

101   competition. The accurate determination of impact forces experienced by players

102   during games may provide sports performance specialists with novel insight into the

103   position-specific demands of competition and highlight ways in which GPS and IA data

104   can be used to optimize athlete performance programs.

105

106   The aims of the present study were to 1) examine the positional impact profiles of

107   NCAA division I college football players associated with competitive game performance

108   using IA technology, and 2) determine if positional differences in impact profiles exist

109   within offensive and defensive teams. We hypothesized that significant positional

110   differences will exist in the number and intensity of impacts associated with competitive

111   performance in NCAA division I college football. Data obtained will provide information

112   for performance coaches seeking to optimize position-specific training programs.

113

114 **METHODS**

115

116 **EXPERIMENTAL APPROACH TO THE PROBLEM**

117

118 To examine the positional impact characteristics during NCAA division I football games,

119 portable accelerometer data were collected from players during 12 regular-season

120 games. All games were 60 minutes in duration, comprised of four 15 minute quarters,

121 each followed by a brief recovery period, and played outdoors between the hours of

122 12:00 and 21:00 over a period of thirteen weeks from September to November. All

123 participants were required to participate in a minimum of 75% of the total offensive or

124 defensive plays for the GPS and IA derived datasets to be included in the present study.

125 Each individual GPS and IA dataset was characterized as constituting either offensive

126 or defensive team performance, and subsequently divided into specific positional

127 groups for the offense that included wide receivers (WR, 41 datasets), quarterbacks

128 (QB, 12 datasets), running backs (RB, 41 datasets), tight ends (TE, 22 datasets),

129 offensive linemen (OL, 37 datasets), and for the defense that included defensive backs

130 (DB, 55 datasets), linebackers (LB, 36 datasets), defensive ends (DE, 33 datasets) and

131 defensive tackles (DT, 17 datasets).

132

133 **SUBJECTS**

134

135   Thirty-three National Collegiate Athletic Association (NCAA) Division I Football Bowl

136   Subdivision (FBS) football players (age 20.7 ± 1.0 years; height 188.6 ± 7.2 cm; and

137   mass 106.7 ± 19.6 kg) participated in the present study. Positional anthropometric data

138   are presented in Table 1. All subjects were collegiate athletes whom had been selected

139   to participate in the football program eight months prior to the commencement of the

140   study. All participants in the present study completed the teams' off-season physical

141   development training program that included a full-body strength and power training

142   program and specific skills and conditioning sessions designed to simulate the demands

143   of NCAA division I college football competition. The present study comprises statistical

144   analysis of data collected as part of the day to day student athlete monitoring and

145   testing procedures within the university's football program. Researchers were provided

146   with de-identified GPS and IA datasets from twelve regular season games for analysis.

147   De-identified data included participant playing position for the purposes of position-

148   specific data analysis. Ethical approval was obtained from the university's human

149   research ethics committee.

150

151   *Insert Table 1 Here**

152

153   **PROCEDURES**

154

155   *Global Positioning System Units*. The present study used commercially available GPS

156   receivers (SPI HPU, GPSports, Canberra, Australia) which operated in a non-differential

157   mode at a sampling frequency of 15 Hz. The GPS receivers also contain integrated

158   triaxial accelerometers (IA), which operated at 100 Hz and assessed the frequency and

159   magnitude of full-body acceleration (m·second^{-2}) in three dimensions, namely, anterior-

160   posterior, mediolateral, and vertical (16,21). Impacts were derived from the vector of

161   the X-Y-Z axes of the triaxial accelerometer and calculated as the square root of the

162   sum of the squares of each axis, whereby 27.7 G was the maximum accelerometry

163   output (8). Subjects had previously worn GPS and IA receivers in outdoor training

164   sessions that included football-specific running, and skill-related and game-simulated

165   contact activities during a three-week pre-season training period. Prior to the

166   commencement of each game, GPS receivers were placed outside for 15 minutes to

167   acquire a satellite signal, after which, receivers were placed in a custom designed

168   pocket attached to the shoulder pads of the subjects. Shoulder pads were custom-fit for

169   each individual, thereby minimizing movement of the pads during games. The GPS and

170   IA receivers used in the present study (66 g; 74 mm x 42 mm x 16 mm) were positioned

171   in the center of the upper back, slightly superior to the scapulae. Subjects were

172   outfitted with the same GPS receiver for each of the twelve games. Following the

173   completion of games, GPS receivers were removed from the shoulder pads, and

174   subsequently downloaded to a computer for analysis utilizing commercially available

175   software (Team AMS, GPSports, Canberra, Australia). The GPS and IA receivers used

176   in the present study have demonstrated both inter- and intra-accelerometer reliability

177   (CV = 1.87 – 2.21%) (13), while similar integrated accelerometers have been validated

178   for quantifying the number and intensity of collisions in Rugby League (6) and

179   measuring peak impacts in team-sport (CV = 4.8%, filtered at cut-off frequency of 12Hz)

180   (31).

181

182   Data provided from IA were assessed as impact profile variables including very light,

183   light to moderate, moderate to heavy, heavy, very heavy, and severe impacts.

184   Classifications of parameters of impact profile variables are described below and

185   presented in Table 2. Each of the GPS and IA derived variables measured in the

186   present study were calculated using commercially available software (Team AMS,

187   GPSports, Canberra, Australia). The impact classification system utilized in the present

188   study was based on methods previously described in Rugby League (18,21), Rugby

189   Union (3,5,20) and manufacturer recommendations (GPSports, Canberra, Australia).

190   GPSports reports peak accelerations, irrespective of the nature of the peaks, from

191   which impact forces can be calculated, given the fact that acceleration is proportional to

192   force if mass is constant (32).

193

194   *Impact Classification System.* Player exposure to impact was determined via

195   accelerometer data provided in 'G' force. A classification system within Team AMS

196   (GPSports, Canberra, Australia) software allows for six zones of impact to be preset

197   and used for subsequent analysis. Zone one is indicative of the lowest intensity of

198   impact, with each zone progressively categorizing impact intensity to zone six, reflecting

199   the highest impact and intensity of movement. Each impact classification was coded as

200   one of six intensities of impact (Table 2). Very light impacts such as accelerations,

201   decelerations, and changes of direction were considered to be 5.0 - 6.0 G. Light to

202   moderate impacts, such as minor collisions with other players and contact with the

203   ground, were considered to be 6.1 – 6.5 G. Moderate to heavy impacts resulting from

204   physical contact with the opposition at moderate velocities were considered 6.6 – 7.0 G.

205   Heavy impacts from high-intensity collisions were classified as 7.1 – 8.0 G, while very

206   heavy impacts resulting from high-intensity collisions and high velocities were classified

207   as 8.1 – 10.0 G, and severe impacts resulting from high-intensity collisions between

208   players traveling at high velocities, were classified as those exceeding 10 G.

209

210   **Insert Table 2 Here***

211

212   **STATISTICAL ANALYSES**

213

214   All movement variables from the present study were presented as descriptive statistics,

215   mean ± standard deviation (SD). Hypothesis testing was conducted to determine any

216   main effects for impact profile data between position groups on the offensive and

217   defensive teams. A one-way ANOVA was used to determine positional group main

218   effects. In the event homogeneity of variance assumption was violated, a Welch Robust

219   Test of Equality was used to determine main effects between position groups. For all

220   main effects detected by a one-way ANOVA, post-hoc Bonferroni tests were utilized.

221   Alpha intervals for all hypothesis testing were set at $p < 0.05$. To determine the

222   magnitude of main effects and interactions, partial eta-square (n^2) effect size statistics

223   were adopted, which indicate the percentage of variance accounted for by the effect,

224   with values of 0.01 – 0.06, 0.06 – 0.15, and > 0.15 considered small, moderate, and

225   large, respectively. All statistical analyses were performed using the Statistical Package

226   for the Social Sciences (SPSS for Windows, version 14.0; SPSS, Inc., Chicago, IL.

227   USA).

228

229   **RESULTS**

230

231   *Offense:* Significant ($p<0.001$) main effects from ANOVA testing were reported for all

232   impact profile variables measured in the present study for the offensive position groups

233   (Table 3). Post-hoc analysis of impact profile variables, revealed significant ($p<0.05$)

234   inter-position differences across all impact zones, with the exception of zone 5. The

235   WR position group sustained significantly ($p<0.001$) more very light (zone 1) impacts

236   than all other offensive position groups, while the OL position group underwent

237   significantly ($p<0.01$) more very light impacts than RB and QB position groups. Analysis

238   of light to moderate impacts (zone 2) demonstrated a significantly ($p<0.001$) greater

239   number of impacts for WR than all other offensive position groups. Similarly, both TE

240   and OL position groups underwent significantly ($p<0.01$) more light to moderate impacts

241   than RB and QB position groups. The number of moderate to heavy (zone 3) impacts

242   sustained during games were similar among WR, TE, and OL position groups, and

243   significantly ($p<0.001$) greater than both QB and RB position groups. The WR and OL

244   position groups experienced significantly ($p<0.001$) more heavy (zone 4) impacts than

245   both the RB and QB position groups. Analysis of very heavy (zone 5) impacts revealed

246   no significant (p<0.05) inter-position differences, while the number of severe (zone 6)

247   impacts was significantly (p<0.05) greater for the RB position group than the WR, TE,

248   and OL position groups. Finally, the QB position group sustained significantly more

249   severe (zone 6) impacts than the TE position groups.

250

251   *Defense:* Significant (p<0.001) main effects from ANOVA testing were reported for all

252   impact profile zones measured in the present study for the defensive position groups,

253   with the exception of zone 2 impacts (Table 4). Post-hoc analysis of impact profile

254   variables, revealed significant (p<0.05) inter-position differences across all impact

255   zones, with the exception of zone 2 and zone 6. The DB position group sustained

256   significantly (p<0.001) more very light (zone 1) impacts than the DT and DE position

257   groups, while the LB group was involved in significantly (p<0.001) more very light

258   impacts than the DT position group. The DT position group was involved in significantly

259   (p<0.001) more moderate to heavy (zone 3), heavy (zone 4), and very heavy (zone 5)

260   impacts than all other defensive position groups, while the DE position group sustained

261   significantly more (p<0.01) heavy and very heavy impacts than the DB position group.

262   The DT position group was involved in more light to moderate (zone 2) impacts than all

263   other defensive position groups, while the DE position group engaged in more severe

264   (zone 6) impacts than any other defensive group, however none of the inter-position

265   differences within either of these impact zones reached a level of significance (p<0.05).

266

267 **DISCUSSION**

268

269   The present study examined the impact profiles associated with competitive games in

270   NCAA division I college football players using portable IA technology, and assessed

271   differences in positional groups within offensive and defensive teams. The results of the

272   present study provide novel insight into the competitive demands experienced by NCAA

273   division I college football players, and may provide scope for the design of position-

274   specific and game-specific physical preparation strategies for coaches seeking to

275   optimize training for the demands of competition. Results from the present study confirm

276   our hypothesis that significant (p<0.05) differences in the number and intensity of

277   impacts associated with competition exist between playing positions in NCAA division I

278   college football players. The most notable findings for competitive game impact profile

279   characteristics of offensive position groups were the WR position group undergoing

280   more zone 1 and 2 (very light and light to moderate) impacts than all other offensive

281   position groups, while the WR and OL group participated in more zone 3 and 4

282   (moderate to heavy and heavy) impacts than the RB group. The RB position group

283   recorded the greatest number of severe impacts throughout the course of competition,

284   which may reflect the characteristic high-velocity collisions with defenders associated

285   with the positional demands of being the primary offensive ball carrier. Defensively, the

286   DB and LB position groups were involved in more zone 1 impacts than all other position

287   groups. The DT group participated in more zone 3, 4, and 5 (moderate to heavy, heavy,

288   and very heavy) impacts than all other defensive position groups, which may be

289   attributed to the physical demands of the DT position, often involving physical contact

290   with numerous offensive players on each play throughout the course of competition.

291

292   Comparing the findings of the present study with the existing knowledge of positional

293   game demands is problematic due to the lack of research on impact profiles in

294   American football players. Positional analysis in contact team-sport similar to American

295   football, including Rugby League (18,21) and Rugby Union (3,5,20,26), have

296   demonstrated inter-positional differences in the quantity and intensity of impacts

297   associated with competition, supporting the findings of the present study. Although the

298   influence of the number and intensity of impacts sustained during competition on the

299   duration of post-game recovery in Rugby League players has been investigated (18,21),

300   and the biochemical and endocrine responses to competitive games in American

301   football and Rugby league players have been reported (15,22), there is a lack of

302   research quantifying the relationship between the physical demands of competition and

303   the time-course of recovery associated with college football games. Accordingly, there

304   is a need to establish the relationship between the physical demands of games,

305   including movement and impact profiles, and the subsequent duration of recovery in

306   NCAA division I football players, to provide insight into the effects of competition on

307   athlete recovery.

308

309   The present study found significant (p<0.05) inter-position differences in the number of

310   impacts encountered during competitive NCAA division I football games. The WR

311   position group was involved in significantly (p<0.001) more zone 1 impacts than all other

312   offensive position groups. Similarly, on defense, the DB position group recorded

313   significantly (p<0.001) more zone 1 impacts than both the DT and DE position groups,

314   while the LB group recorded significantly (p<0.001) more than the DT position group.

315   The manufacturer (GPSports, Canberra, Australia) of the GPS and IA receivers used in

316   the present study have indicated that low-intensity impacts (2.0-6.0G) are commonly

317   attributed to walking and running, and thus a large amount of very light impacts may be

318   a reflection of running volume throughout the course of competition (8). Additionally,

319   high-intensity changes of direction, falling to the ground, landing from jumps, blocking,

320   collisions, and tackles are all capable of eliciting high-intensity impacts (8). Significant

321   (p<0.05) inter-position differences in running volumes in NCAA division I players

322   participating in competitive games have been demonstrated (29). Wellman et. al. (29)

323   examined movement profiles associated with competitive games in NCAA division I

324   football players and reported the WR group covered significantly (p<0.05) more total

325   distance than all other offensive position groups, while the DB and LB position groups

326   covered significantly (p<0.05) more total distance than both DT and DE position groups.

327   The results of Wellman et. al. (29) support the findings of the present study, indicating

328   the increased number of very light impacts detected in the WR and DB position groups

329   may be attributed to the increased running volumes experienced as a result of the

330   unique position-specific demands of these groups. Positional alignment at the

331   commencement of each play that provides greater distance from the placement of the

332   football gives these athletes a larger area for movement, providing increased movement

333   requirements during plays. Additionally, the WR and DB cover more distance between

334 plays as they are required to jog back to the line of scrimmage at the conclusion of

335 plays, which may be a distance of 20-30 m to either huddle or re-assume their

336 alignment for subsequent play, while other positions characteristically walk short

337 distances during recovery between plays (24).

338

339 Offensively, the WR and OL position groups sustained significantly ($p < 0.05$) more zone

340 2, 3, and 4 impacts than the RB and QB groups. While no significant inter-position

341 differences were demonstrated with respect to very heavy impacts, the RB position

342 group was involved in significantly ($p < 0.05$) more zone 6 (severe) impacts than all

343 offensive position groups, with the exception of the QB position group. These findings

344 are substantiated by previous descriptions of the nature of severe impacts in contact

345 team-sport (21). McLellan et. al. (21) described severe impacts as being indicative of

346 high-intensity collisions with the opponent, making a direct front-on tackle on an

347 opponent traveling at a high velocity, or being tackled by multiple opponents while

348 running at maximal velocity. The RB position is primarily responsible for carrying the

349 football on running plays and catching the ball on short passing plays, in addition to

350 blocking DT, DE, and LB on passing plays which require protection of the QB. The

351 responsibility of running with the football at high velocities lends itself to direct blunt

352 force trauma, often from multiple opponents, and supports the findings of the present

353 study which indicated an increased number of severe impacts when compared to other

354 offensive positions. Defensively, there were no significant differences between position

355 groups with respect to light to moderate impacts, however the DT group registered

356 significantly ($p < 0.05$) more zone 3, 4, and 5 impacts than all other defensive position

357   groups. Additionally, the DE position group was involved in significantly ($p < 0.05$) more

358   zone 4 and 5 impacts than the DB group. The greater number of zone 4 and 5 impacts

359   demonstrated within the DT and DE position groups may result from the position-

360   specific demands of these position groups, including rapid accelerations at the

361   commencement of each play, followed by contact with the opposing offensive player,

362   and the subsequent pursuit and tackling of the ball carrier.

363

364   Inter-positional differences in impact profiles resulting from Rugby Union competition

365   revealed significant ($p < 0.05$) differences between forwards and backs which is

366   consistent with the findings of the present study for offensive and defensive positions

367   (20,26). The significant differences in zone 1-4 impact counts between the WR and OL

368   group when compared to the RB and QB group highlight distinct physiological impact

369   characteristics associated with competition, which may require different training and

370   recovery protocols to achieve optimal performance. The positional differences in the

371   present study may be explained by the position-specific requirements of these

372   individuals. Additionally, the tactics of the offensive team employed during games,

373   namely the number of running and passing plays undertaken, may affect the positional

374   impact distribution. During NCAA division I football games, the WR group is involved in

375   significantly ($p < 0.05$) more maximal acceleration and deceleration efforts than all other

376   offensive position groups (29), likely resulting from the frequent changes of direction

377   due to repeated route running. Additionally, the WR group is responsible for blocking

378   the opposition on running plays and is involved in impacts resulting from physical

379   collisions associated with carrying the ball following a reception on passing plays. The

380   OL position group engages in physical contact with the opposition on nearly every play,

381   with the intensity and quantity of impacts presumably dictated largely by offensive

382   strategy. Running plays typically require the OL group to quickly accelerate forward or

383   laterally from a stationary position, initiate contact with the opposition, and move the

384   defender thereby creating a running lane for the ball carrier. Passing plays involve the

385   OL group moving backward or laterally in attempt to protect the QB, while waiting for the

386   opposition to initiate contact. The RB group was involved in significantly ($p<0.05$) more

387   severe impacts than all other offensive position groups with the exception of the QB

388   group. These findings are likely the result of impacts with opponents, and subsequent

389   impact with the ground, resulting from carrying the ball during running plays. The lack

390   of a significant difference in the number of severe impacts between the RB and QB

391   position groups may be due to offensive strategy. On plays involving the QB as the ball

392   carrier, increased opportunity exists for multiple impacts with the opposition, and

393   similarly, as the number of passing attempts increases, there is greater possibility of the

394   QB being sacked or knocked down.

395

396   Defensively, while no significant inter-positional differences were observed for light to

397   moderate impacts, significant ($p<0.05$) differences were demonstrated in the number of

398   zone 3, 4, and 5 impacts between the DT group and all other defensive position groups.

399   Characteristically, players in the DT position group accelerate short distances and

400   perform rapid change of direction movements before engaging individual or multiple OL,

401   followed by accelerating to pursue and tackle the ball carrier. The DB group initiates

402   play further from the line of scrimmage and is primarily responsible for defending the

403   WR on passing plays and provides secondary support on running plays, thereby limiting

404   the amount of physical contact with the opposition. The LB group characteristically

405   commences play 4-5 m from the line of scrimmage and is generally responsible for

406   providing support on running plays, in addition to defending TE and RB on passing

407   plays. Due to the increased responsibilities in defending running plays within the

408   position-specific responsibilities of the LB group compared to the DB group, and a

409   closer alignment to the line of scrimmage at the initiation of play, the opportunity for

410   physical contact with offensive players is increased. The present study indicated a

411   larger number of zone 4 and 5 impacts for the LB group when compared to the DB

412   group, although these results did not reach significance. Aligning directly on the line of

413   scrimmage prior to the commencement of each play provides opportunity for the DT

414   position group to be involved in physical contact from multiple players on every play,

415   which is indicated in the present study with significantly ($p<0.05$) more zone 3, 4, and 5

416   impacts recorded for the DT group than all other defensive positions. In similar contact

417   team-sport, significant ($p<0.05$) correlations have been demonstrated between the

418   number of high-intensity ($>7G$) impacts sustained and post-match neuromuscular

419   performance decrements and markers of skeletal muscle damage (18,21). As such, the

420   accurate monitoring and prudent modification of practice impact loads of position groups

421   involved in significantly more zone 4-6 impacts during competition may enhance

422   recovery and improve subsequent competitive performance.

423

424   Significant inter-position differences in the intensity and distribution of impacts

425   associated with NCAA division I college football competition exist. The greater number

426   of zone 1 and 2 impacts for the WR, DB, and LB groups may be attributed to the

427   significant differences in competitive game running volumes, including accelerations

428   and decelerations, between position groups previously demonstrated (29). The

429   position-specific physicality required of the OL group presumably resulted in more zone

430   3 and 4 impacts, while the significant differences in severe impacts of the RB position

431   group compared to other offensive groups may result from high-intensity collisions from

432   direct tackles at high-velocities, or being tackled by multiple opposing players, as

433   described in investigations of impacts associated with Rugby League competition

434   (18,21). The starting position of the DT group upon commencement of each play, along

435   with rapid changes of direction and physical contact with multiple opponents which

436   generally characterizes DT positional demands, resulted in more zone 3, 4, and 5

437   impacts than all other defensive position groups. Collectively, the results of the present

438   study highlight distinct impact profiles for offensive and defensive teams, which may

439   require the development of position-specific training and recovery protocols.

440

441   The results of the present study provide novel insight into the impact profiles of NCAA

442   division I college football games and provide physical performance staff with quantified

443   information. The present study demonstrated substantial differences in positional impact

444   profiles associated with NCAA division I football games, emphasizing the importance of

445   position-specific training to appropriately prepare players for the rigors of competition.

446

447   **PRACTICAL APPLICATIONS**

448

449   The present study provided a novel analysis of the number and intensity of impacts

450   associated with NCAA division I college football games. The findings of this study

451   suggest that repeated high-intensity impacts during NCAA division I football games are

452   position specific in nature and support the use of position-specific training in the

453   preparation of NCAA division I college football players for competitive games. Data

454   from the present study augment our understanding of the competitive demands

455   experienced by NCAA division I college football players, and provide scope for position-

456   specific training strategies for performance coaches seeking to optimize competitive

457   performance.

458

459   Maximizing performance and mitigating the effects of fatigue present unique challenges

460   to performance coaches, and consequently, quantifying the physical demands

461   associated with weekly practice and competition is critical. In contact team-sport similar

462   to American football, the number of impacts exceeding 7 G has been significantly

463   correlated with decreases in neuromuscular performance following competition (18).

464   During the in-season period judicious monitoring, and the subsequent alterations of

465   weekly practice and conditioning loads of individuals within position groups involved in

466   large numbers of impacts, particularly those registering as heavy, very heavy, and

467   severe, may reduce fatigue, expedite recovery, and improve competitive performance.

468   As such, the DT, OL, and WR position groups may benefit from position-specific, and

469   perhaps, individually prescribed practice loads. Because the OL and DT position

470   groups often compete against one another in practice, limiting the number of live

471 contact drills and scrimmage situations may result in a reduction of intense impacts

472 sustained during the course of a practice week, possibly enhancing recovery and

473 improving subsequent performance. Limiting the amount of contact the WR position

474 sustains in practice sessions is common in American football, and this rationale is

475 substantiated by the present study. Given the significant quantity of severe impacts

476 sustained by the RB position, performance coaches should monitor, and in some cases,

477 reduce the impact load of individual practice sessions by limiting the number of

478 scrimmage situations the RB group is involved in. Data obtained from the study

479 contribute new insight into the competitive demands of NCAA division I college football

480 and provide a foundation from which to implement a systematic approach to the

481 development of individual and position-specific training prescriptions. During the pre-

482 season practice period, monitoring and periodizing training loads based upon position-

483 specific impact profiles may allow performance specialists to scale the intensity of

484 practices to better prepare athletes for forces encountered during competition.

485

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