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Wellman, Aaron D.; Coad, Sam C; Goulet, Grant C.; McLellan, Christopher P

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

4
5 Aaron D. Wellman¹, Sam C. Coad¹, Grant C. Goulet², Vernon G. Coffey¹, Christopher P.
6 McLellan¹

7
8 **ABSTRACT**

9
10 The aims of the present study were to 1) examine positional impact profiles of NCAA
11 division I college football players using global positioning system (GPS) and integrated
12 accelerometry (IA) technology, and 2) determine if positional differences in impact
13 profiles during competition exist within offensive and defensive teams. Thirty-three
14 NCAA Division I Football Bowl Subdivision players were monitored using GPS and IA
15 (GPSports, Canberra, Australia) during 12 regular season games throughout the 2014
16 season. Individual player datasets (n = 294) were divided into offensive and defensive
17 teams, and positional sub-groups. The intensity, number, and distribution of impact
18 forces experienced by players during competition were recorded. Positional differences
19 were found for the distribution of impacts within offensive and defensive teams. Wide
20 receivers (WR) sustained more very light and light to moderate (5-6.5 G force) impacts
21 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 inherent 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 ($m \cdot \text{second}^{-2}$) 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 \pm 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 (η^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

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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487

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