SciMedCentral

Annals of Sports Medicine and Research

Research Article

Elevated Pre-Season BESS Scores Not-Predictive of Development of Lower Extremity Injuries in Division 1 Football Players and a Prophylactic Ankle Program did not Reduce Risk

Lauren Porras[1]*, Brendan Lawson[2], Caroline M. Barrett[3], Kenzie Jane Bowen Johnston[4], Andrea Dotson[5], Crystal Higginson[6], John D. Hales III[7], Marcia Newby-Goodman[8], Julie McNabb[9], Iva Darkina Ward[9], Kunal Agnihotri[9] and Harry Stafford[10]

[1]*Department of Family Medicine/Human Performance Center, Department of Orthopaedics University of North Carolina Chapel Hill, USA*

[2]*UNC School of Medicine, USA*

[3]*UNC-Chapel Hill, Division of Gastroenterology and Hepatology, USA*

[4]*Duke University Team Physician, Duke University Student Health, Duke Department of Family Medicine and Community Health, USA*

[5]*UNC-Chapel Hill Department of family medicine, USA*

[6]*University of Notre Dame, USA*

[7]*Ashville Orthopaedic Associates, UNC Asheville Team Physician, USA*

[8]*Primary Care Specialists Inc, USA*

[9]*Clinic Athletic Trainer, Novant Health, USA*

[10]*Department of Sports Medicine, University of North Carolina Chapel Hill and North Carolina Central University Athletics*

***Corresponding author**

Lauren Porras, Department of Family Medicine/Human Performance Center, Department of Orthopedics University of North Carolina Chapel Hill, United States, Email: lauren_porras@med.unc.edu

Submitted: 16 January 2021

Accepted: 15 March 2021

Published: 21 March 2021

ISSN: 2379-0571

Keywords

- BESS Test
- Concussion
- Lower Extremity Injury

Context

BESS scores have been shown to be reflective of balance deficits that can cause LE injury or concussions. There is no current literature that addresses whether these scores are predictive of injury.

Objective: To find if a preseason BESS scores of 15 or greater is predictive of the development of LE injury or concussion and whether a prophylactic ankle rehabilitation program lowers this risk.

Design: Prospective Cohort Study

Setting: Sport Setting

Patients or Other Participants: The North Carolina Central University football team from 2014 – 2016, and 2018.

Interventions: A prophylactic ankle rehabilitation HEP was performed twice daily during the 2016 and 2018 seasons.

Main Outcome Measures: Athlete preseason BESS scores and injury data from the season was analyzed using a multiple logistic regression. Those athletes with a BESS score of x≥15 underwent prophylactic ankle rehabilitation and the injury results were compared to see if there was a reduction in risk.

Results: Elevated Bess scores (x≥15) proved to be non-predictive of LE Injury or concussion in both the control seasons ($p = .55$, $p = .81$) or the intervention seasons ($p = .90$, $p = .69$), nor did the ankle rehabilitation reduce the injury risk ($p = .52$, $p = .71$). A previous concussion did increase the risk of LE injury in the control seasons ($p = .03$).

Conclusion: An athlete's BESS score proved to be non-predictive of LE injury or concussion and the prophylactic ankle program did not reduce the risk of either. Suffering a previous concussion did show an increase in risk to subsequent LE injury.

Cite this article: *Porras L, Lawson B, Barrett CM, Bowen Johnston KJ, Dotson A, Higginson C, et al. (2021) Elevated Pre-Season BESS Scores Not-Predictive of Development of Lower Extremity Injuries in Division 1 Football Players and a Prophylactic Ankle Program did not Reduce Risk. Ann Sports Med Res 8(2): 1177.*

KEYPOINTS

- An elevated BESS score is nonpredictive of future LE injury or concussion.
- Previous concussions do increase an athlete's risk of subsequent LE injuries.
- Although an elevated BESS score demonstrates increased ankle instability, prophylactic ankle rehabilitation does not diminish an athlete's risk to future LE injury or concussion.

The Balance Error Scoring System (BESS) is a clinical tool originally developed for concussion assessment of athletes suffering from mild head injury and to aid in deciding whether they should return to play. The BESS is a reliable test to evaluate static postural stability and is used regularly by clinicians. It is currently used for in-season assessment of concussion in athletes at North Carolina Central University, as well as many other Division I athletic programs. At NCCU, pre-season BESS scores are collected on most football players at their pre-season physicals. These baseline scores are used for comparison when evaluating the athlete after a head injury.

The BESS can be useful as an outcome measure beyond its original role in head injury [1]. Studies have shown that those with ankle instability perform worse on the BESS. Docherty et al [2] reported in a 2006 study of sixty Division I athletes, thirty with functional ankle instability and thirty controls, those with ankle instability scored more errors than controls and, therefore, had higher total BESS scores. This study showed that deficits in postural control resulting from functional ankle instability are reflected in the BESS score. In addition, Smith & Bell [3] showed in a 2013 study that patients with prior ACL reconstruction have poorer postural control than healthy controls, reflected in higher BESS scores.

Thus, BESS scores reflect balance deficits that can be attributed to lower extremity instability. However, there are no studies in the literature that address whether BESS can be used as a tool to predict if athletes with higher pre-season scores are more likely to develop lower extremity injuries during the season. We hypothesize that football players with preseason BESS scores greater than 15 will be more likely to develop lower extremity (LE) injuries during the season.

BESS has been used as an outcome measure in assessing balance improvements after neuromuscular training. In a study of high school female basketball players who underwent a neuromuscular training program, trained subjects had a significant decrease in BESS scores compared to controls [4]. We will take our retrospective review one step further to examine data from the season in which a prophylactic ankle strengthening program was implemented at NCCU in the 2016 and 2018 season to determine if this program diminished the risk of lower extremity injuries in those athletes with elevated scores.

METHODS

Study Design

We performed a retrospective review of football athletes' BESS scores and medical records for the 2014- 2016 seasons at NC Central University while also gathering the data for the 2018 season. A summary can be seen in Table 1. Our primary outcome of interest was LE injury with a secondary outcome of interest in the type of injury, duration of injury, if the injury was season ending, and if the athlete suffered an in-season concussion. We also reviewed potential cofounders: previous LE injury, previous

Table 1: Participant Demographic & BESS Scores (N).

		Control	Intervention				
Variable	Total	2014+15	2016+18	2014	2015	2016	2018
N	310	182	128	86	96	98	30
Bess score							
Mean (± SD)	9.6 (± 7.9)	6.8 (± 8.1)	13.5 (± 5.7)	7.5 (± 8.8)	6.2 (± 7.3)	13.2 (± 5.6)	14.2 (± 6.1)
Range	0 - 37	0 - 37	0 - 28	0 - 37	0 - 37	0 - 28	3 - 27
n ≥ 15	85	31	54	18	13	39	15
Grade							
Freshman	64	35	29	23	12	18	11
Sophomore	36	19	17	6	13	12	5
Junior	36	22	14	8	14	12	2
Senior	20	13	7	6	7	7	0
Redshirt freshman	33	16	17	5	11	9	8
Redshirt sophomore	40	29	11	21	8	8	3
Redshirt junior	46	34	12	13	21	11	1
Redshirt senior	30	10	20	1	9	20	0
Position							
Offense	150	88	62	42	46	47	15
Defense	138	80	58	34	46	45	13
Special teams	14	8	6	5	3	4	2
Injury history							
Previous LE injury	130	110	20	51	59	4	16
Previous LE surgery	104	37	67	19	18	61	6
Previous concussion	95	69	26	34	35	19	7

LE surgery, previous concussion, offensive/defensive/special teams player, and year in school. BESS scores were measured and recorded for new players (freshman and transfers) their first year and every two years for current players. The scores were taken in the preseason by Athletic Trainers and Athletic Training Students using a standard BESS test. The BESS test consists of athletes holding three stances (single-leg, double-leg, and tandem) on both a firm and a foam surface. Athletes hold the stance for 20 seconds with their eyes closed and hands on their hips. The total number of errors between the three stances comprises the individual's BESS score.

Those athletes in 2016 and 2018 with a BESS score of 15 or higher were provided a prophylactic ankle rehabilitation program (Table 2). The ankle rehabilitation was provided as a home exercise program with instructions to perform the exercises twice daily for the entirety of the season. We did not monitor whether the athletes were compliant.

We chose 15 as a cutoff point due to data from Valovich et al's [4] study. In Table 2 of the study, the two control groups had an average BESS score of 13.7 and 14.2. Respectively, and a standard deviation of 1 [4]. Thus we thought that setting the BESS at 15 would consistently be above the standard deviation of the mean.

Participants

We chose football athletes of the NC Central University Division I football team from the 2014-2016, and 2018 seasons. For the secondary analysis, the previous athletes with a preseason BESS score of 15 or higher in the 2016 and 2018 seasons were used.

Analysis

We performed the primary and the secondary analysis through the UNC Odum Institute for Research in Social Science using SAS Enterprise Guide Software. For the primary analysis we used a multivariate logistic regression model to determine if elevated BESS scores of 15 or higher in the 2014-2016 and 2018 seasons were predictive of suffering a LE injury or concussion during the season. This was done by individual year and combined groups: the control seasons of 2014 and 2015 and the intervention seasons of 2016 and 2018. We performed a chi square goodness of fit test for the secondary analysis to observe the effectiveness of the prophylactic ankle rehabilitation on lowering the risk of LE injury or concussion. The results were reviewed on an intent-to-treat basis.

RESULTS

In the primary analysis, there were 121 reported lower extremity injuries out of 310 entries for all four seasons. The majority of the injuries were ankle (36%) and knee (30%) injuries. Injuries lasted on average 4.3 weeks (± 6.4) and with an average of 5.25 season ending injuries per year. For all four years combined, Redshirt Juniors were found to be injured the most (19.0%) while Seniors were the least injured (7.4%). There were a total of 24 sports related concussions during the four seasons with an athlete taking on average 3.2 weeks (± 4.1) to return to play for the 2014, 2015, and 2018 seasons. Of the 5 concussions in the 2016 season, no athletes returned to competition. A breakdown of the injuries and concussion by category can be seen in Table 3 and Table 4.

Table 2: Prophylactic Ankle Rehab HEP.

No.	Exercise	Reps/Sets/ Hold time	Description
1	Ankle Circles	10 reps / 2 sets	While seated, move your ankle in a circular pattern one direction for several repetitions and then reverse the direction
2	Ankle ABC's	2 sets	While seated, write out the alphabet in the air with your big toe while moving your ankle
3	Gastrocnemius/Soleus Stretch	3 sets/ 15 sec.	Keep back leg straight and heel on the floor, lean into the wall until a stretch is felt in the calf. Then perform on the opposite leg. After all sets are done, repeat the exercise with the back leg slightly bent at the knee.
4	Half On/Half Off Towel Stretch	3 sets/ 30 sec.	Place a folded towel a few feet away from a wall. Stand with the involved foot half on/half off the inside edge of the towel. Perform the gastrocnemius stretch in exercise 3. Repeat with your foot on the outside edge of the towel
5	One Leg Standing Eyes Open/Eyes Closed	3 sets/ 1 min.	With your eyes open, stand on one leg and hold that position for as long as you can. If you do not need outside assistance to maintain balance within 10 seconds, progress to one leg standing with your eyes closed.
6	Posterior Leg Reach	15 reps / 2 sets	Start by standing on one leg. Reach back with the other leg as you reach forward with the hand on that same side. Return to the starting position.
7	Anterior Reach	15 reps / 2 sets	Start by standing on one leg. Reach forward with the opposite foot, bending the knee you are standing on. Return to the starting position and repeat.
8	Lateral Reach	15 reps / 2 sets	Start by standing one leg. Reach out to the side with your opposite leg, bending the knee of the stance leg. Return to start position and repeat.
9	Adduction Reach	15 reps / 2 sets	Start by standing on one leg. Reach across your body with the opposite leg, slightly bending the stance leg. Return to starting position
10	One Leg Standing, Pillow, Eyes Open/Closed	3 sets / 1 min.	With your eyes open, stand with one leg on a standard pillow and maintain balance as long as you can. If you do not need outside assistance within 10 seconds, progress to standing with your eyes closed.
11	4 Square Single Leg Jump Forward	2 reps / 10 sets	Create four, connected, squares on the ground using tape. On one leg, jump from one square to another maintaining knee alignment and balance. Switch legs between sets. Be sure to jump in all 6 directions.

Table 3: In-Season LE Injury (N).

		Control	Intervention				
Variable	**Total**	**2014+2015**	**2016+2018**	**2014**	**2015**	**2016**	**2018**
N	121	68	53	34	34	34	19
Grade							
Freshman	20	8	12	5	3	5	7
Sophomore	15	6	9	2	4	6	3
Junior	14	10	4	4	6	2	2
Senior	9	7	2	4	3	2	-
Redshirt freshman	16	8	8	4	4	4	4
Redshirt sophomore	11	7	4	6	1	1	3
Redshirt junior	23	18	5	8	10	5	0
Redshirt senior	13	4	9	1	3	9	-
Position							
Offense	70	38	32	18	20	20	12
Defense	48	28	20	15	13	14	6
Special teams	3	2	1	1	1	0	1
Injury history							
Previous LE injury	81	48	33	24	24	22	11
Previous LE surgery	31	18	13	11	7	9	4
Previous concussion	51	35	16	20	15	12	4

Table 4: In-Season Concussions (N).

		Control	Intervention				
Variable	**Total**	**2014+2015**	**2016+2018**	**2014**	**2015**	**2016**	**2018**
N	24	17	7	9	8	5	2
Grade							
Freshman	5	4	1	4	0	0	1
Sophomore	3	3	0	0	3	0	0
Junior	4	3	1	1	2	1	0
Senior	0	0	0	0	0	0	-
Redshirt freshman	1	1	0	0	1	0	0
Redshirt sophomore	5	4	1	3	1	0	1
Redshirt junior	1	1	0	1	0	0	0
Redshirt senior	5	1	4	0	1	4	-
Position							
Offense	12	7	5	4	3	3	2
Defense	12	10	2	5	5	2	0
Special teams	0	0	0	0	0	0	0
Injury history							
Previous LE injury	12	7	5	3	4	4	1
Previous LE surgery	4	3	1	1	2	1	0
Previous concussion	10	8	2	5	3	2	0

BESS scores in both the control seasons (2014 and 2015) and the intervention seasons (2016 and 2018) proved to be non-significant in predicting LE injury (p = .55 and p = .90 by multivariate logistic regression). Additionally, there was not a significant difference of injury when the total control and intervention results were compared against each other (p = .59 by multivariate logistic regression). A summary of the breakdown by individual and combined years can be seen in Table 5. Players with a previous concussion were found to be at a significantly higher risk of LE injury in both the control seasons and 2014 season (p = .03 and p = .02 by multivariate logistic regression). Players had a 35% (95% Confidence Interval [CI] = 22.3%, 51.0%) and 33% (CI = 14.7%, 57.5%) chance of LE injury in the controlled and 2014 season's models respectively. In the intervention seasons, player position was found to be significant (p =.04 by multivariate logistic regression) with offense having a 55% (CI = 32.6%, 75.1%) chance of being injured *vs* defense with a 38% (CI = 24.6%, 53.8%) chance within the model. Individual positions were only gathered for the 2014 -2016 seasons but offensive linemen were found to be the most injured (n = 21 total injuries), followed by defensive backs (n = 19), defensive linemen (n = 16), wide receivers (n = 12), running backs (n = 11), and tight ends (n = 10). All other variables proved to be nonsignificant in predicting LE injuries.

BESS scores were also not significant in predicting concussions for players in both the control and intervention

Table 5: Variable Effect on LE Injury during Season, (*P*).

	Control	Intervention				
Variable	**2014+15**	**2016+18**	**2014**	**2015**	**2016**	**2018**
BESS score	.55	.90	.91	.26	.74	.65
Grade	.14	.87	.12	.39	.33	.82
Position (off, def, st)	.49	.04	.56	.15	.08	.12
Previous LE injury	.48	.92	.70	.45	.89	.70
Previous LE surgery	.55	.38	.33	.71	.33	.59
Previous concussion	.03	.76	.02	.48	.50	.82

Table 6: Variable Effect on Concussions during Season (*P*).

	Control	Intervention				
Variable	**2014+15**	**2016+18**	**2014**	**2015**	**2016**	**2018**
BESS score	.41	.29	.21	.82	.30	.97
Grade	.29	.03	.64	.31	.05	.91
Position (off, def, st)	.49	.12	.91	.43	.34	-
Previous LE injury	.04	.41	.06	.32	.51	.97
Previous LE surgery	.50	.30	.97	.30	.48	-
Previous concussion	.08	.36	.06	.56	.59	-

seasons (p = .81 and p = .69 by multivariate logistic regression) and there was not a significant difference when compared against each other (p =.18). For the control seasons, a player without a previous LE injury was at a significantly higher risk of injury (p = .04 by multivariate logistic regression). These athletes had a 16% (CI 4.7%, 40.9%) chance of injury while athletes who had a previous LE injury had a 4% (CI = 1.4%, 12.4%) chance within the model. This was not carried over to the intervention seasons. In the intervention seasons a player's grade was found to be significant of concussions (p = .03 by multivariate logistic regression). The highest risk was in Redshirted Seniors at 22% (CI = 3.2%, 71.5%) as opposed to Freshman with the least risk at 1% (CI = 0.2%, 12.0%) within the model. All other variables were found to not be significant and are shown in Table 6. As there were only two in-season concussions in the 2018, some of the categories were excluded.

A summary of the results for the prophylactic ankle rehabilitation program can be found in Table 7. The ankle rehabilitation program in 2016 and 2018 was found to not be significant (p = 0.52 by Chi square analysis) in lowering the LE injury rate for those athletes with a BESS score of 15 or above when compared to the control years. Similarly, the ankle rehabilitation program did not significantly decrease the risk of concussions in the intervention seasons when compared to the control seasons (p = 0.71 by Chi square analysis). Of the 24 total concussions in the study, only 7 occurred to players with a BESS score of 15 or above, 3 in the control years and 4 in the intervention years preventing analysis.

DISCUSSION

Concussions and LE injuries are a major risk for varsity NCAA football players. Between the 2009, 2010, and 2011 seasons there was an average of 20.45 LE injuries per 1000 exposures [5]. This climbed to 23.55 LE injuries per 1000 in the 2012, 2013, and 2014 seasons [5] Similarly, sports related concussion rates in football rose 34% in the same time frame, with an annual national average of 3417 concussions a year [5,6] This accounts for over a third of all NCAA sports related concussions [6]. Thus, any easily identifiable preseason risk factor, such as a BESS score, that could be screened for and treated prophylactically should improve a player's chances of staying injury free.

The BESS test is a commonly administered baseline tool used to gather data for concussions and assess an athlete's balance and stability [1]. It has been shown that athletes with joint instability receive higher BESS scores [2,3]. Additionally, football players with balance deficits, and thus higher BESS scores, are at an increased risk of LE injury [7] Despite this, pre-season BESS scores proved to be non-significant in their ability to predict whether an athlete would suffer an in season injury or not. Furthermore, although the BESS test has been proven to be helpful in the assessment of concussions, it did not prove to be predictive of them.

This study did find that athletes with a previous concussion were significantly more at risk in suffering a LE injury, supporting similar results in previous studies. These previous studies showed athletes suffered injuries in a variety of time, sports, and competitive settings following a concussion [7-12]. The odds of injury for previously concussed players ranged from 1.6 [11] to 3.39 [12] times greater than non-previously concussed players. Our study strengthens the current literature that concussions raise the risk of a subsequent LE musculoskeletal injury, as opposed to just head injuries.

Offensive players were found to be at a higher risk of LE injury than defensive players, with offensive lineman sustaining the most injuries out of all the positions. This mirrors the results previous studies on football positional injury rates. In Badgeley et al, [13]. High school offensive linemen were found to suffer the most injuries. Similarly, in a review of the NFL, Kluczynski et al [14] found offensive linemen to lead the league in knee injuries and in the top three positions to suffer ankle injuries. These injuries can be attributed to current blocking techniques, targeting of knees and ankles, and increased player-to-player contact [13,15].

Table 7: LE injuries of athletes with a BESS score x≥15 in 2014+15 *vs* 2016+2018.

	2014 + 15, (N)		2016 + 18, (N)		
Variable	**Healthy**	**Injured**	**Healthy**	**Injured**	***P***
Total					
BESS score x≥15	20	11	31	23	*.52*
Injury by grade					
Freshman	5	0	12	3	*.33*
Sophomore	4	0	3	4	*.06*
Junior	1	1	5	0	*.09*
Senior	2	2	2	0	*.22*
Redshirt freshman	1	2	2	5	*.88*
Redshirt sophomore	4	1	3	2	*.49*
Redshirt junior	3	4	1	3	*.55*
Redshirt senior	0	1	3	6	*.49*
Injury by position					
Offense	11	8	15	14	*.67*
Defense	7	3	14	9	*.61*
Special teams	0	0	2	0	*n/a*
Injury with history of concussion					
No previous concussion	11	2	23	12	*.20*
Previous concussion	9	9	8	11	*.63*
Injury with history of LE injury					
No previous LE injury	14	6	15	13	*.25*
Previous LE injury	6	5	16	10	*.69*
Injury with history of LE surgery					
No previous surgery	19	7	28	17	*.35*
Previous surgery	1	4	3	6	*.59*

Previous LE injury and a player's grade proved to be significant risk factors for concussions within the study. Both of the results can be attributed to practice and playing time. Athletes who had suffered a previous LE injury were at a greater chance of missing practice/playing time due to the injury versus those athletes that had stayed healthy. Thus, the injured players had a decreased time of exposure to the risk of a concussion. Similarly, seniors who had previously been redshirted were more likely to practice/play than other grades, increasing their exposure risk, while freshmen had the least chance of practice and playing time, decreasing their risk.

In the second part of the study, we chose to see whether those athletes who had a BESS score of 15 or above and underwent a prophylactic ankle rehabilitation program had a significant decrease in risk of a concussion or a LE injury as compared to the two control years. The ankle rehabilitation proved to be ineffective in changing a player's risk of LE injury or concussion with the results all coming back non-significant. As can be seen in Table 7, several of the variables had under 5 participants which can disrupt the results. Similarly, there were 24 concussions during all 4 seasons of the study, of which only 7 qualified for the secondary analysis. Due to this, almost all the variables had less than 5 participants in each category making the results unreliable.

Our study had several imitations. First, the pre-season BESS scores were taken by different athletic trainers and athletic training students which subjects the scores to interrater reliability. Interrater reliability of administering the BESS test ranges with an overall ICC of 0.57, [16] and the individual sections of the test ranging from 0.44 to 0.96 [16-18] Meanwhile intratester reliability of the BESS test is 0.74 overall, with individual sections ranging from 0.50 to 0.99 [16-18]. For perspective, some studies have suggested that ICCs below 0.75 have poor/moderate reliability while those above 0.75 have good reliability.[16] A second limitation is that the ankle rehabilitation program was a HEP. We did not follow whether or not the athletes performed the program twice a day, every day, as instructed. This adds to the study's limitations since we analyzed the ankle rehabilitation program on an intent-to-treat basis, with every athlete considered to be compliant. Finally, there might have been other unnoted variables that could have affected the injury rates, some examples being: changes in coaching practices and styles, strength and conditioning changes, and quality of equipment or opposing teams.

Though we used a BESS score of 15 as a differentiation point in our study analysis, this may not have been the most appropriate cutoff point to use. Post-hoc linear analysis found that risk may have increased using a cutoff BESS score as low as

9 for LE injury and 3 for concussions. This indicates that there may be more of an effect from the screening and the prophylactic ankle rehabilitation if a lower BESS score is used as a cutoff.

While the BESS test is a common and easily administered test that can set a baseline on an athlete's LE instability, it did not prove to be predictive of LE injury or concussions. Furthermore, the prophylactic ankle rehabilitation program did not prove to be effective in lowering the risk of LE injuries or concussions. Our study did find that those players with previous concussions were at a higher risk of LE injury, strengthening the argument that concussions raise the risk of subsequent overall injury. Future studies may continue the investigation into objective measures that are predictive of concussion and injury. Additionally, future studies may look back at the prophylactic ankle program with monitored compliance as opposed to a HEP.

ACKNOWLEDGMENT

We would like to thank Chris Wiesen, of the UNC Odum Institute for Research in Social Science, for his help in the data analysis.

REFERENCES

1. Bell DR, Guskiewicz KM, Clark MA, Padua DA. Systematic Review of the Balance Error Scoring System. Sports Health. 2011; 3: 287-295.
2. Docherty CL, Valovich McLeod TC, Shultz SJ. Postural Control Deficits in Participants with Functional Ankle Instability as Measured by the Balance Error Scoring System. Clin J Sport Med. 2006; 16: 203-208.
3. Smith MD, Bell DR. Negative Effects on Postural Control After Anterior Cruciate Ligament Reconstruction as Measured by the Balance Error Scoring System. J Sport Rehabil. 2013; 22: 224-228.
4. Valovich McLeod TC, Armstrong T, Miller M, Sauers JL. Balance Improvements in Female High School Basketball Players after a 6-Week Neuromuscular Training Program. J Sport Rehabil. 2009; 18: 465-481.
5. Westermann RW, Kerr ZY, Wehr P, Amendola A. Increasing Lower Extremity Injury Rates Across the 2009-2010 to 2014-2015 Seasons of National Collegiate Athletic Association Football. Am J Sports Med. 2016; 44: 3230-3236.
6. Zuckerman SL, Kerr ZY, Yengo-Kahn A, Wasserman E, Covassin T, Solomon GS. Epidemiology of Sports-Related Concussion in NCAA Athletes from 2009-2010 to 2013-2014. Am J Sports Med. 2015; 43: 2654-2662.
7. Fino PC, Becker LN, Fino NF, Griesemer B, Goforth M, Brolinson PG. Effects of Recent Concussion and Injury History on Instantaneous Relative Risk of Lower Extremity Injury in Division I Collegiate Athletes. Clin J Sport Med. 2019; 29: 218-223.
8. Cross M, Kemp S, Smith A, Trewartha G, Stokes K. Professional Rugby Union players have a 60% greater risk of time loss injury after concussion: a 2-season prospective study of clinical outcomes. Br J Sports Med. 2016; 50: 926-931.
9. Brooks MA, Peterson K, Biese K, Sanfilippo J, Heiderscheit BC, Bell DR. Concussion Increases Odds of Sustaining a Lower Extremity Musculoskeletal Injury After Return to Play Among Collegiate Athletes. Am J Sports Med. 2016; 44: 742-747.
10. Nordström A, Nordström P, Ekstrand J. Sports-related concussion increases the risk of subsequent injury by about 50% in elite male football players. Br J Sports Med. 2014; 48: 1447-1450.
11. Gilbert FC, Burdette GT, Joyner AB, Llewellyn TA, Buckley TA. Association between Concussion and Lower Extremity Injuries in Collegiate Athletes. Sports Health. 2016; 8: 561-567.
12. Herman DC, Jones D, Harrison A, Moser M, Tillman S, Farmer K, et al. Concussion May Increase the Risk of Subsequent Lower Extremity Musculoskeletal Injury in Collegiate Athletes. Sports Med. 2017; 47: 1003-1010.
13. Badgeley MA, McIlvain NM, Yard EE, Fields SK, Comstock RD. Epidemiology of 10,000 high school football injuries: patterns of injury by position played. J Phys Act Health. 2013; 10: 160-169.
14. Kluczynski MA, Kelly WH, Lashomb WM, Bisson LJ. A Systematic Review of the Orthopaedic Literature Involving National Football League Players. Orthop J Sports Med. 2019; 7: 2325967119864356.
15. Bradley J, Honkamp NJ, Jost P, West R, Norwig J, Kaplan LD. Incidence and variance of knee injuries in elite college football players. Am J Orthop (Belle Mead NJ). 2008; 37: 310-314.
16. Finnoff JT, Peterson VJ, Hollman JH, Smith J. Intrarater and Interrater Reliability of the Balance Error Scoring System (BESS). Pm&r. 2008; 1: 50-54.
17. Hansen C, Cushman D, Chen W, Bounsanga J, Hung M. Reliability Testing of the Balance Error Scoring System in Children Between the Ages of 5 and 14. Clin J Sport Med. 2017; 27: 64-68.
18. Mcleod TCV, Perrin DH, Guskiewicz KM, Shultz SJ, Diamond R, Gansneder BM. Serial Administration of Clinical Concussion Assessments and Learning Effects in Healthy Young Athletes. Clin J Sport Med. 2004; 14: 287-295.

Cite this article

Porras L, Lawson B, Barrett CM, Bowen Johnston KJ, Dotson A, Higginson C, et al. (2021) Elevated Pre-Season BESS Scores Not-Predictive of Development of Lower Extremity Injuries in Division 1 Football Players and a Prophylactic Ankle Program did not Reduce Risk. Ann Sports Med Res 8(2): 1177.