



Original research

Can the Y balance test identify those at risk of contact or non-contact lower extremity injury in adolescent and collegiate Gaelic games?



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ABSTRACT

Objectives: Lower extremity (LE) injuries are common in Gaelic games and lead to a significant economic and injury burden. Balance is considered a predictor of injury in other sports, however no research has examined its effect on LE injury in Gaelic games. This study aims to present normative data for the Y Balance Test (YBT), determine whether the YBT can identify those at risk of contact and non-contact LE and ankle injuries and generate population specific cut-off points in adolescent and collegiate Gaelic games.

Design: Prospective cohort study.

Methods: A convenience sample of 636 male adolescent ($n = 293$, age = 15.7 ± 0.7 years) and collegiate ($n = 343$, age = 19.3 ± 1.9 years) Gaelic footballers and hurlers were recruited. The YBT was completed and injuries were assessed at least weekly over one season. Univariate and logistic regression was performed to examine if the YBT can classify those at risk of LE-combined and ankle injuries. ROC curves were used to identify cut-off points.

Results: Gaelic players performed poorly in the YBT and between 31–57% of all players were identified as at risk of injury at pre-season using previously published YBT cut-off points. However, poor YBT scores were unable to ascertain those at risk of contact or non-contact LE-combined and ankle injuries with sufficient sensitivity. High specificity was noted for contact LE-combined and non-contact ankle injuries. **Conclusions:** The YBT as a sole screening method to classify those at risk of LE and ankle injuries in Gaelic games is questionable. However, the YBT may be a useful preliminary screening tool to identify those not at risk of contact LE-combined or non-contact ankle injury. Generalising published cut-off points from other sports is not supported.

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Practical implications

- For the first time, normative data for the YBT in adolescent and collegiate Gaelic games was presented.
- Using published cut-off points, 31.0–56.9% of players were identified as at risk of a LE injury. However, only 30.1–52.5% of those that actually sustained a LE injury were identified as at risk.
- Poor scores on the YBT was unable to identify those at risk of sustaining a contact and non-contact LE and ankle injuries with sufficient accuracy.

- The usefulness of the YBT as a sole screening method in Gaelic games is questionable but it may be helpful as a preliminary screening tool to identify those that need a more comprehensive assessment.

1. Introduction

Gaelic football and hurling (Gaelic games) are two of Ireland's most popular national field sports and are governed by the Gaelic Athletic Association (GAA). Gaelic football is similar to Australian football but played with a round ball.¹ Hurling is considered similar to shinty, lacrosse and field hockey, and is played with a stick called a hurley and a small hard leather ball called a sliotar.¹ Lower extremity (LE) injuries are predominant in Gaelic games, with 58–75% of all injuries to adolescent and collegiate male Gaelic foot-

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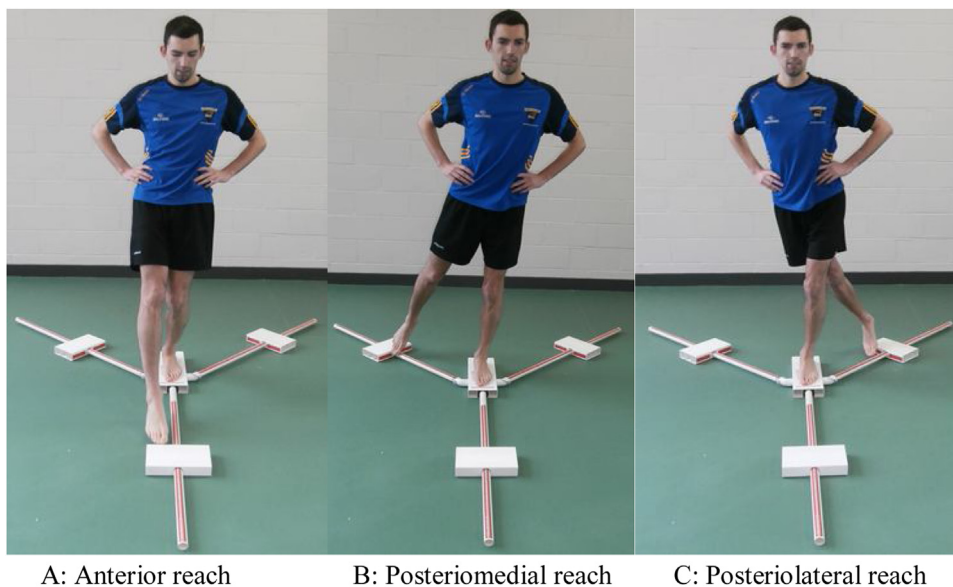


Fig. 1. The Y balance test in the anterior (A), posteromedial (B) and posterolateral (C) reach directions.

ballers and hurlers occurring to the LE.^{1,2} In fact, the LE accounted for 60% of all insurance claims made to the GAA.³ The ankle is one of the most commonly reported injuries occurring to the LE during Gaelic games,^{1,2} and lead to a significant injury burden to collegiate Gaelic footballers (52.8 days absent per 1,000 h).² Therefore in order to reduce the economic and injury burden LE injuries can place on players and the GAA, modifiable risk factors should be identified and injury prevention programmes designed and implemented.⁴

Pre-participation screenings are commonly used at the beginning of a season to identify modifiable risk factors and form the basis of tailored injury prevention programmes for that season.⁴ Deficits in dynamic balance have been identified as a predictor for injury^{5,6} and is related to reduced motor coordination, range of motion and strength of muscles.⁷ However, the gold standard methods of assessing balance (e.g. force plates, pressure plates) are time consuming and require expensive equipment,^{6–8} which may not be feasible in amateur sports such as Gaelic games. On the other hand, the modified star excursion balance or Y balance test (YBT) is a commonly used field balance measure as it is a simple to administer, relatively dynamic and utilises portable standardized inexpensive equipment.^{5,6,9} It is a multidirectional test of balance, where a single leg stance on one leg is required to be maintained on a plastic platform, while maximally reaching with the contralateral leg in an anterior, posteromedial and posterolateral direction with the distance reached being measured.¹⁰ The YBT has demonstrated high inter-^{6,10} and intra-tester reliability.^{5,6,10,11} Six prospective studies have examined the ability of this test to identify those at risk of sustaining injury in the sporting population,^{5,12–15} with conflicting findings. Four of these studies reported positive findings. High school basketball players⁵ and collegiate American footballers that presented with a normalised composite reach distance of $\leq 94\%$ and $\leq 89.6\%$ of leg length in the YBT were 6.5 and 3.5 times more likely to sustain a LE injury and non-contact injury respectively ($p < 0.05$). In addition, those with an asymmetrical difference of greater than 4 cm in the anterior direction,^{5,12} or posteromedial direction¹⁴ are more likely to sustain a LE or non-contact injury. In contrast, both Lai et al.¹⁵ and Wright et al.¹⁶ reported that the YBT did not predict LE injury in NCAA division 1 athletes and cautioned clinicians against solely using the YBT as a screening method for LE injury in this population.

Thus, despite the fact that this is a widely used test, the conflicting findings of previous research questions whether the YBT can accurately predict LE injury. In addition, it is questionable whether we can generalise previous positive research findings for example in basketball and American football, to other sporting populations, and more specifically to Gaelic games players. Therefore, the aim of this study was to establish if deficits in dynamic balance as measured by the YBT, is a risk factor for sustaining contact or non-contact LE injuries and ankle injuries in adolescent and collegiate Gaelic footballers and hurlers. This study also aimed to present normative data for the YBT and generate population specific cut-off points for the YBT that could identify players at risk of sustaining a contact or non-contact LE injury in Gaelic games. We hypothesize that poor YBT scores can classify those at risk of sustaining non-contact LE injuries and ankle injuries in Gaelic games. In addition, we hypothesize that we can develop cut-off points specific to Gaelic games players to identify those at risk of sustaining a non-contact LE injury.

2. Methods

A prospective cohort study was implemented to examine if poor scores on the YBT classified those at risk for sustaining a contact or non-contact LE and ankle injuries in adolescent and collegiate Gaelic footballers and hurlers. Six hundred and thirty-six male adolescent ($n = 293$, age = 15.7 ± 0.7 years, height = 1.76 ± 0.08 m, weight = 67.7 ± 10.1 kg) and collegiate ($n = 343$, age = 19.3 ± 1.9 years, height = 1.8 ± 0.09 m, weight = 77.6 ± 9.3 kg) Gaelic footballers and hurlers were recruited from 6 schools and 2 collegiate institutions. Participants were excluded if they were unable to complete the YBT due to a current injury or vestibular disorder during the pre-season assessment. Informed consent and parental consent and participant assent for minor participants, was provided prior to testing. Ethical approval was granted by the University's Research Ethics committee.

Prior to the season commencing the YBT was implemented on all adolescent and collegiate players (Fig. 1). Participants were required to wear shorts and a t-shirt and the YBT was completed barefoot. Leg length (LL) was measured from the anterior superior iliac spine to the most distal portion of the lateral malleolus⁶ as the results were normalised for leg length. Participants began the test by placing the distal end of their longest toe at the red line

on the platform of the testing kit and pushing the reach indicator with their toe from the other leg as far as they can. Participants completed 4 practice trials¹⁷ starting with the right leg in the anterior (A) direction, before swapping to complete the same test with the left leg. Participants then alternated between the right and left leg in the posteromedial (PM) and posteriolateral (PL) directions respectively.¹² Three trials utilising the same procedure were then completed, with results recorded to the nearest centimetre and the average of the three trials calculated. A trial was discarded and repeated if any of the following occurred: loss of balance of the stance leg that resulted in movement off the platform or touch-down by the opposite leg; failure to maintain contact with the reach indicator throughout the movement; increasing distance reached by kicking the reach indicator; placement of the foot on top of the reach indicator or use of the reach indicator for support; and failure to maintain hands on hips throughout the movement.¹⁸ Normalised reach distances in all three directions expressed as a percentage of LL (%LL), asymmetry between sides in centimetres for all three directions and composite scores were captured. The combined composite score was generated using Equation 1 using the average reach scores of the right and left side in centimeters from all three directions.

$$\text{Composite score} = \left[\frac{A + PM + PL}{LL \times 3} \right] \times 100$$

Equation 1. Calculation of the composite score

Over the course of the season injury examinations were conducted on an at least weekly basis by the primary author (Certified Athletic Therapist) and third and fourth year undergraduate athletic therapy and training students that were completing their undergraduate placement with the school or collegiate participants. The athletic therapy and training students had completed and passed all necessary classes relating to the diagnosis of injury in sport, and had at least one academic year of placement prior to the commencement of the study. An injury was defined as any injury sustained during training or competition resulting in restricted performance or time lost from play.^{1,2} All injury data was recorded in a standardised injury report form^{1,2} that was completed immediately after the injury assessment. For any injury assessments where the primary author was not present, the injury diagnosis and standardised injury report form was reviewed and confirmed with the student athletic therapist. In cases where there were any queries on any aspect of the diagnosis or injury information, a re-assessment of the injured player was completed by the primary author. All LE injuries that occurred were included in this study, and for clarity purposes, LE injuries that were analysed collectively, will be referred to as LE-combined injuries. In addition, ankle injuries were examined individually. Both LE-combined and ankle injuries were further sub-divided into contact or non-contact injuries and examined separately.

Firstly, normative data for the YBT in this population was examined. The means and standard deviations of age, the normalised reach distances in all three directions, the composite score and the differences in centimeters between sides for all directions and the composite score were examined for all participants combined, as well as for seven sub-groups, (i) adolescent players, (ii) collegiate players, (iii) contact LE injured participants, (iv) non-contact LE injured participants, (v) contact ankle injured participants, (vi) non-contact ankle injured participants and (vii) uninjured participants. The percentage of participants identified as at risk using previously identified cut off points of a composite score of less than 89.6%,¹³ 94%⁵ of leg length and 4cm asymmetry in the A¹² and PM direction¹⁴ were also calculated. The percentage of participants that were identified as at risk, that went on to sustain a LE-combined injury or non-contact LE-combined injury, were also measured.

Univariate regression analysis was initially performed to examine whether YBT normalised and asymmetry scores could identify those at risk of contact or non-contact LE-combined and ankle injuries. Variables with a p value of <0.20 on the Wald test in the univariate models were entered into the multivariate analysis.¹⁹ Age and whether they had sustained a previous injury at the same site as the current injury was controlled for in the multivariate analysis. Logistic regression was employed to examine whether a predictive model could be generated from the variables that demonstrated a predictive relationship with contact LE-combined injury in the univariate regression analysis. This was then again repeated separately for non-contact LE-combined injuries, contact ankle injuries and non-contact ankle injuries. An alpha level of .05 was used to judge statistical significance of the model and both sensitivity and specificity of the models were noted. Odds ratios (OR) and their 95% Confidence Intervals (CI) of each individual variable in the model was calculated. 95% CI that did not cross 1 were considered statistically significant.

To identify the optimal cut-off points for the YBT scores, receiver operating characteristic (ROC) curves were implemented. The area under the curve (AUC) is a value that combines the sensitivity and specificity measures to describe the inherent accuracy of the cut-off points.²⁰ An AUC of greater than 0.6 was required to create a cut-off point, as values below this demonstrate low overall accuracy, with a value of 0.5 equalling chance.²¹ All statistical analyses were performed using SPSS for Windows version 23.

3. Results

Two hundred and twenty-two LE-combined injuries occurred over the course of the study, with 65 contact and 157 non-contact injuries. Thirty-five ankle injuries were noted (contact=17; non-contact=18). The normative values for age and YBT scores are presented in Table 1. Table 2 demonstrates the percentage of players identified as at risk using previously published cut-off points and the percentage of those that were identified as at risk that went on to become injured. No statistical significant difference between the age of those that sustained a contact or non-contact LE-combined injury and uninjured players was noted.

With regard to contact (AUC=0.39–0.55) and non-contact (AUC=0.45–0.52) LE-combined and contact (AUC=0.23–0.55) and non-contact (AUC=0.45–0.59) ankle injuries, ROC curves for all YBT scores produced an AUC value of ≤0.6, therefore cut-off points were unable to be generated. Univariate logistic regression was first performed to assess whether the YBT scores could correctly classify those at risk of LE-combined and ankle injuries and the OR with their 95% CI are presented in Table 3.

Age and previous injury at the same location were controlled for in all multivariate analyses. Composite %LL, PM %LL, PL %LL and PM difference were included in the multivariate analysis for contact LE-combined injury identification. The variables were firstly examined for multicollinearity, and composite %LL was removed due to a VIF value greater than 10 and tolerance value less than 0.10. The model was able to significantly distinguish between those that would sustain a contact LE-combined injury and those that did not ($\chi^2 = 14.65$, $p = 0.01$) but explained just 7.1–11.0% of the injury variance, demonstrated a sensitivity of 11.9%, specificity of 98.7% and correctly classified 80.4% of cases. PM difference, PM %LL and PL %LL presented with odds ratios of 1.11 [95% CI: 1.02–1.20], 1.01 [95% CI: 0.94–1.07] and 1.01 [95% CI: 0.96–1.07] respectively. A smaller PL difference actually statistically significantly identified those at risk of a contact ankle injury ($\chi^2 = 9.98$, $p = 0.02$, OR = 0.65 [95% CI: 0.44–0.98]), with a specificity of 100% and sensitivity of 0%. The model correctly classified 97.0% of cases and as a whole explained between 4.8–20.6 % of the variance in injury status. Similarly, a

Table 1
Mean and standard deviation of age and YBT scores for participants.

		Total	Age group		LE-combined injury		Ankle injury		No LE injury
		Mean ± SD	Adolescent	Collegiate	Contact	Non-contact	Contact	Non-contact	Mean ± SD
			Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Comp	LL (%)	94.8 ± 10.7	93.3 ± 9.6	96.1 ± 11.3	97.5 ± 8.6	95.0 ± 10.7	97.7 ± 6.4	95.4 ± 10.6	94.4 ± 10.8
	Diff (cm)	3.8 ± 3.1	4.1 ± 3.1	3.4 ± 2.8	3.7 ± 2.8	3.8 ± 2.9	2.8 ± 1.4	3.3 ± 2.3	3.8 ± 3.1
A	LL (%)	71.9 ± 10.5	72.1 ± 9.2	71.7 ± 11.6	72.4 ± 10.2	71.9 ± 10.8	70.2 ± 8.6	72.7 ± 11.5	71.9 ± 10.5
	Diff (cm)	5.0 ± 4.9	4.8 ± 4.0	5.3 ± 5.7	4.8 ± 4.1	5.1 ± 5.5	4.8 ± 4.0	4.6 ± 5.2	5.0 ± 4.9
PM	LL (%)	106.2 ± 11.9	104.6 ± 11.5	107.6 ± 12.1	109.7 ± 8.1	107.5 ± 10.9	110.8 ± 6.9	107.5 ± 10.5	105.6 ± 12.4
	Diff (cm)	5.5 ± 4.8	5.8 ± 4.9	5.3 ± 4.7	7.4 ± 5.2	4.8 ± 3.7	5.0 ± 3.0	4.8 ± 3.7	5.5 ± 4.9
PL	LL (%)	106.3 ± 13.1	103.0 ± 11.9	109.3 ± 13.5	110.4 ± 11.1	106.6 ± 13.4	112.3 ± 8.0	106.8 ± 12.8	105.9 ± 13.2
	Diff (cm)	5.8 ± 4.7	6.0 ± 4.7	5.6 ± 4.6	5.4 ± 5.0	6.3 ± 5.7	2.0 ± 1.5	6.1 ± 5.2	6.0 ± 4.7

*LE: lower extremity; Diff: difference; % LL: Normalised score; Comp: Composite, A: anterior; PM: posteromedial.

Table 2
Percentage of players identified as at risk using previous research.

		Total	Adolescents	Collegiate	LE Injury	Non-contact LE injury	No LE Injury
Comp	<94% LL ^a	51.3%	54.3%	48.5%	47.6%		52.5%
	<89.6% LL ^b	31.0%	31.4%	30.6%		30.1%	32.8%
A	>4 cm diff ^c	49.0%	52.1%	46.1%	48.6%		49.1%
PM	>4 cm ^d	56.9%	58.7%	55.2%		52.5%	56.7%

*LE: lower extremity; Diff: difference; % LL: Normalised score; Comp: Composite, A: anterior; PM: posteromedial.

^a Plisky et al. (2006).⁵
^b Butler et al. (2013).¹³
^c Smith et al. (2015).¹²
^d Gonell et al. (2015).¹⁴

Table 3
Univariate logistic regression analysis for contact and non-contact LE-combined and ankle injuries.

		Lower extremity						Ankle					
		Contact			Non-contact			Contact			Non-contact		
		p	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p	OR	95% CI
Composite	%LL	0.07	1.03	0.99–1.06	0.82	1.00	0.98–1.02	0.49	1.03	0.96–1.10	0.61	0.98	0.93–1.05
	Difference	0.79	0.98	0.88–1.11	0.94	1.00	0.92–1.08	0.45	0.88	0.64–1.22	0.03	1.21	1.02–1.44
A	%LL	0.57	1.01	0.98–1.04	0.96	1.00	0.98–1.02	0.68	0.98	0.90–1.07	0.21	0.95	0.89–1.03
	Difference	0.70	0.99	0.92–1.05	0.84	1.00	0.96–1.05	0.93	0.99	0.84–1.17	0.33	1.05	0.95–1.16
PM	%LL	0.05	1.03	1.00–1.05	0.26	1.01	0.99–1.03	0.34	1.03	0.97–1.10	0.59	1.01	0.96–1.07
	Difference	0.03	1.07	1.01–1.12	0.07	0.96	0.91–1.00	0.76	0.97	0.81–1.17	0.44	1.05	0.94–1.17
PL	%LL	0.03	1.03	1.00–1.05	0.82	1.00	0.99–1.02	0.26	1.04	0.98–1.10	0.45	0.98	0.94–1.03
	Difference	0.49	0.97	0.91–1.05	0.46	1.02	0.97–1.06	0.05	0.68	0.46–1.01	0.22	1.07	0.96–1.19

smaller PM difference statistically significantly classified those at risk of sustaining a non-contact LE-combined injury ($\chi^2 = 11.85$, $p = 0.01$, $OR = 0.92$ [95% CI: 0.86–0.98]). A sensitivity of 52.6%, specificity of 59.6%, correctly classified 56.2% of cases and explained just 5.7–7.6% of variance in injury status. A greater composite difference statistically significantly identified those that proceeded to receive a non-contact ankle injuries ($\chi^2 = 7.90$, $p = 0.048$, $OR = 1.25$ [95% CI: 1.05–1.53]). The model had a sensitivity of 22.2% and specificity of 100.0%, and as a whole explained between 4.6–13.5% of the variance in injury status, and correctly classified 95.8% of cases.

4. Discussion

This study aimed to present normative data from the YBT in adolescent and male Gaelic games, identify if deficits in dynamic balance measured using the YBT is a risk factor for sustaining a LE injury and generate population specific cut-off points for Gaelic games. Adolescent and collegiate Gaelic footballers and hurlers primarily performed worse in the YBT in comparison to previously published normative data. Adolescent Gaelic footballers and hurlers presented with lower YBT composite score (93.3% vs 100.9%) and normalised scores in the A (72.1% vs 83.9%), PM (104.6% vs 113.4%) and PL (103.0% vs 106.4%) directions than high school basketball players.⁵ Collegiate players had lower PM (107.6% vs

119.9%) and PL (109.3% vs 117.2%) scores than adult soccer players, but performed better in the A direction (71.7% vs 62.7%).¹³ In addition, a greater asymmetry score was found in Gaelic games than in young healthy adults for the composite score (3.8 cm vs 1.2 cm) and scores in the A (5.0 cm vs 0.4 cm), PM (5.5 cm vs 2.5 cm) and PL (5.8 cm vs 0.3 cm) directions.²² In addition, when previously published cut-off points are applied, a significant percentage of players were identified as at risk of sustaining a LE injury following the pre-season screening. In fact, approximately half of players were identified as at risk of injury, due to asymmetry of >4 cm in the A (49.0%) and PM reach direction (56.9%), a composite score of <94% (51.3%) and just under a third presented with a composite score of <89.6% (31.0%).

However, poor scores measured using the YBT did not distinguish between those that went on to sustain non-contact LE-combined injury and contact ankle injury during the season. While, balance deficits identified by the YBT at preseason did classify those at risk of contact LE-combined and non-contact ankle injuries, the sensitivity of the model was low and explained only a minimal amount of the variance in injury status. The specificity of the model was high however, indicating that the YBT may be useful as a preliminary screening tool to identify those who are not at risk of sustaining a non-contact ankle or contact LE-combined injury and highlight players that require a more comprehensive

assessment. This disputes previous research that found the YBT a useful tool in predicting injury in high school basketball players,⁵ collegiate American footballers¹³ and adult soccer players.¹⁴ Two prospective studies on NCAA division 1 collegiate athletes across multiple sports found that the YBT was not a useful method of identifying those at risk of LE injury.^{15,16} In addition, Smith et al.¹² found that in division 1 athletes, YBT composite scores were not significantly associated with increased risk of non-contact injuries ($p > 0.05$). Methodological differences between studies, such as injury definitions or analysis used in the previous research, may account for the differences in previous research findings. In addition, potentially, the ability for the YBT to identify those at risk of injury may be particularly sports specific. The YBT has been shown to classify soccer players at risk of LE injury,¹⁴ a field sport considered similar to Gaelic games. However, despite their similarity in playing skills and tasks,²³ they do intrinsically differ. Therefore, the use of the YBT as a sole screening tool for predicting LE injury in Gaelic games should be questioned and its alternative use as a preliminary screening tool to instead identify those not at risk of sustaining a contact LE-combined or non-contact ankle injury should be considered. In addition, the generalisability of findings examining the YBT in specific sporting populations should be cautioned against.

Side to side differences are proposed to increase the stress being placed on the more proficient limb with the opposite limb unable to effectively provide a stable base for sporting movements, thereby increasing injury risk.⁵ Previous research found that asymmetrical differences of greater than 4 cm in the A direction increased the odds of sustaining a LE injury in high school basketball players' by 2.5⁵ and non-contact injuries in division 1 collegiate athletes by 2.3¹² and in the PM direction in soccer players by 3.9 times.¹⁴ In the current study, when controlling for age and previous injury, the odds of sustaining a non-contact ankle injury increased by 1.25 if they had a greater composite asymmetry between sides during preseason screening. However, in direct contrast those with less asymmetry in the PL and PM direction were statistically significantly more at risk of sustaining a contact ankle injury ($p = 0.02$, OR = 0.65) and non-contact LE-combined injury ($p = 0.01$, OR = 0.92). This finding has not been noted in previous research and indicates that greater balance asymmetry may not influence common LE mechanisms of injuries in Gaelic games, and so is not a consistent predictor of contact LE injury in this population in particular. It is not clear why symmetry itself would lead to an increase in the risk of injury; further research is required to further examine the influence balance asymmetry has on Gaelic games lower extremity injuries.

ROC curves were unable to generate population specific cut-off points for adolescent and collegiate Gaelic footballers and hurlers for both contact and non-contact LE-combined and ankle injuries due to poor sensitivity and specificity as determined by the AUC value. In fact, most AUC values were around 0.5, indicating the use of the cut-off points would be no better than chance²¹ at identifying those at risk of a contact LE injury. Using previously published cut-off points generated for high school basketball players,⁵ and collegiate athletes,¹² under half of all Gaelic players that sustained a LE injury during the season in this study were identified as at risk. For non-contact LE injuries, just 30.1% were identified as at risk using cut-off points developed for collegiate American football players¹³ and 52.5% for professional soccer players.¹⁴ Together this indicates very poor accuracy of the cut-off points across multiple sports not solely the population they were developed in. Thus caution should be taken against the generalisation of cut-off points developed in specific sporting populations to other sports.

The current study has a number of limitations that should be considered when interpreting the findings. This study examined LE injuries for a single season only, a longer prospective study may

be more insightful; however, our study did identify a reasonable number of injuries by which to build the injury prediction models. Previous concussion history or current upper respiratory infections were not included in the exclusion criteria and may have impacted participants' balance scores. During data collection, only previous injuries that occurred in the same location was captured and controlled for in the multivariate analysis. Future research should also capture and control for previous injuries to other sites in the lower extremity. In the non-elite setting, as was examined in the current study, funding is not commonly available to hire clinicians with each team. Therefore, to complete a prospective examination of injuries over one season, the primary author (a Certified Athletic Therapist) along with athletic therapy and training students completed all injury assessments on at least a weekly basis. To ensure the accuracy of the injury diagnosis, the primary author reviewed and confirmed all injury data captured by the athletic therapy and training students. The current method of solely examining reach distance as the outcome measure from the YBT may not be sufficient in the Gaelic games population, and recent research has begun to also examine qualitative aspects of performance in the YBT.¹⁶ De la Motte et al.²⁴ found that there was no significant difference in reach distances using the star excursion balance test in those with chronic ankle instability and matched controls. However, it was noted that those with chronic ankle instability rotated the trunk and pelvis more toward the stance leg, potentially as a compensatory movement pattern to maintain a stable posture. Thus future research should examine not only reach distances but potentially trunk, pelvic, hip, knee and ankle measures during the YBT to determine if this improves the ability of the YBT to identify those at risk of injury in Gaelic games. While we found that poor scores identified using the YBT as the sole screening was not able to or did not have sufficient sensitivity to classify those at risk of LE injury, incorporating it as part of a large pre-participation screening, involving other tests and assessments may be useful and should be further examined.

5. Conclusions

Adolescent and collegiate Gaelic footballers and hurlers perform worse in the YBT than previous research, and a significant proportion of them were identified as at risk of sustaining a LE or non-contact LE injury when using previously published cut-off points. However, population specific cut-off points specific to Gaelic footballers and hurlers were unable to be established. In addition, balance deficits identified by the YBT alone were unable to ascertain with high sensitivity those at risk of contact and non-contact LE-combined injuries and ankle injuries. Thus its use as the sole screening tool to classify those at risk of contact or non-contact LE injury or ankle injury in Gaelic games is questionable. High specificity was noted however, indicating that the YBT may be a useful preliminary screening tool to identify those who are not at risk of a contact LE-combined and non-contact ankle injury. Future research should examine the use of the standard YBT as an initial screening tool, in conjunction with a more comprehensive balance assessment for those identified as at risk.

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References

- O'Connor S, McCaffrey N, Whyte EF et al. Epidemiology of injury in male adolescent Gaelic games. *J Sci Med Sport* 2016; 19(5):384–388.
- O'Connor S, McCaffrey N, Whyte E et al. Epidemiology of injury in male collegiate Gaelic footballers in one season. *Scand J Med Sci Sports* 2017; 27(10):1136–1142.
- Roe M, Blake C, Gissane C et al. Injury scheme claims in Gaelic Games: a review of 2007–2014. *J Athl Train* 2016; 51(4):303–308.
- Maffey L, Emery C. Physiotherapist delivered preparticipation examination: rationale and evidence. *N Am J Sports Phys Ther* 2006; 1(4):176–186.
- Plisky PJ, Rauh MJ, Kaminski TW et al. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther* 2006; 36(12):911–919.
- Clark RC, Saxion CE, Cameron KL et al. Associations between three clinical assessment tools for postural stability. *N Am J Sports Phys Ther* 2010; 5(3):122–130.
- Bressel E, Yonker JC, Kras J et al. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *J Athl Train* 2007; 42(1):42–46.
- Martinez-Ramirez A, Lecumberri P, Gomez M et al. Wavelet analysis based on time–frequency information discriminate chronic ankle instability. *Clin Biomech* 2010; 25(3):256–264.
- Thorpe JL, Ebersole KT. Unilateral balance performance in female collegiate soccer athletes. *J Strength Cond Res* 2008; 22(5):1429–1433. <http://dx.doi.org/10.1519/JSC.0b013e31818202db>.
- Plisky PJ, Gorman PP, Butler RJ et al. The reliability of an instrumented device for measuring components of the star excursion balance test. *N Am J Sports Phys Ther* 2009; 4(2):92–99.
- Filipa A, Byrnes R, Paterno MV et al. Neuromuscular training improves performance on the star excursion balance test in young female athletes. *J Orthop Sports Phys Ther* 2010; 40(9):551–558.
- Smith CA, Chimera NJ, Warren M. Association of y balance test reach asymmetry and injury in division I athletes. *Med Sci Sports Exerc* 2015; 47(1):136–141. <http://dx.doi.org/10.1249/MSS.0000000000000380>.
- Butler RJ, Lehr ME, Fink ML et al. Dynamic balance performance and noncontact lower extremity injury in college football players: an initial study. *Sports Health* 2013; 5(5):417–422.
- Gonell AC, Romero JA, Soler LM. Relationship between the Y Balance Test Scores and Soft Tissue Injury Incidence in a Soccer Team. *Int J Sports Phys Ther* 2015; 10(7):955–966.
- Lai WC, Wang D, Chen JB et al. Lower quarter Y-Balance Test Scores and lower extremity injury in NCAA division I athletes. *Orthop J Sports Med* 2017; 5(8), 2325967117723666.
- Wright AA, Dischiavi SL, Smoliga JM et al. Association of lower quarter Y-Balance Test with lower extremity injury in NCAA Division 1 athletes: an independent validation study. *Physiother* 2017; 103(2):231–236.
- Robinson RH, Gribble PA. Support for a reduction in the number of trials needed for the star excursion balance test. *Arch Phys Med Rehabil* 2008; 89(2):364–370.
- Shaffer SW, Teyhen DS, Lorensen CL et al. Y-balance test: a reliability study involving multiple raters. *Mil Med* 2013; 178(11):1264–1270.
- Van Middelkoop M, Kolkman J, Van Ochten J et al. Risk factors for lower extremity injuries among male marathon runners. *Scand J Med Sci Sports* 2008; 18(6):691–697.
- Hajian-Tilaki K. Receiver operating characteristic (ROC) curve analysis for medical diagnostic test evaluation. *Caspian J Intern Med* 2013; 4(2):627–635.
- Zou KH, O'Malley AJ, Mauri L. Receiver-operating characteristic analysis for evaluating diagnostic tests and predictive models. *Circulation* 2007; 115(5):654–657, 115/5/654 [pii].
- Alnahdi AH, Alderaa AA, Aldali AZ et al. Reference values for the Y Balance Test and the lower extremity functional scale in young healthy adults. *J Phys Ther Sci* 2015; 27(12):3917–3921.
- McIntyre MC. A comparison of the physiological profiles of elite Gaelic footballers, hurlers, and soccer players. *Br J Sports Med* 2005; 39(7):437–439, 39/7/437 [pii].
- De La Motte S, Arnold BL, Ross SE. Trunk-rotation differences at maximal reach of the star excursion balance test in participants with chronic ankle instability. *J Athl Train* 2015; 50(4):358–365.