Effectiveness and implementation of the BokSmart Safe Six injury prevention programme

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CHAPTER 8

EFFECTIVENESS OF THE BOKSMART *SAFE SIX* EXERCISE PROGRAMME ON INJURY RATES AND INJURY RISK PROFILES OF UNDER-16 MALE RUGBY PLAYERS

Submitted

Abstract

Background
Exercise-based interventions have proven effective in many sports to reduce injury risk. The BokSmart *Safe Six* is a preventive warm-up programme developed for youth rugby, consisting of six exercises targeted to decrease injury risk. The aim of this study was to determine the effectiveness of the BokSmart *Safe Six* programme on improving injury risk profiles.

Methods
A cluster-randomised controlled trial was performed during the 2017 rugby season in the Western Cape, South Africa. A total of 6 schools participated (3 in the intervention and 3 in the control group), consisting of 210 rugby players between the ages of 15 and 16 years. Intervention schools were instructed to perform the *Safe Six* exercises at least three times a week during the entire season. Changes in Functional Movement Screen (FMS), the BokSmart Musculoskeletal Screening Assessment as mediators of injury risk, and match time-loss injury incidence densities were measured and recorded during the season. The trial ran for eighteen weeks and the FMS and the BokSmart Musculoskeletal Screening Assessment were performed at three time points: 0 weeks (pre-intervention), 9 weeks (mid-intervention) and 18 weeks (post-intervention). Linear mixed model analysis, Magnitude-based inferences, generalised estimating equations and survival analyses were performed for the various variables.

Results
There was a significant change in nine of the BokSmart Musculoskeletal Screening Assessments, however there were no changes in the overall FMS score. No differences in injury incidence densities between groups were found.

Conclusions
The BokSmart *Safe Six* showed small changes in the BokSmart Musculoskeletal Screening Assessment and no changes in the FMS scores over the season (18 weeks), and BokSmart should investigate adjusting the programme with additions from other effective rugby interventions.

Introduction

Youth rugby has a high risk of injury compared to other sports.[1-3] The popularity of the sport[4] and this high injury risk has led to the need for the effective implementation of injury prevention strategies. The nature of the injuries sustained in rugby (specifically concussions and contact-related injuries) has made it difficult to design effective injury prevention programmes.[5, 6, 2, 3, 7] However, four underpowered studies with a low level of evidence have shown hamstring exercises,[8] neck strengthening exercises,[9] proprioceptive training[10] and progressive training to be effective in reducing injuries in contact sports.[11] Furthermore, a sufficiently powered, cluster-randomised controlled trial (cRCT) in England showed reduced concussion rates in youth and senior rugby players, who had followed an exercise-based injury prevention programme.[12, 13] Although this specific intervention required intensive coach training and training programme progressions throughout the season, it indicated that exercise-based injury prevention programmes can be effective in rugby.[12]

In accordance with the need for an exercise-based injury prevention programme, BokSmart, together with the South African Rugby Union (SARU), developed and implemented the BokSmart *Safe Six* in 2014. The *Safe Six* programme was designed to be incorporated in the regular warm-up before training and matches, requiring no equipment and minimal training. Awareness about this programme has grown since its launch.[14, 15] The simplicity of the *Safe Six* makes it different to the programme used in the above-mentioned RCT performed in England,[13, 12] and makes it more applicable to the disparate socio-economic conditions in South Africa. The *Safe Six* exercises were chosen based on clinical practice and previous research, and target the commonly injured sites in rugby.[16, 5, 7] Exercise-based interventions (such as the *Safe Six*) in collision sports are hypothesised to assist in improving motor control patterns, that potentially result in a decrease in contact and non-contact injuries sustained.[17] Previous studies have established the association between motor control measures and injury, where motor control outcomes are mediating injury risk.[18-21] Assessment of motor control scores, as mediators of injury risk, can serve to establish injury risk profiles.[18-20] Examples of a tool to assess motor control scores include the Functional Movement Screen (FMS) and other range of motion measurements.[22-28]

The aim of this study was to determine the effectiveness of the BokSmart *Safe Six* exercises on improving injury risk profiles. The secondary aim is to determine the effectiveness of the BokSmart *Safe Six* on reducing injury rates in under-16 rugby union players. The hypothesis is that the BokSmart *Safe Six* programme will be associated with improvements in injury risk profiles and with decreases in injury incidence density.

Methods

Design & recruitment

All eight secondary schools from the Western Province Rugby Union's School Premier League or Division (based on location and similar skill level) were approached to participate in this study. Despite being in the same league, the eight schools are geographically separated by at least 40 km: four schools were in the Stellenbosch/Paarl region and four were in the Southern Suburbs region. A 'coin-flip' was used to randomise the intervention and control schools, based on geographic region. This coin-flip decided that the Southern Suburbs schools would receive the *Safe Six* intervention. All schools were approached through their headmaster, head of sport, head of rugby and head under-16 rugby coach to participate in the study. Two of the eight schools (one from the control and one from the intervention group) declined to participate, as the one team was travelling overseas and the other team was already trialling another intervention, leaving six participating schools (three in each arm). The school's medical resources on match day were standardised by BokSmart protocols. [29] All schools were required to have access to at least a physiotherapist for their players when necessary, and therefore in the case of injuries a diagnosis was available. Once the school had agreed to participate, written assent from players, and written consent from parent/guardian and the coach of those willing to participate were obtained before the study began.

The Human Research Ethics Committee granted Ethical approval (HREC 850/2015) and the study was performed in accordance to the Consolidated Standards of Reporting Trials Statement and was registered prospectively (trial number: PACTR201608001730223).

Sample size

The sample size was calculated before the start of the study[30, 14] to be able to detect a 30% improvement in FMS scores at the 95% confidence level, with a clustering effect, requiring 4 schools in each arm (hence the recruitment numbers). However, the school random effect (clustering effect) did not add to the mixed model and therefore the clustering effect was not necessary. Using an individualized randomized controlled trial design, the sample size required was 8 participants in the intervention group and 8 in the control group to see a 30% improvement in FMS scores, assuming a standard deviation of 3.0 and 2.0 for the control group and the intervention group, respectively.[30] The study was not statistically powered to detect changes in injury incidence densities.

Intervention

The schools allocated to the intervention group were instructed to perform the BokSmart *Safe Six* exercises three times a week during their warm-up at practice (the schools could choose whether they wanted to add more exercises into their warm-up). The coaches were trained to administer the exercises. Training included one-on-one training, and YouTube videos and posters about the intervention. All six exercises took approximately six minutes to complete and included shuttle runs, multidirectional lunges, Nordic hamstring curls, push-ups with rotation, lunges with a knee lift and dynamic reaches.[14] The lead researcher (NS) visited the schools every two weeks to retrieve video footage of the warm-ups for both the control and intervention schools' in an attempt to improve compliance of the intervention group (the schools were notified the day before of the visit). This material was also used for accountability reasons.

Blinding was not possible in this study, as the control group was not given an intervention. However, this was overcome to some extent by not informing either group that another group was performing something different. The control group was instructed that the study was investigating warm-ups performed by schools and their preventive effects. It must be noted that there was no specific instruction to the control group to not perform the *Safe Six* exercises (as it is a freely available programme), however as the lead researcher did visit the schools often, it is known that the control group did not perform the intervention exercises regularly.

Outcome Measures and Data Collection

Each school was tested three times during the study to determine the players' level of motor control and functional movement. The testing battery included: 7 FMS exercises (leading to individual test scores [scale 0 – 3] and to a composite score [range 0 – 21]),[23, 24] and eight range of motion tests from the BokSmart Musculoskeletal Screening Assessment (active knee extension [°], modified Thomas test [°], active internal and external range of motion of the hip [°], ankle dorsiflexion lunge [cm], sit and reach [cm], lumbar spine extension [cm] and forward flexion [cm], shoulder internal and external rotation [°]).[22, 26, 31, 27, 28] Anthropometrical (sum of four skinfolds (bicep, triceps, subscapular, suprailiac), body height and body mass) and maturation status (derived from seated height and standing body height to determine years after peak height velocity) were also measured as these factors might confound results.[32, 33] All tests were performed once at three time points (before the teams' first match, before the mid-season break and after their final match) by biokineticists/ physiotherapists/sports scientists specifically trained for the study. The testers were blinded to the group allocation (control/intervention) of each school.

Match time-loss injury data were recorded by the coach and reported to the researcher. The lead researcher followed up on each injury telephonically every week to register an accurate return-to-play date. Time-loss match injuries (an injury occurring during a match which resulted in a player being absent following said match for more than 24 hours of rugby training or match-play) [34] were recorded using a standardised injury data collection form designed by BokSmart, in accordance with the Consensus Statement on injury definitions and data collection procedures for studies of injuries in rugby union.[34]

A total of 210 participants was tested over the eighteen weeks, and six teams in the control group (three different schools) and five teams in the intervention group (three different schools) were followed over the season to track injuries (Figure 8.1). The dropout of tested participants throughout the trial was due to school and extramural commitments of the players. None of the teams dropped out during the season for the injury surveillance part of the study. At the end of the trial, during an interview regarding compliance, two of the three schools implemented the exercises three times a week, and the third school implemented the exercises once a week.

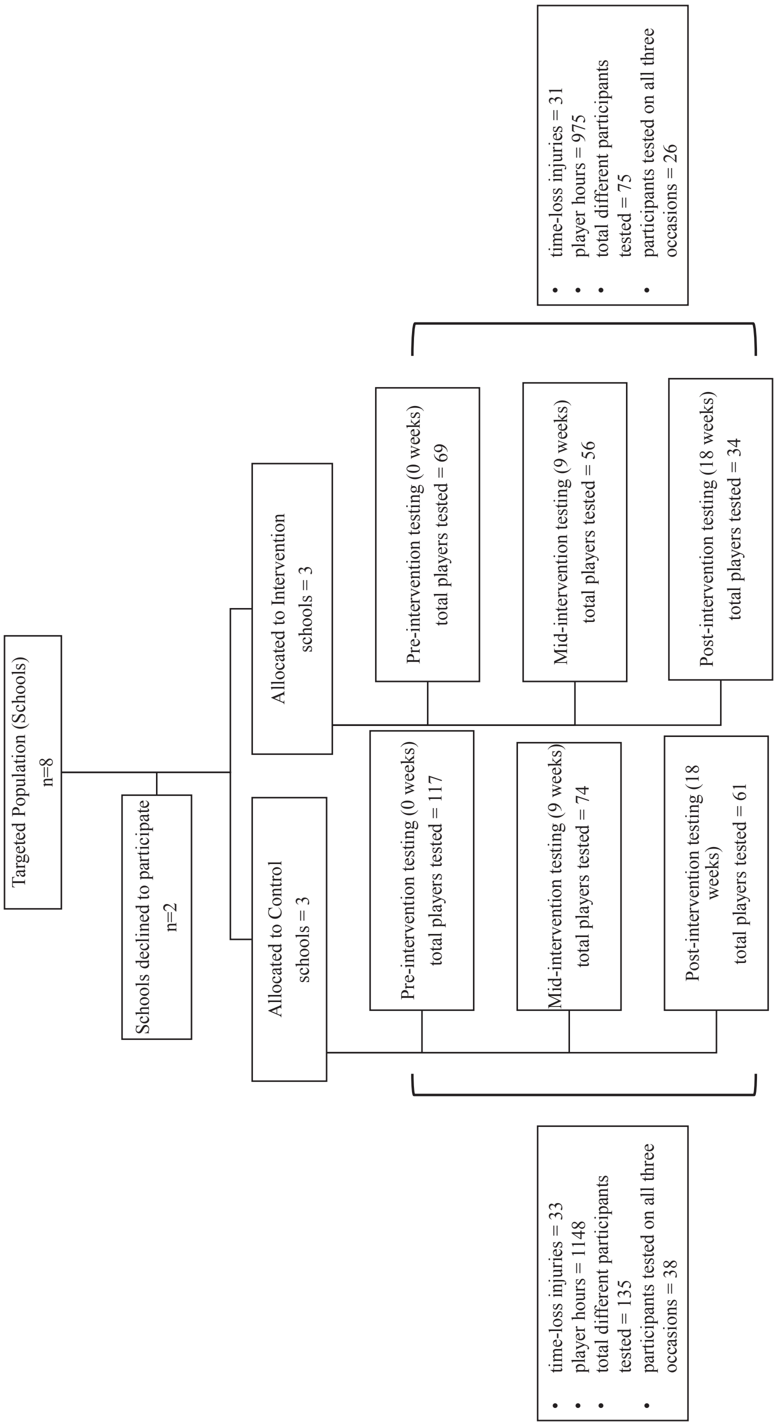

Figure 8.1: Flow diagram of participants enrolled and tested during the cRCT over the eighteen weeks.

Statistical Analyses

Descriptive statistics on the players in each group were performed using means, standard deviations and an independent samples T-test. The differences in Musculoskeletal Screening Assessment scores and FMS scores between the intervention and control group at the different time-points were determined using a linear mixed model analysis, adjusting for baseline measures and maturation status (using the Mirwald calculation to determine years after peak height velocity).[33] Furthermore, Magnitude-based inferences (MBIs) were also calculated using raw difference between means and 90% CI to determine if the changes were attributed to the control or intervention.[35-37] The effects were classified according to the following scale, 0 – 0.5% most unlikely, 0.5 – 5% very unlikely, 5 – 25% unlikely, 25 – 75% possibly, 75 – 95% likely, 95 – 99.5% very likely, 99.5 – 100% most likely.

For the individual FMS assessment scores (because the data was ordinal), the score was first dichotomised (two categories: ≤2; 3), and then generalised estimating equations were performed to determine the intervention effect at the different time-points, adjusting for baseline measures and maturation status producing an odds ratio (OR) with 95% confidence intervals (95% CI).

Intention-to-Treat (ITT) analysis was performed using the injury data to calculate the injury incidence density (IID) as the number of injuries per 1,000 player hours with corresponding 95%CI [34] for the control and intervention group, separately. A survival analysis was then performed to determine differences between the two groups (using a Kaplan Meier log rank). All data analyses were performed using IBM SPSS Statistics 24 (2016) and a significance level of $p<0.05$ was accepted for all statistical analyses.

Results

The descriptive characteristics of the players in the two groups were not significantly different at baseline (Table 8.1).

Table 8.1: Summary and comparisons in the player characteristics between the intervention (n = 69) and control (n = 113) groups at baseline. (mean ± standard deviation; PHV – peak height velocity). P-value determined using an independent samples T-test.

Trial arm	Intervention	Control	p-value
Age (years)	15.8 (± 0.3)	15.8 (± 0.2)	0.183
Stature (cm)	176.2 (± 6.9)	174.9 (± 7.1)	0.207
Body Mass (kg)	74.3 (± 11.9)	75.5 (± 13.4)	0.529
Maturation Status (years after PHV)	1.7 (± 0.6)	1.6 (± 0.6)	0.474

Risk profiles

There were no significant differences between the two groups in the FMS composite score or in the individual FMS assessment scores (Supplementary table 8.1). Following the first nine weeks, there were four positive changes, and one negative change (Table 8.2). After the next nine weeks, there were six positive effects from the intervention and three negative effects. After the eighteen weeks, lumbar flexion positively improved, along with both active knee extension appendages. The Thomas hip scores both favoured the control group, however the knee favoured the intervention group. Internal hip scores had both favourable and negative results after eighteen weeks. Shoulder internal rotation favoured the intervention after nine weeks and external rotation favoured the control after nine weeks but favoured the intervention after eighteen weeks.

Table 8.2: Differences in the Musculoskeletal Screening Assessment scores and FMS composite score between the intervention and control group at 9 and 18 weeks. (R – Right appendage; L – Left appendage)(*sign changed from a negative to a positive sign to ensure all results are intuitive to represent a beneficial difference)(MBI interpretation: favours intervention|trivial|favours control; * likely)

Assessment	Difference between Intervention and Control					
	9 Weeks			18 Weeks		
	Difference [95% CI]	**p-value**	**MBI**	**Difference [95% CI]**	**p-value**	**MBI**
FMS Composite Score (AU)	0.8 (-1.0 – 2.6)	0.305		-0.2 (-2.0 – 1.6)	0.800	
Sit and Reach (cm)	2.0 (-1.2 – 5.1)	0.165	**(85|11|4)***	0.7 (-2.4 – 3.9)	0.596	
Lumbar Flexion (cm)*	0.7 (-0.2 – 1.6)	0.111		1.4 (-0.3 – 2.4)	**0.011**	**(85|14|1)***
Lumbar Extension (cm)*	1.4 (-1.1 – 4.0)	0.210	**(79|17|4)***	-0.3 (-2.9 – 2.2)	0.758	
Active Knee Extension R (°)*	-0.4 (-4.8 – 3.9)	0.847		4.1 (-0.8 – 8.9)	0.100	**(93|4|3)***
Active Knee Extension L (°)*	-2.1 (-8.0 – 3.8)	0.429		2.9 (-3.1 – 9.0)	0.300	**(81|8|11)***
Thomas Hip R (°)*	-1.0 (-4.1 – 2.2)	0.481		-2.0 (-5.3 – 1.1)	0.181	**(5|11|84)***
Thomas Hip L (°)*	-1.0 (-3.7 – 1.7)	0.482		-3.7 (-6.8 – -0.5)	**0.022**	**(0|2|98)****
Thomas Knee R (°)*	-5.6 (-20.0 – 8.9)	0.449		4.3 (-15.8 – 24.3)	0.654	
Thomas Knee L (°)*	1.9 (-3.6 – 7.4)	0.442		3.0 (-2.7 – 8.6)	0.270	**(82|8|10)***
Hip External Rotation R (°)	-0.5 (-9.5 – 8.5)	0.893		-1.5 (-10.5 – 7.4)	0.678	
Hip External Rotation L (°)	-0.8 (-12.4 – 10.8)	0.864		0.1 (-3.2 – 3.4)	0.949	
Hip Internal Rotation R (°)	0.5 (-3.8 – 4.9)	0.777		-2.1 (-5.4 – 1.3)	0.222	**(7|11|82)***
Hip Internal Rotation L (°)	2.9 (-4.8 – 10.7)	0.455		4.5 (-3.4 – 12.4)	0.262	**(84|5|11)***
Ankle Dorsiflexion Lunge R (cm)	-1.5 (-6.6 – 3.7)	0.475		-0.1 (-5.3 – 5.0)	0.944	
Ankle Dorsiflexion Lunge L (cm)	-1.5 (-7.0 – 4.1)	0.502		0.2 (-5.2 – 5.7)	0.911	
Shoulder External Rotation R (°)	-1.7 (-15.9 – 12.5)	0.817		9.0 (-7.7 – 25.6)	0.290	**(84|3|13)***
Shoulder External Rotation L (°)	-6.1 (-15.1 – 2.9)	0.146	**(6|3|91)***	0.8 (-9.9 – 8.2)	0.836	
Shoulder Internal Rotation R (°)	9.9 (-9.4 – 29.2)	0.235	**(87|2|11)***	-0.3 (-19.5 – 18.9)	0.969	
Shoulder Internal Rotation L (°)	7.8 (-10.5 – 26.1)	0.307	**(83|3|14)***	-2.6 (-20.7 – 15.5)	0.721	

Injury Incidence Density

The match time-loss IID (95% CI) for the control group was 28.8 (95%CI: 18.9 – 38.6) injuries per 1,000 player hours, and for the intervention group it was 31.8 (95%CI: 23.6 – 43.0) injuries per 1,000 player hours. Using survival analysis, the mean exposure before a player sustained an injury for the control group was 10.5 (95%CI: 9.7 – 11.3) player match hours, compared to the intervention group that was 10.7 (95%CI: 9.9 – 11.4) player match hours (Figure 8.2). This difference was not significantly different (p = 0.749, using ITT analysis).

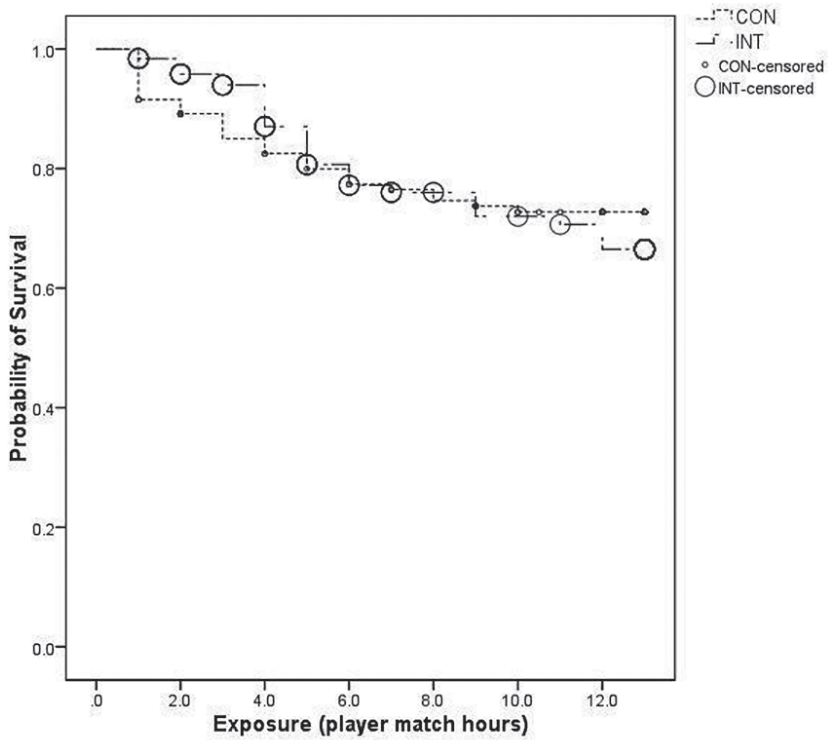

Figure 8.2: Survival analysis of the injury data for the control and intervention groups over the duration of the cRCT (p = 0.749). (CON – Control group; INT – Intervention Group)

Discussion

Out of the twenty risk profile assessments, the *Safe Six* intervention was associated with improvements: 1) after nine weeks an improvement in sit and reach, lumbar extension, shoulder internal rotation, and a decrease in shoulder external rotation; 2) after eighteen weeks an improvement in lumbar flexion, active knee extension, range of motion in the quadriceps (Thomas knee score), hip internal rotation, shoulder external rotation, decrease in range of motion of the hip (Thomas hip score). However, the total FMS score did not change at any stage in the study. Therefore, it was also expected that there would be no differences in injury rates between the two groups. However, it should be noted that this study was not powered to detect changes in IID.

The Musculoskeletal Screening Assessments that tested range of motion (ROM) showed equivocal findings. The improvement in the lumbar flexion and extension ROM score over the various time-points could be attributed to the combined nature of the *Safe six* exercises and general stretching exercises, however, none of the exercises specifically targeted the lumbar region. Therefore, it is possible that the increase in lumbar flexion and extension was a chance finding and was not related to the intervention. The sit and reach test scores improved in the intervention group at the nine week mark. The sit and reach test has been used as a predictor of relative risk for hamstring injury.[31] A study by Gabbe *et al*. (2006) on elite football players indicated that an increased sit and reach score, therefore increased flexibility of the hamstring group and/or lumbar spine, was associated with a higher risk of subsequent hamstring compared to a reduced score.[31] Another score that favoured the intervention, but after eighteen weeks, was the active knee extension assessment. The *Safe Six* exercises including the 'Six'-Point lunge, the 'Six'-Bok lunge and the Butt-Smart 'Six' could explain this increase in range of motion, owing to the involvement of the quadriceps and hamstring muscle groups in the above-mentioned exercises. The exercises may have increased the strength of these muscle groups resulting in the improvement following the intervention. These improvements in the sit and reach scores could have been elicited through a similar mechanism to that occurring in the active knee extension.

Shoulder internal rotation was also improved (in both the right and left shoulder) following the intervention at nine weeks. In overhead throwing sports, loss of internal rotation in the shoulder has been well investigated and the subsequent association with pathology.[38] Upper limb injuries in youth rugby, of which shoulder injuries comprise the majority, have been reported at 8 injuries per 1000 player hours.[2] These injuries account for 24% of all injuries,[3] indicating the need to reduce them. One of the *Safe Six* exercises in particular (dynamic reaches) targeted the shoulder area and could be responsible for the improvement in the range of motion. However, there was a decrease in external rotation at the same time point, which could account for this change.

The decrement in the Thomas hip score, however, could be attributed to an increase in muscle strength in the quadriceps, and as a result, loss of range of motion or, it could also be a chance finding not related to the intervention. The *Safe Six* intervention exercises incorporated multiple exercises targeting these specific muscles. Injuries to the lower limbs are common in youth and senior rugby,[39, 7] and therefore the improved range of motion of the hip and lower limb area is important, but so is strength improvement. However, it must be noted that at this eighteen week point there was also an increase in Thomas knee score, which could be the change in range of motion from the hip to the knee. Furthermore, the changes in the internal rotation at the hip were different in both legs, illustrating the varying effect of the exercises at the hip level. The exercises included in the *Safe Six* included two lunges recruiting the hamstrings, quadriceps and the muscles around the ankle joints, and the dynamic reaches could all have contributed to the lumbar flexion results. All these exercises should also have contributed to an improvement in Thomas hip results.

Unexpectedly, there were no changes in the FMS scores (both composite and individual) as a result of the intervention. Similarly, to the Musculoskeletal Screening Assessment, it was hypothesised that the FMS scores would be significantly different between the two groups as a result of the exercises performed in the *Safe Six,* and would therefore result in beneficial changes in motor control and ROM. The implications of no changes in FMS scores would imply there would be no change in IID. As this study showed, there was no difference in IID (the study was, however, not statistically powered to detect changes in IID). The control group had an IID of 29 time-loss injuries per 1000 player hours and the intervention group had an IID of 32 time-loss injuries per 1000 player hours. These IID's are comparable to findings in other youth cohorts. Previous studies have shown IID's ranging between 24 – 35 time-loss injuries per 1000 player hours.[40, 2, 12, 3] Our study only looked at match injuries only, and therefore it is unknown what the effect of the *Safe Six* intervention might have been on training injuries. The *Safe Six* programme is a comprehensive warm-up and could reduce training injuries as it recruits most muscles required for rugby training. However, it must be noted that the training IID is low in rugby and therefore would not make a large contribution to a potential preventive effect.[7]

As illustrated above, there was little improvement following the *Safe Six* intervention, and therefore, adjustments to the programme should be investigated. A comparably effective exercise-based intervention in youth rugby has been implemented recently in England. The main difference between this intervention and the *Safe Six* intervention was that the English intervention included a neck strengthening component and exercise progressions throughout the season.[12] This neck strengthening component has been associated with reductions in concussion incidences[12] and if added to the *Safe Six*, could potentially increase its effectiveness in reducing IID in particular.

Limitations

This study was implemented in well-resourced rugby-playing schools, and therefore the application in under-resourced schools might produce different results. The study was not sufficiently powered for finding statistical differences between the control and intervention group for the IID. Another limitation was that the warm-ups of the control groups were not assessed to determine if they were performing any of the *Safe Six* exercises.

Practical Implications

The BokSmart *Safe Six* programme is simple, time-efficient and requires no equipment. The intervention schools have maintained the intervention following the trial, and a further study regarding the barriers and facilitators towards the *Safe Six* will be conducted. However, the intervention showed minimal effectiveness. The BokSmart *Safe Six* should potentially include a neck strengthening component (as shown effective in decreasing concussion IID in another injury prevention programme).[12] Injury surveillance should continue for re-evaluation to occur, before further promotion of the programme is advised.

Conclusion

The BokSmart *Safe Six* improved a number of screening assessments significantly after an eighteen week-long intervention. BokSmart should investigate adjusting the *Safe Six*, such as incorporating a neck strengthening component, to improve the effectiveness of the *Safe Six* going forward.

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Supplementary Table 8.1: Individual FMS assessment scores. (OR – Odds Ratio with 95% confidence intervals)

Assessment	9 Weeks		18 Weeks	
	OR [95% CI]	p-value	OR [95% CI]	p-value
FMS Individual Tests				
Overhead Squat	0.62 (0.92 – 1.01)	0.274	0.88 (0.32 – 2.40)	0.801
Single Leg Hurdle Step	1.12 (0.44 – 2.84)	0.808	2.01 (0.63 – 6.40)	0.239
Single Leg Lunge	1.04 (0.45 – 2.39)	0.935	1.76 (0.67 – 4.67)	0.254
Shoulder Mobility	0.53 (0.21 – 1.32)	0.172	0.65 (0.22 – 1.93)	0.441
Straight Leg Raise	0.52 (0.23 – 1.21)	0.128	0.86 (0.28 – 2.06)	0.585
Push Up	1.11 (0.47 – 2.63)	0.812	1.57 (0.62 – 3.94)	0.338
Rotary Stability	-	-	-	-