Journal of Science and Medicine in Sport 20 (2017) 648–652

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

Risk factors that predict severe injuries in university rugby sevens players

Rezvan Mirsafaei Rizi [a], Simon S. Yeung [a], Nathan J. Stewart [b], Ella W. Yeung [a,*]

[a] Centre for Sports Training and Rehabilitation, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong
[b] Hong Kong Rugby Union, Hong Kong

ARTICLE INFO

Article history:
Received 29 August 2016
Received in revised form
11 November 2016
Accepted 13 November 2016
Available online 24 January 2017

Keywords:
Rugby injuries
Risk factors
Physical tests
Speed
Agility

ABSTRACT

Objectives: To investigate injury incidence and the influence of physical fitness parameters on the risk of severe injuries in players on rugby sevens university teams.
Design: Prospective cohort study.
Methods: Rugby players from three universities ($N = 104$; 90M:14F; 20.6 ± 1.9 years) were recruited before the beginning of the season. Players underwent pre-season assessments of power, strength, speed, agility, endurance, stability, and flexibility. Throughout the season, rugby-related injury and exposure data were collected. Potential predictor variables were analyzed using Cox proportional regression model to identify risk factors associated with severe injuries (time loss > 28 days).
Results: Thirty-one injuries occurred during the rugby season. The match and training injury incidence rates were 59.3 injuries and 3.3 injuries per 1000 player-hours, respectively. Lower limb injuries were most common and most severe. The ankle joint was the most prevalent site of injury, and ligamentous injury was most common (48.4%). Nine severe injuries were sustained resulting in an average time loss of 51.3 ± 14.6 days. Female (hazard ratio [HR] = 8.35; 95% confidence intervals [CI] = 2.01–34.8), slower (HR = 3.51; 95% CI = 1.17–10.5), and less agile (HR = 2.22; 95% CI = 1.26–3.92) players as well as those with hip flexors tightness (HR = 1.12; 95% CI = 1.00–1.25) were at significantly greater risk for sustaining severe injuries.
Conclusions: Limited studies are available on risk factors associated with amateur rugby players in the Sevens version. The development of gender-specific injury prevention measures that emphasize speed and agility training, and improve hip flexor extensibility may be important to reduce the risk of severe injuries.

1. Introduction

The popularity of rugby has increased tremendously in the past decade, both locally and internationally. This is due to players' attraction to the rugby sevens (rugby-7s) game and to the inclusion of the sport in the Rio Olympics 2016. The global participation in rugby increased from 2.6 million in 2007 to 7.7 million in 2015 and it is predicted to reach 11 million by 2020.[1] There is an effort to boost rugby participation in schools and universities. In the United States, rugby is considered as an emerging team sport in universities.[2] Despite increased participation in rugby at the university level, there is limited research on injury prevention approaches for university students who play rugby.

Rugby-7s differs from the 15-a-side rugby (rugby-15s) in the number of players (7 vs. 15 players) and the duration of match (7-min vs. 40-min halves). The physical demands in the sevens game is greater than in the 15-a-side, with frequent high-intensity sprints, open-field tackles, rapid acceleration, deceleration, and change of direction.[3] The fast pace of the game can result in numerous physical collisions and tackles and the athletes are vulnerable to serious injuries. The incidence and severity of injuries were reported to be higher in rugby-7s than rugby-15s. For instance, the injury incidence sustained by elite, professional players during match play in rugby-7s was 106.2 per 1000 player-hours and 84 per 1000 player-hours in rugby-15s.[4] For concussions, the incidence and severity sustained were greater in men's elite rugby-7s players (8.3 per 1000 player-hours) than rugby-15 players (5.2 per 1000 player-hours).[5]

Prospective injury surveillance is much needed to evaluate risk factors and to help develop injury prevention strategies. Numerous risk factors have been examined through epidemiological studies,

* Corresponding author.
E-mail address: ella.yeung@polyu.edu.hk (E.W. Yeung).

http://dx.doi.org/10.1016/j.jsams.2016.11.022
1440-2440/

including previous injury, training volume, body-mass index, ligament laxity, cigarette smoking status, experience, age, weather and ground conditions, level of play, length of season, and foul play.[6–8] Other research indicates that physical fitness can predict injuries: players with lower upper body strength, lower maximal aerobic capacity, and high-intensity intermittent running ability had a greater risk of injury.[9,10] However, these studies were conducted for elite and club-level players. There are limited injury surveillance studies for amateur players. Furthermore, the contribution of different components of physical fitness to injury risk for players, specifically in the Sevens version, is not well known.

In a study on amateur rugby players, a considerable proportion of injuries (40%) sustained were severe, resulting in at least five missed training/games. In addition to loss of training, the athletes lost study time and work and also incurred medical costs.[11] This clearly points to the need to assess the risk for severe injuries associated with amateur athletes who play rugby-7s, necessary for developing effective injury prevention strategies. Therefore, this study was undertaken (i) to determine the incidence of severe injuries [an absence from rugby for greater than 28 days (>28 d)] sustained; and (ii) to identify risk factors for injury in amateur rugby-7s players at the university level. The hypothesis is that there would be an association between physical fitness and the occurrence of severe injuries in these players.

2. Methods

The study was conducted over one rugby season, from September 2014 to April 2015. A total of 104 rugby players (90M:14F) aged 20.7 ± 2.0 years (mean ± SD) were recruited from three university rugby teams in Hong Kong. The participants had played rugby for an average of 21.0 months (range, 0–144 months); 28 players were completely new to the sport. All players in this cohort were at least 18 years and received no remuneration. The study was approved by the Human Subjects Ethics Sub-Committee of the Hong Kong Polytechnic University (HSEARS20150609001). All players were informed of the study procedures and gave written informed consent. All participants in the study were undergraduate members of university rugby teams. Players with health problems that prevented participation in the physical tests were excluded.

The players underwent the physical testing in July and August 2014, before the start of formal rugby training. Each player provided information regarding gender, age, height, weight, playing experience, medical history, and history of previous injury. Ten tests were used to assess different components of physical function (aerobic capacity, upper and lower body muscle strength and power, speed, agility, balance, and flexibility) related to rugby. These included: yo–yo intermittent recovery test[12]; push-up test[13]; isometric mid-thigh pull test[14]; single leg bridge test[15]; vertical jump test[16]; 40-m speed test[17]; Illinois agility test[18]; Y balance test[19]; sit and reach test[20]; and Thomas test.[21] Good to excellent test–retest and inter-rater reliability of these tests have been demonstrated previously. On the test day, players were given verbal and physical demonstrations for each test. After a structured 10-min warm-up, the players rotated between different testing stations. Sufficient rest periods between tests were given to avoid fatigue.

During the season, any player that sustained an injury either in matches or during training was contacted by the team. The player was followed up within 24 h of the injury. Specific details of the injury were collected, including body location, type of injury, whether it was new or recurrent injury, mechanism of injury, contact vs. non-contact injury, diagnosis, treatment, and number of days off lost from playing rugby. For the purpose of the study, injury was defined as "*any physical complaint sustained during a match or training session that prevented the athlete from taking a full part in all training or match for one day or more following the day of injury, irrespective of whether match or training sessions were actually scheduled*".[22] Recurrence was defined as "*injury of the same type and at the same site and that occurs after a player's return to full participation from the original injury*".[23] The number of days lost from training or match play was used to define injury severity: slight (0–1 days), minimal (2–3 days), mild (4–7 days), moderate (8–28 days), severe (>28 days).[23]

Exposure time was quantified as the total time the players were exposed to the possibility of injury during training or competition. Over the 28-week period, rugby training and competition volumes for each player were reported by coaches based on attendance records. Injury incidence was expressed as number of injuries per 1000 player-hours of exposure.[22]

Descriptive statistics were calculated for all variables. Kaplan–Meier curves were plotted for estimates of players who remained free of injury throughout the season. Mantel–Cox log rank test was used for comparison of injury occurrence stratified by injury severity (<28 days time loss vs. >28 days time loss).

Preliminary Spearman's rho analysis was conducted to assess correlations between serious injuries (>28 days time loss) and each potential predictor variable (previous injury, gender, age, playing experience, weight, height, and physical test data). All predictor variables were assessed for multi-collinearity. Variables with a trend for significance ($p < 0.10$) at the Spearman rho's test were included into the Cox proportional hazards regression model to identify significant risk factors for serious injuries. Time to occurrence of the initial serious injury or to the end of the season free of serious injury across the players was the primary dependent variable. Hazard ratios (HR) were reported with 95% confidence intervals (95% CI). Data analyses were conducted using the Statistical Package for the Social Sciences (SPSS) Software (version 20.0; SPSS, Inc., Chicago, IL, USA). The significance level was set at $\alpha = 0.05$. Data is expressed as mean ± SD.

3. Results

Ninety male (age: 20.73 ± 2.06 years; height: 174.2 ± 5.42 cm; weight: 70.8 ± 9.56 kg) and 14 female (age: 20.30 ± 1.16 years; height: 160.8 ± 3.88 cm; weight: 53.3 ± 5.10 kg) rugby players were recruited. All players participated in regular training and competition, with an average of 43.5 ± 26.0 training hours and 2.6 ± 1.6 match hours during the season. The total number of training hours was 4525.5 ± 26.0 h, and the total number of match hours was 270.0 ± 1.6 h over the 28-week period. The injury incidence during training and match play was 3.31 and 59.25 injuries per 1000 player hours, respectively.

The characteristics of the injuries sustained are presented in Table 1. Twenty-eight players (21M:7F) sustained a total of 31 injuries over the 28-week season. Three players were each injured twice. Of these injuries, 15 (48.4%) occurred during training, while the other 16 (51.6%) injuries occurred during a match. A majority of the injuries observed was new injuries (64.5%) compared to recurrent injuries associated with previous rugby season (9.7%) and from the current rugby season (6.5%). Regarding the injury mechanism, 26 of the injuries (83.9%) were caused by contact, and being tackled or tackling contributed to the majority of contact injuries. Of the five non-contact injuries, running, changing direction, and passing were implicated as the injury mechanism. Furthermore, ground conditions, foul play, fatigue, cold weather, previous injury, inadequate warm-up, and poor skills were suggested by the players as the possible causes of injuries. Lower limb injuries comprised the greatest proportion of injuries (15 out of 31; 48.4%) and also were the most severe; followed by upper extremity (11 out of 31; 35.5%); head

Table 1
Characteristics of the 31 injuries sustained in rugby sevens in this study.

	No. of injuries
Time of injury	
Training	15
Match	16
New/recurrent injury	
New injury	20
Recurrent injury with previous rugby season	9
Complication of injury from current season	2
Body region	
Ankle	7
Shoulder	6
Knee	4
Fingers	4
Head	3
Hamstring	3
Toes	1
Hand	1
Face	1
Upper back	1
Injury type	
Ligament sprain	11
Ligament tear	4
Muscle strain	4
Concussion injury	3
Joint dislocation	2
Fracture	2
Tendon injury	2
Hematoma	2
Open wound	1
Injury mechanism	
Contact	26
Tackling	9
Tackled	9
Collision (non-tackle)	3
Ruck	3
Tackle collision (no use of arm)	2
Non-contact	5
Running	3
Changing direction	1
Passing rugby	1
Injury severity	
Slight (0–1 days)	2
Minimal (2–3 days)	2
Mild (1–7 days)	8
Moderate (8–28 days)	10
Severe (>28 days)	9

and face (4 out of 31; 12.9%) and trunk (1 injury; 3.2%). The most prevalent sites of injury were ankles (22.6%); followed by shoulders (19.4%), knees (12.9%), fingers (12.9%), hamstrings (9.7%), and heads (9.7%). Ligamentous injuries were the most common type of injury encountered (48.4%), followed by muscle strains (12.9%) and concussion (9.7%). The mean severity for match injuries was 25.5 ± 23.2 missed days, while for training, the mean severity was 8.62 ± 8.0 missed days.

Nine severe injuries were sustained during the season, resulting in an average of 51.3 ± 14.6 days of lost time. The injury incidences for matches and training were 22.22 and 0.66 per 1000 player-hours, respectively. Six injuries occurred during match play as a result of contact in a tackle or collision. All nine players (5M:4F) required medical attention, with five injuries needing hospital admission and four injuries being diagnosed and treated by health care professionals (general practitioners, physiotherapists or orthopedic specialists). The type of injuries sustained was ligamentous tears to the knee (two injuries); ligament sprains (four injuries: two knees, one ankle, and one shoulder); ankle joint dislocation (one injury), ankle fracture (one injury) and finger fracture (one injury). The Kaplan–Meier survival curve of the time to initial injury is shown in Fig. 1. There was a significant difference in time to first injury when severe injuries (that resulted in >28 days loss) were compared to less severe injuries (that resulted in <28 days loss; $\chi^2 = 30.3$; $p < 0.0001$). The mean time of injury for slight to moderate injuries and severe injuries were 70.5 h and 24.8 h, respectively. The median survival time for severe injury is 21.8 h.

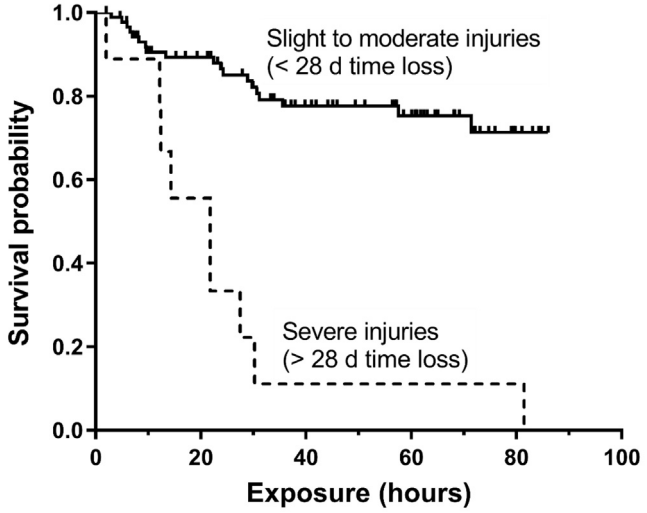

Fig. 1. Kaplan–Meier survival curves for survival probability of severe injury (>28 days time loss) and slight to moderate injury (<28 days time loss) events during the rugby season.

Spearman's rho analysis revealed association of nine potential variables: gender, height, previous injury, global muscle strength (isometric mid-thigh pull test), hamstring muscle strength (single leg bridge test), lower limb power (vertical jump test), speed (40 m speed test), agility (Illinois test) and hip flexor flexibility (Thomas test). These variables were entered into the Cox regression analyses using backward stepwise selection to develop a multivariate model. The final model included gender, speed, agility, and hip flexors flexibility which significantly predicted time-to-serious injury. Female players had a greater risk to severe injury than male players (HR = 8.35; 95% CI = 2.01–34.8). Slower players (adjusted HR = 3.51; 95% CI = 1.17–10.5) and less agile players (adjusted HR = 2.22; 95% CI = 1.26–3.92) had a significantly increased risk to serious injury. Lower hip flexors flexibility showed a trend toward risk of severe injuries (adjusted HR = 1.12; 95% CI = 1.00–1.25; Table 2).

4. Discussion

This prospective study examined the injury incidence and risk factors for injuries in university athletes on rugby-7s teams. We report the injury incidence, injury types, and nature of injuries these players sustained over one rugby season. The main findings of this study were that female gender, slower speed, decreased agility are predictors for severe rugby-related injuries resulting in a time loss of >28 days. Our study differs from others,[9,10,24] in that we considered only severe injuries for analysis of risk factors. Due to the contact nature of the game, minor to moderate injuries are relatively common. However, we believe that surveillance of more severe injuries is important, particularly as these may have major consequences to the athlete's playing career.

The incidence and severity of injury were considerably lower compared to those reported for 7s players at the professional level.[4] However, the match injury incidence (59.3 injuries per 1000 player hours) is similar to previously reported for amateur players during the course of a rugby-7s tournament series season (55.4 injuries

Table 2
Risk factors from Cox proportion hazard regression model for severe injuries.

Predictor variables	[a]Injured ($n = 9$)	Not injured ($n = 95$)	[b]Spearman's rho coefficient	Cox regression model	
				Adjusted HR (95% CI)	p
Gender (M:F)	5:4	85:10	−0.28	8.35 (2.01–34.8)	0.004*
Height (cm)	168.7 ± 9.50	173.0 ± 6.42	−0.23		
Previous injury (Y:N)	7:2	39:56	0.21		
Isometric mid-thigh pull test (kg)	110.0 ± 17.7	143.0 ± 38.2	−0.28		
Single leg bridge test (sum of two sides, in reps)	54.9 ± 13.6	70.7 ± 26.0	−0.20		
Vertical jump test (cm)	44.7 ± 7.41	57.8 ± 9.20	−0.35		
40 m speed test (s)	6.13 ± 0.50	5.84 ± 0.51	0.18	3.51 (1.17–10.5)	0.025*
Illinois test (s)	17.6 ± 1.30	16.7 ± 1.09	0.19	2.22 (1.26–3.92)	0.006*
Thomas test (sum of two sides, in degree)	26.7 ± 6.10	16.6 ± 12.2	0.22	1.12 (1.00–1.25)	0.036*

HR = hazard ratio; 95% CI = 95% confidence interval
[a] Refers to severe injuries (>28 days time loss).
[b] Spearman's rho analysis was used to test the association of predictor variables to severe injuries. Nine variables with a trend for significance ($p < 0.10$) were fitted to Cox regression model.
* $p < 0.05$.

per 1000 player hours).[24] No study has documented the incidence of injury for 7s players during training. However, we observed 3.3 injuries per 1000 player-hours during training. This is comparable but slightly lower than the training incidence reported for collegiate rugby-15s players, which was 5.5 injuries per 1000 player-hours.[25]

The most commonly reported injuries occurred in the lower limbs, followed by injuries to the upper extremities. This finding is similar to the injury incidence and injury sites in international rugby-7s tournament players[4] but the incidence is greater than for amateur rugby-7s tournament players.[24] However comparison among studies is difficult since the level of play, injury definition and study period are markedly different. In our study, tackling or being tackled resulted in more than half of the injuries. Injuries that result from tackling usually are in the head, neck, or shoulder regions.[26] Of the 6 shoulder injuries we observed, 5 were due to tackles, and all 4 head and face injuries were a result of tackling. Tackling techniques have been found to improve in more experienced players.[27] Players in our cohort had less than 2 years' experience playing rugby and this observation may highlight the importance of emphasizing proper execution of tackling techniques. In addition, there is a clear need for research into the biomechanics and injury mechanisms of tackles with the goal of reducing the associated risk. The most common type of injury was to ligaments, which accounted for about half of all injuries and is consistent with previous findings from amateur rugby union studies.[24,25]

Our study also revealed that 50% of the severe injuries occurred in the first 21.8 h of the season. The transition from off-season to high-volume and high-intensity training without sufficient preparation early season can cause injuries. A proper periodization schedule to gradually increase the training intensity could ensure that players have enough time to build physical fitness to adapt to new loads imposed on the body. Significant differences in aerobic power, speed, muscular power and body fat have been reported between professional and amateur rugby-15s players.[28] Gabbett and Domrow[9] found that lower speed (odds ratio = 9.93) and maximal aerobic power (odds ratio = 6.20) increased the risk of contact injury in amateur rugby league players. Although the physical characteristics of rugby-7s players have been examined,[3] at present, there is no study of the relationship between physical qualities and severe injury risk in amateur players. Results from the present study suggest that speed and agility, as reflected in the 40-m speed test and the Illinois agility test respectively, were strong risk factors for serious injuries. The less agile and slower players had a 2- or 3.5-fold increased risk for severe injury, respectively. Greater injury risk in players slower in speed and agility may reflect their reduced ability to position themselves quickly and correctly before the tackle. The speed characteristics of rugby-7s and 15s players have been reported to be similar over standardized distances (for example, 10 m, 40 m),[3] but acceleration appears to be an important component in rugby sevens. Further studies should examine the acceleration characteristics in rugby-7s players. The incorporation of cognitive components such as decision-making in the agility test will also be useful in discriminating players' abilities. Findings in our study also suggest that the development of speed and agility may help to reduce the risk of severe injuries.

This study also reviewed that female players were at an approximately 8-fold higher risk of serious injuries than males, in agreement with other studies.[26,29] For instance, a recent injury surveillance study[29] of the USA Rugby-7s tournament series revealed that in a multiple-match tournament, 93% of all severe injuries occurred in female players during the last match. Non-elite female players also sustained more severe injuries than elite female players (means: 48.4 days time loss vs. 22.7 days time loss). Furthermore, the incidence of head and neck injuries in females (16% of all injuries) was higher than in male rugby-7s players (5% of all injuries). A limitation of the study was that the sample size for female players was small ($n = 14$). As the popularity of women's rugby continues to grow worldwide,[1] further research would aid in identifying risk factors and in establishing gender-specific injury prevention strategies.

There was a small association of hip flexor flexibility with injury risk in this study. Hip flexor tightness has been associated with lower extremity injury in male collegiate athletes participating in various sports.[30] As different sports have specific inherent injury risks, further work is required to clarify the role of iliopsoas tightness in rugby-related injuries.

There are several limitations to this study. The physical test results were collected before the season started and may have changed throughout the playing season. The sample size of the study is relatively small, limiting its statistical power. Areas for further study include injury surveillance throughout consecutive seasons with a larger sample size and inclusion of more female rugby players.

5. Conclusion

In this study, we report the incidence and severity of injury to university athletes during training and match play of rugby-7s over a rugby season. Female gender, reduced agility, reduced speed, and tightness of the hip flexors were all predictors of severe injuries. Identifying players at risk of injury before the season begins and implementing individualized injury prevention measures may reduce severe rugby-related injuries.

Practical implications

- Injury risk between players in rugby-15s and rugby-7s; and those participating at professional vs. amateur level is different.
- Slower speed and reduced agility account for increased risk factors for serious injuries.
- Female players are at a greater risk of serious injuries.
- Pre-season and regular assessment of speed and agility may help to identify high-risk players. Injury prevention countermeasures can be implemented to reduce risk of injury.

Acknowledgments

This study was supported by the Hong Kong Polytechnic University Block Grant (1-ZVFA). The authors would like to acknowledge the valuable support and assistance from the rugby teams of the Hong Kong Polytechnic University, City University of Hong Kong and the Education University of Hong Kong. We also would like to thank the Hong Kong Rugby Union for providing liaisons between parties and continued support throughout the study.

References

1. World Rugby. 2016-2020 World rugby strategic plan. Available at http://www.worldrugby.org/strategic-plan. [Accessed 29 July 2016].
2. NCAA Sports sponsorship and participation rates report—October 2015. Available at https://www.ncaapublications.com/p-4445-2015-16-ncaa-sports-sponsorship-and-participation-rates-report.aspx. [Accessed 29 July 2016].
3. Ross A, Gill N, Cronin J. Match analysis and player characteristics in rugby sevens. *Sports Med* 2014; 44(3):357–367.
4. Fuller CW, Taylor A, Molloy MG. Epidemiological study of injuries in international rugby sevens. *Clin J Sport Med* 2010; 20(3):179–184.
5. Fuller CW, Taylor A, Raftery M. Epidemiology of concussion in men's elite Rugby-7s (Sevens World Series) and Rugby-15s (Rugby World Cup, Junior World Championship and Rugby Trophy, Pacific Nations Cup and English Premiership). *Br J Sports Med* 2015; 49(7):478–483.
6. Quarrie KL, Alsop J, Waller AE et al. The New Zealand rugby injury and performance project. VI. A prospective cohort study of risk factors for injury in rugby union football. *Br J Sports Med* 2001; 35(3):157–166.
7. Brooks JHM, Kemp SPT. Injury-prevention priorities according to playing position in professional rugby union players. *Br J Sports Med* 2011; 45(10):765–775.
8. Chalmers DJ, Samaranayaka A, Gulliver P et al. Risk factors for injury in rugby union football in New Zealand: a cohort study. *Br J Sports Med* 2012; 46(2):95–102.
9. Gabbett TJ, Domrow N. Risk factors for injury in subelite rugby league players. *Am J Sports Med* 2005; 33(3):428–434.
10. Gabbett TJ, Ullah S, Finch CF. Identifying risk factors for contact injury in professional rugby league players—application of a frailty model for recurrent injury. *J Sci Med Sport* 2012; 15(6):496–504.
11. Gabbett TJ. Severity and cost of injuries in amateur rugby league: a case study. *J Sports Sci* 2001; 19(5):341–347.
12. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test. *Sports Med* 2008; 38(1):37–51.
13. Baumgartner TA, Oh S, Chung H et al. Objectivity, reliability, and validity for a revised push-up test protocol. *Meas Phys Educ Exerc* 2002; 6(4):225–242.
14. Coldwells A, Atkinson G, Reilly T. Sources of variation in back and leg dynamometry. *Ergonomics* 1994; 37(1):79–86.
15. Freckleton G, Cook J, Pizzari T. The predictive validity of a single leg bridge test for hamstring injuries in Australian Rules Football Players. *Br J Sports Med* 2013; 48:713–717.
16. Johnson BL, Nelson JK. *Practical measurements for evaluation physical education*, 3rd ed. Minneapolis, Burgess Pub. Co, 1979.
17. Glaister M, Hauck H, Abraham CS et al. Familiarization, reliability, and comparability of a 40-m maximal shuttle run test. *J Sports Sci Med* 2009; 8(1):77.
18. Hachana Y, Chaabène H, Nabli MA et al. Test-retest reliability, criterion-related validity, and minimal detectable change of the Illinois agility test in male team sport athletes. *J Strength Cond Res* 2013; 27(10):2752–2759.
19. 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.
20. Ayala F, de Baranda PS, Croix MDS et al. Reproducibility and criterion-related validity of the sit and reach test and toe touch test for estimating hamstring flexibility in recreationally active young adults. *Phys Ther Sport* 2012; 13(4):219–226.
21. Peeler J, Anderson JE. Reliability of the Thomas test for assessing range of motion about the hip. *Phys Ther Sport* 2007; 8(1):14–21.
22. Fuller CW, Laborde F, Leather R et al. International rugby board rugby world cup 2007 injury surveillance study. *Br J Sports Med* 2008; 42(6):452–459.
23. Fuller CW, Molloy MG, Bagate C et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med* 2007; 41(5):328.
24. Lopez V, Galano GJ, Black CM et al. Profile of an American amateur rugby union sevens series. *Am J Sports Med* 2012; 40(1):179–184.
25. Kerr HA, Curtis C, Micheli LJ et al. Collegiate rugby union injury patterns in New England: a prospective cohort study. *Br J Sports Med* 2008; 42(7):595–603.
26. Peck KY, Johnston DA, Owens BD et al. The incidence of injury among male and female intercollegiate rugby players. *Sports Health* 2013; 5(4):327–333.
27. Hendricks S, Jordaan E, Lambert M. Attitude and behaviour of junior rugby union players towards tackling during training and match play. *Saf Sci* 2012; 50(2):266–284.
28. Gabbett TJ. Physiological and anthropometric characteristics of amateur rugby league players. *Br J Sports Med* 2000; 34(4):303–307.
29. Ma R, Lopez Jr V, Weinstein MG et al. Injury profile of American Women's Rugby-7s. *Med Sci Sports Exerc* 2016; 48(10):1957–1966.
30. Krivickas LS, Feinberg JH. Lower extremity injuries in college athletes: relation between ligamentous laxity and lower extremity muscle tightness. *Arch Phys Med Rehabil* 1996; 77(11):1139–1143.