

Preseason muscle strength tests in the assessment of shoulder injury risk in collegiate rugby union players

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This study was conducted to provide a muscle strength cutoff value for the assessment of shoulder injury risk in collegiate rugby union players. This prospective cohort study included 28 rugby union players. During the preseason period, five muscle strength tests were performed around both shoulder joints: one repetition maximum (1RM) bench press, 1RM shoulder press, internal rotational (IR), external rotational (ER) isometric muscle strength, and abductor (ABD) isometric muscle strength. Following the preseason tests, the occurrence of time-loss shoulder injury was recorded during the 2011–2012 season. The cutoff values for muscle strength test were determined by receiver operating characteristic curve analysis. Seven players sustained shoulder injuries during the season. The respective cutoff values for the preseason tests were as follows: 1RM bench press = 1.20 kg/body mass (area under the curve [AUC], 0.67; Sensitivity, 71.4%; Specificity, 61.9%), 1RM shoulder press = 0.70 kg/body mass (AUC, 0.69; Sensitivity, 51.7%; Specificity, 81.0%), IR = 2.80 N/body mass (AUC, 0.64; Sensitivity, 92.9%; Specificity, 35.7%), ER = 2.60 N/body mass (AUC, 0.62; Sensitivity, 85.7%; Specificity, 38.1%), and ABD = 1.60 N/body mass (AUC, 0.69; Sensitivity, 85.7%; Specificity, 52.4%). Findings suggest that these cutoff values may be useful for preseason assessment of shoulder injury risk in collegiate rugby union players.

Keywords: Prospective cohort study, Pre-screening, Shoulder muscle strength, Cutoff value

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1. Introduction

Rugby union is a contact and collision sport with a high incidence of player injury (Nicholl, et al., 1995). The incidence of player injury in Australian professional rugby union was reported to be 69 injuries/1000 player-hours (Bathgate, et al., 2002). The most common tackles in rugby are responsible for the greatest number of injuries (Haseler, et al., 2010; Quarrie, & Hopkins, 2008; Schneiders, et al., 2009). Usman et al. (2011) reported that the mean maximum shoulder impact force was 1997 N in active tackles in rugby union.

Shoulder injuries are highly prevalent in rugby union (Bohu, et al., 2014; Brooks, et al., 2005a; Brooks, et al., 2005b; Fuller, et al., 2008; Headey, et al., 2007; Usman, et al., 2015), with an incidence in Super Rugby matches of 13 injuries/1000 player-

hours (Usman, et al., 2015). Headey et al. (2007) presented epidemiological data on time-loss shoulder injuries in professional rugby union players: The most common types of shoulder damage during rugby matches are rotator cuff/shoulder impingement (2.03 injuries/1000 player-hours) and dislocation/instability (1.25 injuries/1000 player-hours). In addition, shoulder dislocations/instability are the most severe shoulder injuries (Brooks, et al., 2005b), have a high rate of recurrence (Chalidis, et al., 2006; Wen, 1999), and are likely to require surgical repair (Bathgate, et al., 2002; Brooks, & Kemp, 2008; Headey, et al., 2007).

The shoulder rotator cuff muscles are partially responsible for the dynamic stability of the shoulder joint (Codine, et al., 1997). A decrease in the strength of the shoulder rotator cuff muscles is reportedly an intrinsic risk factor for shoulder injury among

Japanese collegiate rugby union players (Ogaki, et al., 2014a; Ogaki, et al., 2014b). However, it is important to carefully consider all of the major muscles involved (e.g., pectoralis major and deltoid muscles), and not merely the rotator cuff because tacklers receive high external resistance to the shoulder. Increasing the strength of the rotator cuff and the major shoulder muscles may help to decrease the incidence of shoulder injury in rugby players.

Shoulder rotator cuff muscle exercises and high-intensity strength training are widespread in the field of sports training, and shoulder muscle strength/weakness can be used to evaluate the risk of shoulder injury. This strength training should have cutoff values to prevent shoulder injury; and it is important for these cutoff values to be determined before the start of a new rugby season to assess the risk of injury. Additionally, these cutoff values could become the target value of strength training in rugby union.

The purpose of this study was to provide cutoff values for muscle strength for the assessment of shoulder injury risk in collegiate rugby union players. This will inform the development of strategies for evidence-based injury prevention in rugby union players.

2. Methods

2.1. Subjects

This prospective cohort study included 28 rugby union players from one university club. The groups comprised forwards ($n = 16$: prop, 5; hooker, 2; lock, 4; flanker, 4; number 8, 1) and backs ($n = 12$: scrum half, 3; standoff, 3; centre, 3; wing, 2; full back, 1). **Table 1** summarizes the physical characteristics of the subject players. Players with a history of shoulder surgery or injury, anterior joint instability, complaint of shoulder pain during the muscle strength tests, or

injury prior to the study were excluded as subjects. The Ethics Committee of the Graduate School of Comprehensive Human Sciences at the University of Tsukuba approved this study, and all players provided written informed consent before participation.

2.2. Procedures

All subject players underwent preseason muscle strength tests. Following the preseason tests, the occurrence of time-loss shoulder injury was recorded during the 2011–2012 playing season by the team's athletic trainers. This study was designed to consider only time-loss injury (Fuller, et al., 2007), which is defined as any injury that prevents a player from fully participating in a subsequent training session or rugby match. Shoulder dislocation/subluxation or rotator cuff injuries were included as injuries. All injured players were clinically diagnosed by imaging studies, including MRI scan, CT scan, and X-ray. After playing the season, all subject players were classified as injured or non-injured players. The team's athletic trainers recorded the numbers of matches and training sessions. The injury rate was defined as the number of injuries per 1000 player-hours of exposure time (match exposure and training exposure).

2.3. Muscle strength tests

During the preseason period, five muscle strength tests were performed around both shoulder joints: one repetition maximum (1RM) bench press, 1RM shoulder press, internal rotational (IR) isometric muscle strength, external rotational (ER) isometric muscle strength, and abductor (ABD) isometric muscle strength.

For the 1RM bench press, the players lay in a supine position and pushed the bar upward from the chest until the elbows were fully extended. Further,

Table 1 Physical characteristic of subjects

	Age (year)	Height (cm)	Body mass (kg)	Body fat (%)	Rugby experience (year)
FW, $n = 16$	20.3 ± 0.8	177.9 ± 6.6	94.2 ± 11.9	23.0 ± 4.1	7.2 ± 2.9
BK, $n = 12$	19.8 ± 0.7	173.1 ± 5.6	76.7 ± 5.6	17.7 ± 3.7	10.3 ± 3.1
(All, $n = 28$)	20.1 ± 0.8	175.8 ± 6.7	86.7 ± 13.2	20.8 ± 4.8	7.7 ± 3.6

Data shown as mean values \pm standard deviation; FW, forwards; BK, backs

the players stood up for the 1RM shoulder press, and pushed the bar upward until the elbows were fully extended, with the bar beginning at clavicle and anterior deltoid height. All measurement values were calculated in terms of the body mass ratio (kg/body mass).

A handheld dynamometer (micro-FET; Hoggan Health Industries, Draper, UT, USA) was used to measure isometric muscle strength during shoulder IR, ER, and ABD. Shoulder IR and ER muscle strength were measured with the player in a supine position with 90-degree shoulder abduction and 90-degree elbow flexion. Shoulder ABD muscle strength was measured with the player standing, with 30-degree shoulder abduction (**Figure 1**). A dynamometer was applied to the wrist joints of subject players, and isometric contraction was continued for 3s. Isometric muscle strength was measured by the same athletic trainer. All measurement values were calculated in terms of the body mass ratio (N/body mass).

2.4. Statistical analysis

The intra-rater reliability of isometric muscle strength tests was assessed using intra-class correlation coefficients (ICC) (1, 1). All tests were compared between injured and non-injured players using unpaired Student's t-tests. We calculated the effect size using Cohen's d. The cutoff values for the muscle strength tests were determined by receiver operating characteristic (ROC) curve analysis. Statistical analysis was performed using IBM SPSS statistics version 20 package (IBM Japan. Inc., Tokyo, Japan) and the significance level was set at $p < 0.05$.

3. RESULTS

3.1. Number of shoulder injuries

There were 11,320.2 hours of exposure, including match exposure (36 matches, 402.7 hours) and training exposure (216 sessions, 10,917.5 hours). Seven players (forwards = 6; backs = 1) sustained shoulder injuries to the right or left shoulder during the playing season. All shoulder injuries occurred during training sessions. The incidence of shoulder injury was 0.62 injuries/1000 player-hours (95% confidence interval [CI], 0.16–1.08); the incident of shoulder dislocation/subluxation was 0.27 injuries/1000 player-hours (95% CI, 0.00–0.56); and the incident of shoulder rotator cuff injuries was 0.35 injuries/1000 player-hours (95% CI, 0.01–0.70) (**Table 2**).

3.2. Results of the shoulder muscle strength tests

The 1RM bench press results revealed no significant difference between injured players (1.10 ± 0.2 kg/body mass) and non-injured players (1.23 ± 0.1 kg/body mass) ($p = 0.06$; effect size, 1.00) (**Figure 2**). Conversely, 1RM shoulder press values were significantly lower in injured players (0.66 ± 0.1 kg/body mass) than in non-injured players (0.76 ± 0.1 kg/body mass) ($p = 0.01$; effect size, 1.00) (**Figure 2**).

ICC (1, 1) results showing the intra-rater reliability of the isometric muscle strength tests were as follows: IR = 0.89 (95% CI, 0.77–0.95), ER = 0.81 (95% CI, 0.64–0.91), and ABD = 0.92 (95% CI, 0.84–0.96).

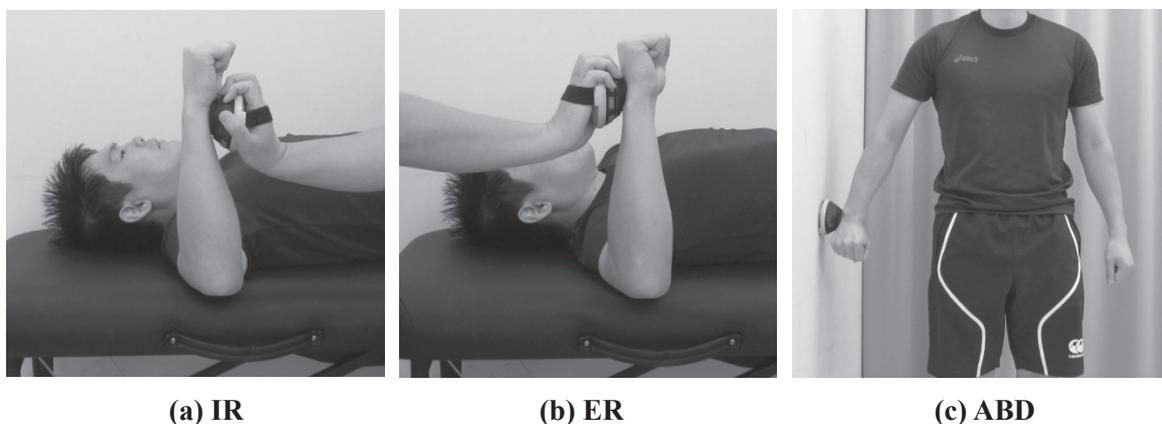
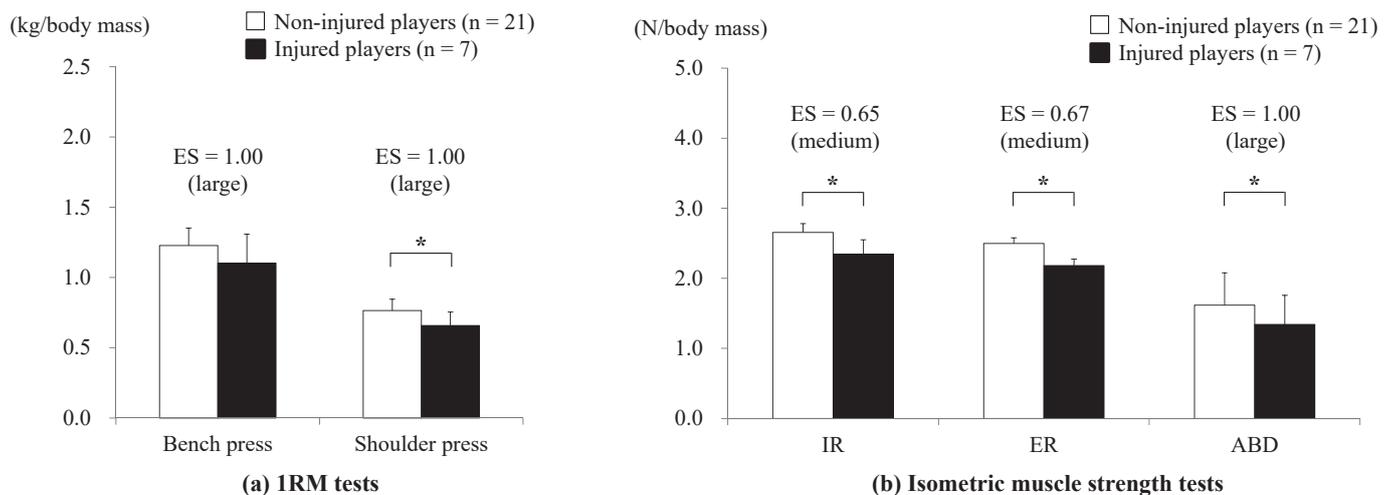


Figure 1 Position of isometric muscle strength tests (a, b, c)
IR, internal rotation; ER, external rotation; ABD, abduction

Table 2 Number of shoulder injuries during the 2011–2012 season

	Injury number (n)	Injury incidence [95% CI] (/1000 player-hours)	Severity (day)
Dislocation/subluxation	3	0.27 [0.00–0.56]	51.0 ± 21.0
Rotator cuff injuries	4	0.35 [0.01–0.70]	17.5 ± 16.0
(All)	7	0.62 [0.16–1.08]	31.9 ± 24.4

CI, Confidence interval; Severity data shown as mean values ± standard deviation

**Figure 2** Results of muscle strength tests (a, b)

1RM, one repetition maximum; IR, internal rotation; ER, external rotation; ABD, abduction; *p* values, unpaired Student's *t*-tests for differences between groups; * *p* < 0.05 (non-injured players vs. injured players); effect size by Cohen's *d*; large, < 0.80; medium, < 0.50

IR, ER, and ABD isometric muscle strengths were all significantly lower in injured players than in non-injured players (2.35 ± 0.4 vs. 2.66 ± 0.5 N/body mass, $p = 0.03$, effect size, 0.65; 2.18 ± 0.4 vs. 2.50 ± 0.5 N/body mass, $p = 0.04$, effect size, 0.67; and 1.34 ± 0.2 vs. 1.62 ± 0.3 N/body mass, $p = 0.01$, effect size, 1.00, respectively) (Figure 2).

3.3. Results of ROC curve analysis

Figure 3 shows the ROC curve for muscle strength tests (Figure 3). The respective cutoff values for the preseason tests were as follows: 1RM bench press = 1.20 kg/body mass (AUC, 0.67; Sensitivity, 71.4%; Specificity, 61.9%), 1RM shoulder press = 0.70 kg/body mass (AUC, 0.69; Sensitivity, 51.7%; Specificity, 81.0%), IR isometric muscle strength = 2.80 N/body mass (AUC, 0.64; Sensitivity, 92.9%;

Specificity, 35.7%), ER isometric muscle strength = 2.60 N/body mass (AUC, 0.62; Sensitivity, 85.7%; Specificity, 38.1%), and ABD isometric muscle strength = 1.60 N/body mass (AUC, 0.69; Sensitivity, 85.7%; Specificity, 52.4%) (Table 3).

4. DISCUSSION

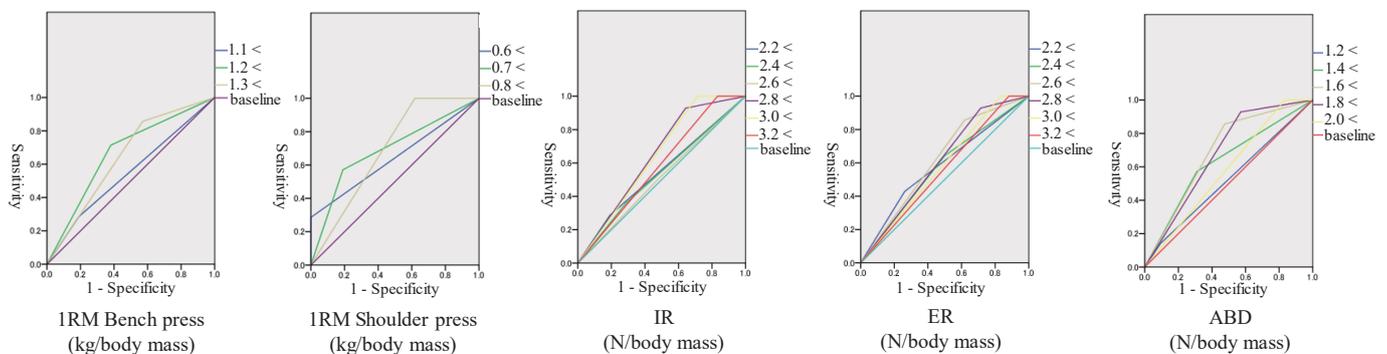
The present study aimed to provide a cutoff value for muscle strength for the assessment of shoulder injury risk in collegiate rugby union players via a single-season prospective cohort study design. The majority of the muscle strength test results during the preseason period were significantly lower in injured players than in non-injured players, suggesting that these cutoff values may be useful for the assessment of shoulder injury risk.

The 1RM shoulder press value was significantly

Table 3 Cutoff values for muscle strength tests

Strength tests	Cutoff value	AUC	Sensitivity (%)	Specificity (%)	<i>p</i> value
1RM bench press (kg/body mass)	1.20	0.67	71.4	61.9	0.19
1RM shoulder press (kg/body mass)	0.70	0.69	51.7	81.0	0.13
IR isometric muscle strength (N/body mass)	2.80	0.64	92.9	35.7	0.11
ER isometric muscle strength (N/body mass)	2.60	0.62	85.7	38.1	0.18
ABD isometric muscle strength (N/body mass)	1.60	0.69	85.7	52.4	0.03 *

ROC, receiver operating characteristic; 1RM, one repetition maximum; IR, internal rotation; ER, external rotation; ABD, abduction; AUC, area under the curve; * $p < 0.05$

**Figure 3** Results of ROC curve for muscle strength tests

IR, internal rotation; ER, external rotation; ABD, abduction

lower in injured players than non-injured players, whereas no significant difference was found in 1RM bench press between injured and non-injured players; however, a large effect size was observed. Powerful muscle strength is necessary for the prevention of shoulder injury in rugby because the shoulder is subjected to high external force. Specifically, the mean maximum shoulder impact force was found to be 1997 N during active tackles (Usman, et al., 2011).

Shoulder injuries resulted from trauma with the elbow in an extended position, forcing the shoulder and the abducted arm behind the player during the tackle (Crichton, et al., 2012; Longo, et al., 2011). The pectoralis major and deltoid muscles resist hyperextension of the shoulder during tackles. These strength tests can also be used as upper body/core exercises during strength training (Appleby, et al., 2012; Smart, & Gill, 2013); and in addition to risk assessment during the preseason period, they can be easily employed to monitor progress during in-season

conditioning.

Shoulder IR, ER, and ABD isometric muscle strengths were significantly lower in injured players than in non-injured players. The shoulder rotator cuff muscles are partially responsible for the dynamic stability of the shoulder joint (Codine, et al., 1997) by ensuring permanent centering of the humeral head. The injured players in the present study were likely at high risk of shoulder injury due to poor muscular strength in the rotator cuff, and recent research has confirmed this hypothesis (Ogaki, et al., 2014a; Ogaki, et al., 2014b). These types of shoulder muscle strength tests may be useful for the assessment of shoulder injury risk.

The intra-rater reliability of the isometric muscle strength tests was higher than 0.8 for all tests. Isometric muscle strength testing using a handheld dynamometer was effective in previous studies of other sports such as baseball (Byram, et al., 2010; Donatelli, et al., 2000), handball (Clarsen, et al.,

2014), and football (Pontillo, et al., 2014). This muscle strength measurement is easier to apply in the field than isokinetic measurements are.

Imbalances in shoulder rotator cuff muscle strength have been reported as a risk factor for shoulder injury in overhead sports (Chandler, et al., 1992; Edouard, et al., 2013; Stickley, et al., 2008). However, previous studies have not reported rotator muscle imbalance in rugby players as a possible risk factor for shoulder injury (Edouard, et al., 2009; Ogaki, et al., 2014b). It may be that maximum muscle strength is more important than the balance of rotator muscles because rugby is a contact and collision sport. In the present study, shoulder rotator cuff strength of the injured players was low. When evaluating the risk of shoulder injury in rugby union players, therefore, it is possible that maximum muscle strength is more important than muscle balance.

The AUCs of the cutoff values for muscle strength tests were all lower than 0.7. ROC curve analysis usually regards 0.7 as the standard. Therefore, the predictability of individual test results is low for these muscle strength tests; and this is likely due to various injury-related factors (internal and external risk factors, as well as specific inciting events) (Bahr, & Krosshaug, 2005). Thus, it is difficult to predict injury using muscle strength tests alone, and these cutoff values should be used as an absolute baseline in screening to identify high-risk players. The examiner should evaluate risk of injury from the results of strength tests for several muscles rather than on the basis of one muscle only.

The cutoff values for the isometric muscle strength tests were highly sensitive. Assessment of shoulder injury risk using these muscle strength tests may result in false positive results. Therefore, these cutoff values should only be used as a screening method as they may prevent shoulder injuries by identifying high-risk players. On the other hand, the 1RM shoulder press was highly specificity. Thus, both strength test types (1RM test and isometric test) may be necessary to increase the accuracy of assessment. Further examination is required to assess the order of priority of muscle strength tests.

The cutoff values from this study may be low for application at the professional level. Generally, when the level of competition increases, the muscular strength level also increases (Argns, et al., 2012). As the subjects in this study were collegiate rugby union players, these cutoff values should only be used for

collegiate-level and/or youth-level players. Future studies should determine the different cutoff values for each competition level. However, as collegiate rugby has a high incidence of recurrent shoulder dislocation/subluxation (Chalidis, et al., 2006; Wen, 1999), the prevention of shoulder injury for this level of competition is an important issue.

The intrinsic risk factors for shoulder injury are reported to be a history of previous injury and anterior joint instability (Ogaki, et al., 2014a; Owens, et al., 2014). We also considered these intrinsic risk factors. A history of injury and anterior joint instability may be confounding factors for muscle strength. Weak muscular strength remains after shoulder dislocation and/or rotator cuff injury (Edouard, et al., 2011); therefore, players with a history of injury or anterior joint instability were excluded from this study. As a result, players who had low levels of muscular strength were classified as high risk because the effect sizes for all the muscle strength tests were stronger than medium. However, the cutoff values for the muscle strength tests may be different in players with a history of injury or anterior joint instability.

This study showed that preseason muscle strength tests may be useful for the assessment of shoulder injury risk in collegiate rugby union players. These tests and the cutoff values may be applied to injury risk assessment during physical examination before the start of a new rugby season. Shoulder rotator cuff muscle exercises and high-intensity upper body strength training are common forms of conditioning training for rugby union. The 1RM bench press and shoulder press are already upper body/core exercises commonly used in strength training programs. Because they performed during team training, they are easy to perform following change. Moreover, these cutoff values may be used to assess whether players are ready to return to play after shoulder injury.

There are several limitations to the present study. First, it investigated a single rugby union team, and cutoff values may differ according to the competition level. Second, only shoulder injuries, more specifically, shoulder dislocation/subluxation and rotator cuff injuries, were studied. Third, the study did not consider the effect of in-season strength training. Future research should assess appropriate interventions to reduce the risk of other sports injuries (van Mechelen, et al., 1992). Whether improvement of shoulder muscle strength effectively reduces

shoulder injury incidence also needs to be confirmed.

5. Conclusion

The present study aimed to provide a cutoff value for muscular strength for the assessment of shoulder injury risk in collegiate rugby union players via a single-season prospective cohort study. Results suggest that these cutoff values are useful for preseason assessment of shoulder injury risk in collegiate rugby union players.

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