別紙様式１（修士申請者用）

修 士 学 位 論 文

Relationship between Shoulder Joint Instability and Physical Performance in High School Rugby Players

高校ラグビー選手における肩関節不安定性と身体機能の関連

（注：学位論文題名が英語の場合は和訳をつけること。）

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Abstract

Rugby football (rugby) is one of the famous collision sports. Of all shoulder joint dislocations, 60% occur during tackles. Many studies have reported that improvement of the tackling skill prevents shoulder joint dislocation. Moreover, there are external and internal risk factors of shoulder joint dislocation have been identified. In Japan, many players start playing rugby in high school. Rugby requires excellent aerobic capacity and high power of the upper limbs for tackle. Therefore, as the rugby career gets longer, some players develop unstable shoulders because of muscle imbalance and deficit shoulder range. The purpose of this study was to clarify the relationship between shoulder joint instability and physical function based on shoulder muscle strength, range of motion, and Upper Quarter Y-Balance Test (UQYBT) results among high school rugby players. For statistical analysis, an independent *t* test was used for intergroup comparison. For a subgroup analysis, the subjects were divided into three groups according to grade. One-way analysis of variance was used.

Sixty-five players participated in this study (age, 16–18 years). Players were divided into the normal and instability groups according to the results of the anterior apprehension and scapula dyskinesis tests. Forty-nine subjects were included in the normal group; and sixteen, in the instability group. ER range at the 2nd position was a significant difference in the group comparison. There was no significant difference in the other range, muscle strength, UQYBT. For the subgroup analysis, third-grade students had significantly larger IR ranges and lower ER ranges.

In conclusion, 30% of the players with shoulder instability had a limited ER range at the 2nd position. When examining by grade, we found the limited shoulder ER range restricted the physical function of the third-grade students. These findings were influenced by the characteristics of rugby and training. We will clarify of initial injury to shoulder dislocation by conducting a follow-up survey in the future.

Key words: Rugby Player, Shoulder Joint Instability, Rugby Career

Ⅰ. Introduction

Rugby football (rugby) is one of the famous collision sports, which is associated with various traumas of the shoulder joint [1]. Shoulder joint dislocation is the most common and severe shoulder injury. Moreover, 60% of shoulder joint dislocation occurs during tackle[2,3]. Shoulder joint dislocation in rugby caused forward dislocation of the Glenohumeral (GH) joint by forceful shoulder joint external rotation (ER) and horizontal extension (HE) during tackle or falls. Players with low tackling skill are more likely to suffer injury and experienced shoulder joint dislocation for the first time at age below 21[4], which may lead to recurrences of shoulder joint dislocation[5]. Therefore, improving player's tackling skill is important to prevent associated shoulder joint injuries[6]. Some aspects of sports rehabilitation after shoulder joint dislocation include improvement of tackling skill, (1) posture, (2) aim the square, (3) upper limb position, (4) gaze, (5) power foot, (6) shrug, (7) head position, and (8) lock on[7]. In addition, high school students with low tackling skill are prone to shoulder joint dislocation; once they experienced such injury, their fear of tackle becomes stronger, and when they tackle, the approach is not good[8]. According, many studies reported the improvement of the tackling skill prevent shoulder joint dislocation, and prevention of recurrence. However, external risk factors have been reported, including the type of play, position, practice amount, playing time, ground surface, etc[9, 10, 11]. In contrast, the reported internal risk factors were followed, (1) a history of shoulder trauma, (2) load and shift test, and (3) shoulder internal muscle and external muscle strength ratio. Players with a history of shoulder trauma have odds ratio of shoulder joint injury risk of 6.56 points in one season. In addition, a history of shoulder joint trauma, instability of the shoulder joint, decrease in range of motion (ROM), and muscle weakness influence the risk of recurrence[12, 13]. Among them, the shoulder internal rotation (IR)/ER muscle strength ratio is important for maintaining the stability of the GH joint[12]. Ogaki reported that the risk of trauma to the shoulder joint increases by 1.39 times when the ratio of shoulder joint IR/ER muscle strength increases by 1.0 point[12]. Moreover, improvement of shoulder muscle imbalance is necessary for prevention.

Furthermore, Nemoto investigated university rugby players for history of shoulder dislocation, fear of shoulder joint dislocation during daily life, strength training, and duration of playing rugby[14]. Some players performed inadequate training and less self-care, which lead to muscle imbalance[14]. The bias in the contents of usual muscle strength training also influences muscle imbalance, which might promote instability of the shoulder joint.

In Japan, many players start playing rugby in high school. Rugby requires excellent aerobic capacity and high power of the upper limbs for tackle. Therefore, as the rugby career gets longer, some players have unstable shoulder because of muscle imbalance and deficit shoulder ROM. In this population, shoulder joints can easily dislocate compared to players who do not have muscle imbalance and ROM deficit when a strong external force in the direction of the shoulder joint ER and HE is applied during tackle.

In this study, the anterior apprehension test (AAT) for the GH joint and scapular dyskinesis test (SDT) for the Scapular thoracic (ST) joint were employed to evaluate the instability of the shoulder joint. Kumar compared AAT results with the magnetic resonance images of 168 subjects and reported 86% sensitivity and 14% specificity of the AAT[15]. Moreover, Christiansen reported intra-rater and inter-rater reliabilities and SDT's kappa coefficients of 0.64-0.86 (95% confidence interval (CI) 0.38-0.95) and 0.59 (95% CI 0.32-0.81) as a result of SDT's intra-rater and inter-rater reliability of 45 subjects with subacromial impingement syndrome[16]. In the present study, we defined the instability of the shoulder joint by combining the results of the two tests.

The Upper Quarter Y-Balance Test (UQYBT) was used for screening the shoulder joint and trunk function[17]. UQYBT has a significant positive correlation with trunk strength such as the side bridge and has high reliability (internal correlation coefficients of 0.9 points)[18]. In rugby, a measurement method is required to comprehensively evaluate upper limb and trunk function. Therefore, UQYBT was selected for this study.

The purpose of this study was to clarify the relationship between the instability of the shoulder joint and physical function based on shoulder muscle strength, ROM, UQYBT results among high school rugby players. As a subgroup analysis, we investigate changes in physical function in every school grade.

Ⅱ. Methods

1. Subjects

Sixty-five players from the four high school rugby teams participated in this study (age, 16-18 years, first grade n = 17, second grade n = 28, third grade n = 20). Exclusion criteria were those who had a history of shoulder joint dislocation, players who had experience rehabilitation of the shoulder or trunk, and players who cannot participate in rugby activities at the time of measurement. Players were divided into the normal and instability group according to the results of AAT and SDT.

A pilot study about the intraclass correlation coefficients (ICC) of each parameter was carried out in five healthy men (age 22-35 years, height 176.9 ± 5.38 cm, weight 68.0 ± 7.77 kg). This study was approved by the Research Safety Ethics Committee of Tokyo Metropolitan University Arakawa Campus (approval no. 17089).

2. Procedure

In this study, we used questionnaire to obtain information regarding height, weight, rugby career, position in the rugby team, and health history and whether the player has dislocation of the shoulder joints. Moreover, other measurements were performed to evaluate shoulder joint instability, such as AAT, SDT, passive ROM of the shoulder joint (internal rotation: IR, external rotation: ER, horizontal flexion: HF, horizontal extension: HE), active ROM of the thoracic and lumbar spine, isometric shoulder strength (IR, ER, HF, HF), and UQYBT.

2-1. Grouping

To divide the subjects, two tests were carried out. AAT was conducted to evaluate instability of the GH joint. AAT was performed the examiner holds the wrist part of the subjects with one hand, holds it during abduction and ER of the shoulder, pushes the humeral head forward while supporting the scapula with the other hand to fully turn the shoulder joint. It was considered positive when the subject complains of pain or anxiety. Then, SDT was performed according to the method of Mcclure[19] to evaluate instability of the ST joint. In this method, subjects flex their shoulder joints for 3 s while in the standing position, and the weight of their hands was measured for 3 s. Two examiners observed the movement of the scapula from behind and classified it into three: normal, mild abnormality, and obvious abnormality. It was considered negative when evaluated "normal" and positive when evaluated "mild abnormality" and "obvious abnormality."

Players who were negative for AAT and SDT were taken as the normal group and those who were positive were regarded as the instability group. Measurements were carried out in bilateral upper limbs. The dominant side was regarded as the normal group, and one side that fulfills the criteria was the instability group. When both sides apply to the instability group, the dominant side was analyzed.

2-2. Range of motion

The results of ICC were 0.98 (IR), 0.91 (ER), 0.97 (HF), and 0.94 (HE). ROM was measured by goniometer. The position of the upper limbs was in the 2nd position, and the examiner facilitated passive movement for IR, ER, HF, and HE. Another examiner obtained measurements using a goniometer. As for the IR and ER ROM, the 3rd position was used. Measurement was carried out according to the method of the Japan Orthopedic Surgery Society which measures the IR, ER, and HE. To evaluate the tightness of the posterior joint capsule, HF was measured with reference to a previous study[20]. The measurement was done twice, and the maximum value was used for analysis.

2-3. Spinal Mouse

Measurement of the ROM of the thoracic and lumbar spine was performed using Spinal Mouse (Index, Japan), and while the subjects were in the standing position. The limb was placed in three positions: resting standing position, spinal maximum flexion, and spinal maximum extension. Measured data were calculated as the sum of the angles of the upper and lower spine bodies. The ROM of the thoracic spine was defined as the sum of angles from the first thoracic spine to the 12th thoracic spine. The ROM of the lumbar spine was defined as the sum of the angles from the first lumbar spine to the first sacral spine. The flexion angles of the thoracic spine and the lumbar spine at the spinal maximum flexion were the difference in the angle at maximum flexion from the resting standing position. Similarly, the thoracic and lumbar spine extension angles at spinal maximum extension were the difference in the angle at maximum extension from the resting standing position. For analysis, thoracic flexion angle, thoracic extension angle, lumbar flexion angle, and lumbar extension angle was used.

2-4. Isometric shoulder strength

The results of ICC were 0.80 (IR), 0.82 (ER), 0.80 (HF), 0.76 (HE). We investigated the activity of the pectoralis major using surface electromyography for same subjects. Subsequently, the pectoralis major was found to have 30% activated % muscle activities during maximal voluntary contraction.

The isometric shoulder strength of IR, ER, HF, HE were measured by a handheld dynamometer (μTas F-1, Anima Corporation, Japan). In IR measurements, we measured HHD manually in supine, and subject's shoulder in 2nd position (Fig. 1). In, ER measurement, we measured 2nd position in prone (Fig. 1). In HF measurement, we measured 90° abduction and 0° IR in shoulder, in supine (Fig. 1). In, HE measurement, we measured same shoulder position as HF, but in prone (Fig. 1). During the measurement, the contralateral upper limbs were placed on the subjects' side. Measurements were performed with the trunk and lower limbs fixed by hand.

Each measurement was performed two times by a break test, and the maximum of two values was used for analysis. Torque (Nm) was calculated using the measured value (N) and forearm length or upper arm length (m). In addition, the ratio of the IR/ER and HE/HF was calculated.

2-5. Upper Quarter Y-Balance Test

The results of ICC were 0.91 (right side) and 0.82 (left side) which were similar to those reported by Richard[18)].

UQYBT was measured according to the method described by Gray, using Y-BALANCE TEST KIT (Perform Better, Japan)[17)]. From the push-up motion with one hand support, reach was performed in three directions: medial, inferolateral, and superolateral (Fig. 2). Total reach distance was measured for the analysis, and the value obtained by the total reach in three directions by three times the upper limb length was calculated and used.

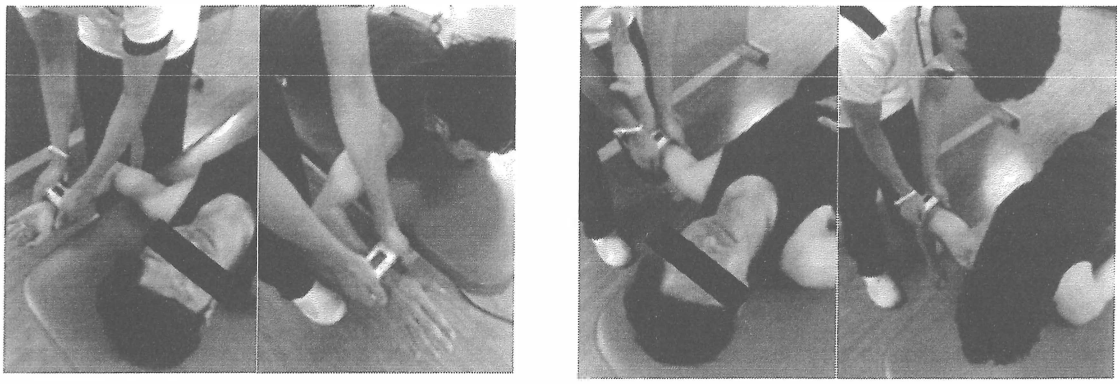

Fig.1 The method of muscle strength measurement (Left : IR and ER, Right : HF and HE)

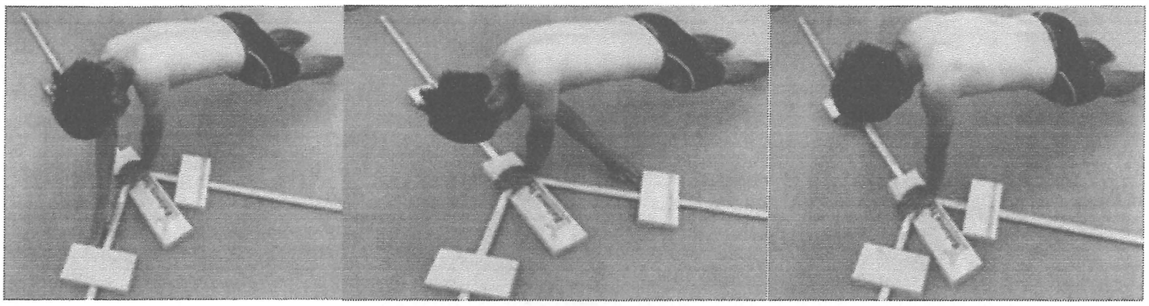

Fig.2. UQYBT

3. Statistical analysis

For statistical analysis, SPSS Statistics version 23 (IBM Corp) was used. For intergroup comparison, Shapiro–Wilk test was conducted, and independent *t* test was used for normality confirmation, and Mann–Whitney *U* test was used if normality cannot be confirmed. In addition, as a sub-analysis, subjects were divided into three groups for each grade, and the difference between the measured values for each grade was examined. After checking the normality, one-way analysis of variance or Kruskal–Wallis test was used. The significance level of all tests was set at 5%.

III. Results

There were forty nine subjects in the normal group and sixteen subjects in the instability group, with no difference in subject profiles (Table 1). In the group comparison, a significant difference in the ER range at the 2nd position was found. ER range was significantly lower in the instability group (normal group

106.1°; instability group 94.8°). There was no difference in other ROM, muscle strength, and UQYBT (Table 2).

For each grade comparison, the number of players in the instability groups of each grade were 3 (first grade), 5 (second grade), and 8 (third grade). In addition, the third grade students had significantly larger IR ROM of the 2nd position (first grade 47.7°, second grade 53.7°, third grade 59.8°), IR range of the 3rd position (first grade 101.9°, second grade 106.6°, third grade 114.3°) HF range (first grade 15.3°, second grade 19.9°, third grade 22.8°). The third year students had significantly lower ER range in the 2nd position (first grade 111.9 °, second grade 103.3°, third grade 94.9°) and ER ROM in the 3rd position (first grade 22.1°, second grade 13.33°, third grade 9.6°). For muscle strength, ER strength was significantly higher in the third grade (Table 3).

Table 1 Descriptive statistics profile for recorded variables of normal and instability players (n = 65)

	Normal (n = 49)	Instability (n = 16)	*p* value
Height (cm)	171.4 (5.42)	171.5 (5.52)	0.995
Weight (kg)	72.8 (11.18)	68.5 (9.31)	0.709
Rugby career (month)	48.1 (54.71)	43.6 (39.27)	0.709
Position (Forward or Backs)	FW22 BK29	FW8 BK8	-

*( ) = Mean (standard deviation)

Table 2 Results of Normal and Instability group

		Normal (n = 49)	Instability (n = 16)	*p* value
Shoulder	IR (2nd)	54.1 (13.76)	51.9 (13.21)	0.333
ROM	ER (2nd)	106.1 (13.15)	94.8 (19.99)	0.041*
	IR (3rd)	108.7 (10.89)	107.7 (8.20)	0.790
	ER (3rd)	14.7 (11.27)	15.1 (7.31)	0.936
	HF	103.0 (5.82)	103.6 (8.28)	0.807
	HE	18.3 (8.61)	19.2 (7.81)	0.273

Trunk ROM	Th flex	20.5 (12.47)	17.1 (7.90)	0.147
	Th ext	7.2 (9.06)	9.6 (7.98)	0.970
	L flex	59.1 (10.06)	56.7 (11.0)	0.577
	L ext	11.9 (11.94)	8.50 (11.62)	0.584
Strength	IR	33.3 (6.18)	24.3 (8.20)	0.124
	ER	24.9 (7.08)	22.2 (5.94)	0.964
	IR/ER	1.3 (0.28)	1.20 (0.57)	0.088
	HF	75.9 (14.55)	74.3 (12.5)	0.629
	HE	58.5 (11.41)	53.1 (5.64)	0.442
	HF/HE	1.31 (0.17)	1.41 (0.3)	0.879
UQYBT	Composite	88.7 (11.98)	93.1 (16.59)	0.098

ROM (degrees), strength (Nm), and UQYBT (%). *$p < 0.05$

Table 3 Comparison of each school grade (1st, 2nd, and 3rd grade).

		1st grade (n = 17)	2nd grade (n = 28)	3rd grade (n = 20)	*p* value
Demographics	Height (cm)	172.0 (5.82)	170.3 (6.37)	169.9 (4.86)	0.535
	Weight (kg)	67.0 (8.55)	69.3 (11.6)	76.0 (12.83)	0.044 *
	Rugby career (month)	4.4 (1.46)	47.5 (26.7)	80.9 (41.0)	0.0001 *
Shoulder ROM	IR (2nd)	47.7 (1.46)	53.7 (14.01)	59.8 (12.01)	0.019 *
	ER (2nd)	111.9 (8.39)	103.3 (9.91)	94.9 (16.74)	0.0004 *
	IR (3rd)	101.9 (10.12)	106.6 (7.81)	114.3 (7.28)	0.001 *
	ER (3rd)	22.1 (9.51)	13.33 (3.14)	9.6 (9.15)	0.003 *
	HF	106.2 (9.29)	107.3 (7.25)	104.8 (7.01)	0.538
	HE	15.3 (6.67)	19.9 (5.68)	22.8 (6.71)	0.008 *
Trunk ROM	Th flex	22.5 (11.77)	17.5 (10.74)	10.8 (16.26)	0.294
	Th ext	8.93 (7.59)	5.76 (10.29)	12.00 (6.89)	0.130
	L flex	57.8 (10.63)	59.2 (11.36)	58.2 (1.48)	0.485
	L ext	9.93 (17.68)	11.23 (6.70)	12.0 (7.17)	0.917
Strength	IR	30.6 (7.24)	29.4 (8.26)	34.4 (9.20)	0.120
	ER	22.8 (4.72)	20.6 (6.45)	27.4 (6.04)	0.044 *

	IR/ER	1.3 (0.48)	1.48 (0.38)	1.29 (0.38)	0.293
	HF	76.2 (9.78)	77.8 (21.46)	80.1 (15.92)	0.794
	HE	57.5 (10.22)	53.9 (14.27)	57.1 (11.10)	0.550
	HF/HE	1.3 (0.13)	1.4 (0.24)	1.4 (0.35)	0.324
UQYBT	Composite	90.3 (5.63)	90.8 (5.8)	91.6 (18.65)	0.983

Height (cm), weight (kg), career (month), range of motion (degree), strength (Nm), UQYBT (%).
$*p < 0.05$

IV. Discussion

In a player who had unstable GH joint, the ST joint had significantly low value in the ER range at the 2nd position. In rugby, the ER range of the instability group shows low values. Rugby is a representative collision sport, and high power of the upper limb is required during play for tackle, scrum, mall, etc. The shoulder joint rotation strength of rugby players were high compared with other sports players[21)]. Therefore, rugby players may have well developed anterior flexor muscles (such as pectoralis major, pectoralis minor, deltoid). The development of shoulder joint muscles has been reported to cause changes in the alignment of the scapula and limitation of the shoulder range[22)]. Accordingly, developed pectoral muscles significantly lower ER range. In addition, the results of a pilot study suggested that players may carry out biased training on a daily and disregard stretching. Therefore, considering that muscle imbalance and limited range may be caused by long career, a subgroup analysis was carried out for each school grade. Compared to first graders, third graders have significantly lower ER range for both 2nd and 3rd positions. The above-mentioned features of rugby, muscle imbalance due to biased training, and self-care deficit cause significant influence. From the above, when considered by grade level, the flexor muscle is developed during training, so that restriction is allowed in the ER range. Furthermore, in the instability group, in addition to physical changes attributed to rugby, the anterior thoracic muscles developed further to supplement the instability of the GH joint and ST joints, and in the group comparison, the shoulder joint ER value was considered low.

In the subgroup analysis, the 2nd and 3rd positions of IR and HE are significantly larger. With this, the tackle movement may have affected the shoulder joint IR and HE. During pitching motion in baseball, repeated abduction or ER in the cocking phase overstretches the lower articular brachial ligament. Damage and loosening of the GH ligament are considered strongly related to the anterior dislocation of the GH joint[23]. Moreover, in the tackle movement in rugby, a force of 1600 N is added in the HE direction of the shoulder joint [24].

The strong external force in the HE direction is repeatedly applied to the shoulder joint so that the joint capsule and other should structures are elongated similar to that in the pitching motion. The extended limb position of the GH ligament is abduction and maximum ER and IR. Internal rotator muscles become tight as the grade advances, the ER range decreased and IR range increased at the third grade. This may suppress the occurrence of joint instability because of the elongation of the joint capsule and soft tissues.

Moreover, no significant difference was observed in the flexion and extension range of the thoracic and lumbar vertebrae. Yoshida reported that changes in spinal alignment are related to the position of the scapula [24]. Posture is a key factor of tackle, and shoulder range was restricted to neck and thoracic spine flexion at the time of tackle[7]. In addition, Ogawa reported the increase in kyphosis as a feature of the tackle posture of rugby players with recurrent shoulder dislocation [6]. In our study, we measured the ROM of flex and extension of trunk. And, there was no significant difference between the groups and among the grades. Therefore, we found that the ROM of the spine does not affect shoulder instability.

There was no significant difference in the muscle strength around the shoulder between the groups. Ogaki found that the risk factor of the first shoulder joint dislocation is the ratio of the IR/ER strength[12]. In this study, to carry out a break test with manual resistance, we measured IR and HF measurements in the supine position, but ER and HE measurements in the prone position. However, in the supine position, the scapula is fixed, but not in the prone position. We speculate that there was not method of controlling the condition of the scapula fixation between measurements. Therefore, we think that it is necessary to examine the fixation method that controls scapula fixation and the muscle force measurement method at the sitting position.

Finally, there was no significant difference between groups for UQYBT. The reason is the trunk strength and diversity of actions during testing. UQYBT is a performance test that can measure upper limb and trunk function on each side[18)]. There is also a positive correlation with trunk muscle strength, trunk rotation ROM, and shoulder IR and ER strength[17, 18)]. Therefore, in the instability group, the upper limb was possibly supported by the trunk function. Another factor is the strategy diversity when UQYBT is implemented. In this test, although the starting limb position is prescribed, details of the reach operation and the order of the reach are not stipulated. Therefore, various actions can be seen during the test.

Therefore, we consider further examination such as examination by reach direction and EMG analysis during UQYBT. It will be more useful as a performance test. In addition, no studies have used UQYBT to compare the dislocation side or non-dislocation side after injury. By controlling the diversity of trunk strength and movement, left-right comparison of data and tracking measurement on the same subject is necessary.

Nevertheless, this study has some limitations. First, we could not follow the players for a long time. To clarify the causal relationship between the data measured and the initial injury in shoulder dislocation, it is necessary to evaluate the subsequent course of the instability group. Therefore, follow-up evaluation is necessary for each season. In addition, it is necessary to reconsider the measurement method regardless of whether the scapula is fixed. The UQYBT was adopted as a functional evaluation of the upper limbs and trunk. As a result, no difference between the groups was noticed, but a comprehensive evaluation of upper limb function is considered useful even though it was already considered from the previous study. In this study, since we measured only the range of the thoracic and lumbar spine, it is necessary to measure trunk strength. In addition, by comparing the dislocation side with the non-dislocation side, function evaluation after surgery, follow-up measurement, and evaluation that reflects the function of the stability of the shoulder joint and the trunk are necessary for rugby.

In Japan, many athletes start rugby at high school. Shoulder joint dislocation often occurs when tackle skill is insufficient. The results of this study suggested limitation of ER range, but we believe that continued investigation is necessary to elucidate the relation between initial injury in shoulder joint dislocation and physical function. We believe that the approach toward improving tackle skills is also important from prevention. In the future, follow-up will be conducted while examining the measurement items, and we will continue to examine factors related to the initial injury of shoulder joint dislocation.

V. Conclusion

In this study, high school rugby players who had uninjured shoulder joints were investigated for the instability of the GH and ST. Of the players, 30% players with instability had limited ER range. In addition, when examining by grade, limited shoulder ER ROM was restricted among third graders and the IR and HE ROM were increased. Moreover, these findings were influenced by the characteristics of rugby and training. We will clarify of initial injury to shoulder dislocation by conducting a follow-up survey in the future.

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＜要旨＞

ラグビーでは上肢に高負荷がかかるため、競技歴が長くなることで筋インバランスが生じ、肩関節に不安定性を有している可能性がある。本研究は、高校ラグビー選手の肩関節不安定性と身体機能の関連を調査することを目的とした。高校ラグビー選手 65 名 65 肩を対象とし、Anterior Apprehension Test、Scapula Dyskinesis Test の結果より正常群、不安定群に群分けした。肩・体幹の関節可動域、肩関節周囲の筋力、Upper Quarter Y-Balance Test を測定し、群間比較を行った。また、サブグループ解析として学年毎に比較した。群間比較においては、肩外旋可動域が有意に低かった。学年毎の比較では、高校 3 年生の肩内旋可動域は有意に大きく、肩外旋可動域は有意に低かった。ラグビーはタックルなど、上肢に高負荷がかかるプレーが多い。したがって前胸部筋群が発達し、肩関節可動域に影響を与えていると考える。以上より、肩関節不安定性を有する選手は、筋インバランスにより肩関節可動域が制限されていることがわかった。

キーワード：ラグビー選手、肩関節不安定性、競技歴