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Standing balance ability of Japanese collegiate rugby union players with past cervical injuries

Yoshiyuki Imoo[*, **], **Masahiro Takemura**[***], **Takuo Furukawa**[***], **Tatsuya Shimasaki**[***], **Ryo Ogaki**[**, ****] and **Shumpei Miyakawa**[***]

[*]Mito Kyodo General Hospital, Tsukuba University Hospital Mito Medical Center
3-2-7, Miya-machi, Mito, Ibaraki, 310-0015 Japan
rugby.imoo@gmail.com
[**]University of Tsukuba, Graduate School of Comprehensive Human Science
1-1-1 Tennodai, Tsukuba, Ibaraki 305-8574 Japan
[***]Faculty of Health and Sport Science, University of Tsukuba
1-1-1 Tennodai, Tsukuba, Ibaraki 305-8574 Japan
[****]Ibaraki Prefectural University of Health Sciences
4669-2 Ami, Ami-cho, Inashiki, Ibaraki 300-0394, Japan.
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Rugby players have high incidence of cervical pain or cervical injuries, and therefore might have impaired standing balance due to accumulated microtrauma in the cervical area. This study aimed to clarify whether past cervical problems influence the static standing balance in rugby players. The study included 44 rugby union players (20.7±1.0 years old) from one university club, who could participate in all competitions and/or training. The players were divided into two groups by cervical disorder for the past season. The first group consisted of players who had no cervical injury (no injury group: NI), and the second group consisted of players who had sustained a cervical injury within the past year (cervical injury group: CI). All participants were measured for center of foot pressure when standing on both legs, using a stable computerized force platform. Results showed that CI had greater postural sway in an anterior direction than NI because rugby players might have altered cervical joint position sense by accumulated microtrauma of cervical muscles, joints and nerves. However, it was not clear which mechanisms affected the static standing balance in detail. Further study must be undertaken to investigate how cervical disorder affects lack of postural control.

Keywords: Standing balance, Rugby, Cervical injuries

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1. Introduction

Cervical pain or cervical injuries are commonly prevalent (Hogg-Johnson, et al., 2009), likely to be repeated (Carroll, et al, 2008), and likely to be a long-lasting (Carroll, et al., 2008) disorder in the general population, workers and drivers (Côté, et al., 2008). This disorder includes cervical muscle weakness (Cagnie, et al., 2007) (Prushansky, et al., 2005) (Ylinen, et al., 2005), limited range of cervical motion (Sjölander, et al., 2003) (Sterling, et al., 2003), and impaired position sense for the head and neck (Armstrong, et al., 2008).

Sjöström, et al. (2003) suggested that cervical disorder caused decreased standing balance. They compared the standing balance of patients with symptoms of a chronic whiplash injury with that of healthy age-matched control subjects. The results showed that the whiplash injury group had greater trunk sway in standing measurements.

With regard to the mechanism of the decreased balance control, it was assumed that altered afferent input from cervical proprioception could cause unstable standing. Otherwise, vestibular receptors in the inner ears, visual sensory system or central vestibular system also might be the causes (Treleaven, 2008a) in the studies that recruited the following subjects: whiplash-associated disorders (Field, et al., 2008) (Stapley, et al., 2006) (Treleaven, et al., 2005), chronic pain (Michaelson, et al., 2003), dizziness (Treleaven, et al., 2005), experimental cervical muscle pain (Vuillerme and Pinsault, 2009) and experimental cervical muscle fatigue (Schieppati, et al., 2003).

Rugby players have a higher incidence of cervical injuries than other athletes in other contact sports. Several studies reported an incidence of cervical injuries of 8.0 injuries /1000 athlete-exposure in matches in rugby union, whereas there were 2.1 in North American football (Marshall, et al., 2010), 0.6 in ice hockey (Watson, et al., 2010), 1.5 in taekwondo (Pieter and Zemper, 2010) and 4.6 in wrestling (Lorish, et al., 1992). In recent years, several studies have reported that rugby players tend to have cervical problems such as a restricted active cervical range and cervical proprioceptive alteration from the effect of accumulated micro trauma on the cervical spine (Lark and McCarthy, 2007) (Lark and McCarthy, 2009) (Lark and McCarthy, 2010) (Pinsault, et al., 2010).

Most studies of cervical problems caused by rugby or other collision sports focus on the frequently discussed degenerative change of the cervical spine (Berge, et al., 1999) (Hogan, et al., 1999) or the importance of cervical muscle strength (Cross and Serenelli, 2003) (Nishimura and Irie, 2010). However, there are no studies which focused on standing balance disorder in rugby players who had sustained cervical disorders, though there are several clinical studies for patients with whiplash injuries. If the mechanism of deteriorated standing balance in rugby players with cervical disorders is similar to that in patients with cervical problems, rugby players who had sustained a cervical injury can have disorder of standing balance. Therefore, clarifying any relationship between cervical problems and physical characteristics of rugby players is important for interventions such as rehabilitation, reconditioning and exercise.

The current study aimed to clarify whether past cervical injuries influence the static standing balance in rugby players. As a hypothesis, it was assumed that rugby players who had cervical problems could have a dysfunction of balance control caused by pathological problems.

2. Methods

2.1. Subjects

The current study included 44 rugby union players (20.7±1.0 years old) from one university club, who were able to participate in all competitions and/or training, without complaints of tinnitus, vertigo, or dizziness. Furthermore, players with damage to lower extremities, cervical spinal cord or head injuries within the past year were excluded (**Figure 1**). They were divided into two groups by the past history of cervical injury for the past season. The first group consisted of players who had no cervical injury (no injury group: NI), and the second group consisted of players who had sustained cervical injury within the past year (cervical injury group: CI).

Injury definition was a full-inclusive time-loss injury, which is any injury in rugby for which time was lost from competition and/or training (Swain, et al., 2010b). Playing year, anthropometrical data (height, weight) including postural alignment (cranio-vertebral angle), positional category (forwards or backs), injury data (type of injury; severity: days absent from competition and/or training; injury time: competition or training), and standing balance on both legs were checked and measured in February 2009 before the collegiate rugby union league season began. The cranio-vertebral angle is an index of head-neck posture and is related with cervical pain (Yip, et al., 2008). This angle is measured between a horizontal line on the spinous process of the seventh cervical vertebra (C7) and a line connecting from the spinous process of C7 to the tragus of the ear on an X-ray image, taken from the right side.

The current study was conducted with the approval of the Ethics Committee, Graduate School of

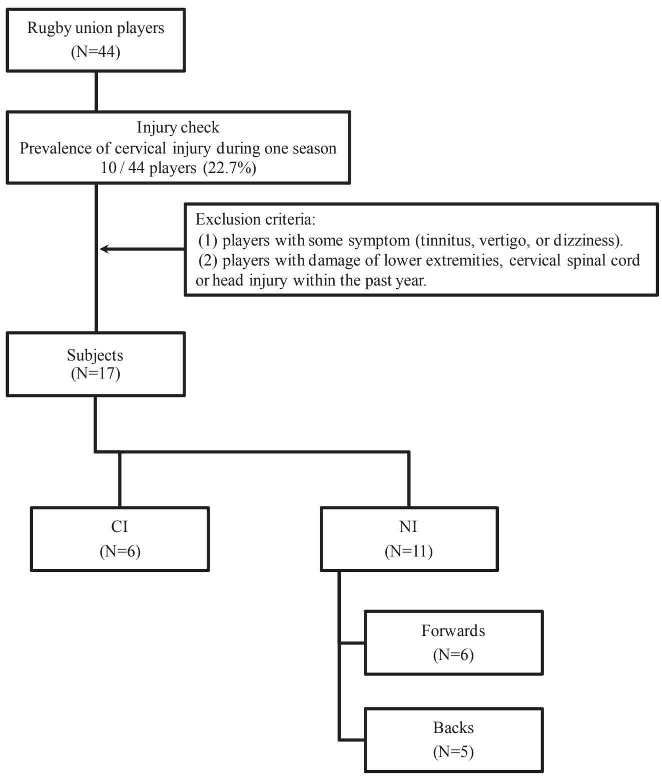


Figure 1 Grouping of players

Comprehensive Human Sciences in University of Tsukuba (Approved number; 22-55).

2.2. Standing balance measurements (Figure 2)

All participants were measured for center of foot pressure standing on both legs using a stable computerized force platform (Gravicorder GS-7; Anima, Inc., Tokyo, Japan). With their gaze on a wall 2 meters in front, each player tried to keep a static standing posture for 30 seconds with eyes open or closed. After the eyes open condition test was completed, the second test for measurement with eyes closed condition started after posture became more stable (after nearly twenty seconds).

2.3. Data analysis

Playing year, anthropometrical data including the cranio-vertebral angle and standing balance data on both legs (mean total path length, enveloped area, root mean square area, displacement along anterior-posterior axes and displacement along medial-lateral axes, with eyes open or closed) were compared between the groups using Student's T test. All statistical analyses were performed using a statistical computer program (SPSS statics 17.0; IBM Japan. Inc., Tokyo, Japan). $P < 0.05$ was considered statistically significant and values in the range $0.05 < P < 0.10$ are considered statically worthy to show potential associations.

3. Results

3.1. Injury data (Table 1)

There were 17 occurrences of cervical injuries for the past season (3 players within 11 affected players had three injuries or more). Injury prevalence for the past season was 22.7%. The most frequent type of injuries was cervical nerve root injuries, and the second most frequent was cervical facet injuries. Average days absent were 16.1±15.9 days (56 days at most, 3 days at least).

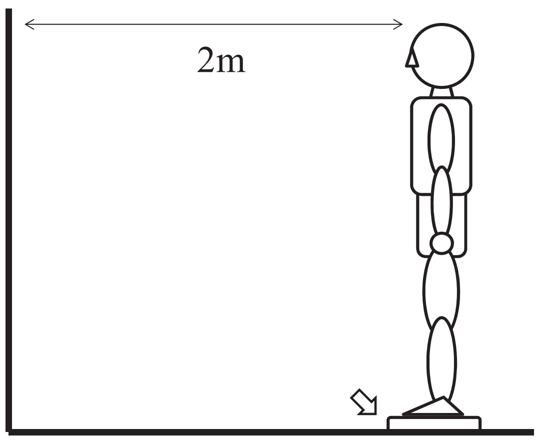


Figure 2 Standing balance measurements

All participants stood on a stable computerized force platform (blank arrow) with both legs. With their gaze on a wall 2 meters in front, each player tried to keep a static standing posture for 30 seconds with eyes open or closed.

Table 1 Profile of injured player (position, type of injury, days absent and activity)

No	Position	Type of injury	Days absent	Activity	Exception
1	1r	cervical facet injury	41	Training	
2	1r	cervical root injury	3	Training	
3	1r	cervical facet injury	5	Match	
	(recurrent)	cervical facet injury	12	Match	
	(recurrent)	cervical disk injury	8	Match	
4	1r	cervical facet injury	10	Match	
	(recurrent)	cervical facet injury	16	Training	
	(recurrent)	cervical facet injury	56	Training	
5	2r	spinal concussion	6	Match	†
6	3r	cervical root injury	8	Training	
7	3r	cervical root injury	16	Match	†
8	3r	cervical root injury	10	Training	
	(recurrent)	cervical root injury	5	Training	
	(recurrent)	cervical root injury	46	Training	
	(recurrent)	cervical root injury	20	Training	
9	BK	cervical facet injury	6	Match	†
10	BK	cervical facet injury	6	Training	†
Ave (SD)			16.1(15.9)		

Excluding criteria : † was excluded from measurement as based on exception criteria.1r: first row in forwards, 2r: second row in forwards, 3r: third row in forwards, BK: backs.

3.2. Comparison of NI and CI

3.2.1. Fundamental data (Table 2)

There was no significant difference between NI (11 players) and CI (6 players) in playing years, height, weight, or cranio-vertebral angle. When NI was further divided into two groups (forwards, backs), there was no significant difference in all of the fundamental data between NI in forwards and CI. However, there was a significant difference in weight between NI in backs and CI.

3.2.2. Standing balance (Table 3, 4)

In both trials of eyes open and closed, the displacement along anterior-posterior axes in CI was significantly longer in the anterior direction than that in NI. As compared with NI in forwards, with eyes open, the displacement along anterior-posterior axes in CI was significantly longer in the anterior direction than that of NI in forwards. With eyes closed, there was no significant difference.

In comparison with NI in backs, with eyes open, CI had longer than NI in backs in the displacement along anterior-posterior axes. With eyes closed, the displacement along anterior-posterior axes in CI was significantly longer than that of NI in backs.

4. Discussion

4.1. Prevalence of cervical injuries in rugby union players for one season

In the current study, cervical injury prevalence in rugby union players was 22.7% for one playing season. There are several previous epidemiological studies available on cervical injuries. Fuller, et al., (2007) recorded 86 time-loss injuries among a total of 546 cohorts during two seasons in England premiership rugby. This is estimated as a prevalence of 15.8% over two seasons. Swain, et al. (2010), concluded that 74 amateur players suffered from cervical injuries out of 262 cohorts (estimated prevalence; 28.2%) in the consecutive seasons. These two studies revealed a two-year prevalence of cervical problems. However, it is difficult to compare our study of Japanese collegiate rugby union players with the previous two studies because we collected the data from just one playing season. Therefore, it is not clear whether cervical injuries occurred more or less frequently in Japanese collegiate players, compared to those studies.

It is also difficult to directly compare our study with other studies because there are a variety of surveillance methods such as applicable injury definition, targeted player age, different football codes, different level of competition and various players' nationality. The cervical injury data in the current study were collected on the basis of a consensus statement regarding injury surveillance in rugby union, which was discussed and concluded by the International Rugby Board (2011). Injury data collection for rugby union is recommended under IRB's consensus statement to promote van Mechelen's injury prevention strategy (van Mechelen, et al., 1992).

4.2. Standing balance

4.2.1. The influence of cervical injury on standing balance

Players in CI had greater sway than those in NI, especially significantly greater sway in the displacement along anterior-posterior axes with eyes open or closed. Mizohata, et al. (2006) (2007) recorded the postural sway of the center of pressure for healthy rugby players. They examined the

Table 2 Fundamental data

	CI (N=6)		NI (N=11)			NI(FW) (N=6)			NI(BK) (N=5)		
	Ave	SD	Ave	SD	*p*	Ave	SD	*p*	Ave	SD	*p*
Playing years (years)	6.5	2.0	8.1	3.0	*NS*	7.0	2.1	*NS*	9.4	3.6	*NS*
Height (cm)	175.2	5.7	177.6	5.0	*NS*	179.1	4.3	*NS*	175.9	5.8	*NS*
Weight (kg)	89.2	11.7	82.3	11.4	*NS*	89.9	8.1	0.03	73.2	7.4	*NS*
Cranio-vertebral angle (degrees)	56.0	5.0	54.5	3.2	*NS*	52.3	2.4	*NS*	57.1	1.8	*NS*

p : P-value is the probability obtained by a static analysis between CI and NI (FW or BK) in this study. NS : not significant (p >0.1).

Table 3 Standing balance measurement as comparison with CI and NI (Total)

	This study (Imoo, et al., 2011)					Japanese collegiate rugby union players (Mizohata, et al., 2006)		General population in Japan (Men, 20-24.9years) (Imaoka, et al., 1997)	
	CI (N=6)		NI (N=11)			division 2 (N=24)	division 1 (N=31)	(N=83)	
Open eyes condition	Ave	SD	Ave	SD	*p*	Ave	Ave	Ave	SD
Mean total path length (cm)	52.2	12.7	49.6	16.3	*NS*	32.7*	33.9*	38.0	11.6
Enveloped area (cm^2)	3.5	1.8	2.9	1.8	*NS*	1.3*	1.4*	1.8	0.9
Root mean square area (cm^2)	3.0	2.2	1.8	1.0	*NS*			1.3	0.7
Displacement along medial-lateral axes (cm)	0.2	0.2	0.2	0.5	*NS*			0.1	0.3
Displacement along anterior-posterior axes (cm)	1.6	1.3	0.1	1.5	0.04			-0.8	1.4
Closed eye condition									
Mean total path length (cm)	49.4	6.5	52.4	21.5	*NS*			50.9	16.8
Enveloped area (cm^2)	3.0	1.3	3.8	2.7	*NS*			2.4	1.3
Root mean square area (cm^2)	2.1	1.1	2.9	2.4	*NS*			1.6	0.9
Displacement along medial-lateral axes (cm)	0.2	0.4	0.1	0.6	*NS*			0.1	0.7
Displacement along anterior-posterior axes (cm)	1.8	1.3	0.3	1.7	0.04			-0.5	1.6

* : Measured raw data was converted into modified value, which was multiplied by 160 and divided by each player's height. *p* : P-value is the probability obtained by a statistic analysis between CI and NI in this study. NS : not significant (p >0.1).

Table 4 Standing balance measurement as comparison with CI and NI (FW or BK)

	CI(FW) (N=6)		NI(FW) (N=6)			NI(BK) (N=5)		
Open eyes condition	Ave	SD	Ave	SD	*p*	Ave	SD	*p*
Mean total path length (cm)	52.2	12.7	54.5	16.8	*NS*	43.8	15.5	*NS*
Enveloped area (cm^2)	3.5	1.8	3.7	2.3	*NS*	2.0	0.6	*NS*
Root mean square area (cm^2)	3.0	2.2	2.2	1.2	*NS*	1.2	0.3	*NS*
Displacement along medial-lateral axes (cm)	0.2	0.2	0.2	0.5	*NS*	0.3	0.5	*NS*
Displacement along anterior-posterior axes (cm)	1.6	1.3	0.1	1.8	0.06	0.1	1.2	0.07
Closed eye condition								
Mean total path length (cm)	49.4	6.5	62.1	23.2	*NS*	40.7	13.2	*NS*
Enveloped area (cm^2)	3.0	1.3	5.2	2.9	*NS*	2.1	1.0	*NS*
Root mean square area (cm^2)	2.1	1.1	4.1	2.6	*NS*	1.4	0.6	*NS*
Displacement along medial-lateral axes (cm)	0.2	0.4	0.1	0.7	*NS*	0.2	0.5	*NS*
Displacement along anterior-posterior axes (cm)	1.8	1.3	0.5	2.2	*NS*	-0.1	0.9	0.02

p : P-value is the probability obtained by a statistic analysis between CI and NI (FW or BK) in this study. NS : not significant (p >0.1).

relationship between balance ability and muscle strength, flexibility, agility and jumping performance. They found an association of trunk muscle strength and flexibility with postural sway. However, except Mizohata's studies, there is no research which examined static standing balance and no research has ever discussed the reason why rugby players who have sustained cervical injuries have greater sway than those without cervical injuries.

Apart from rugby players with a history of cervical injury, previous research suggested the relationship between cervical injury and postural control disorder for non-athletes. Receptors in the muscles/joints of the cervical spine and sympathetic nervous system have some complicated connections to the vestibular system (**Figure 4**) (Armstrong, et al., 2008) (Field, et al., 2008) (Treleaven, 2008a). For example, several studies found that greater postural sway in static standing was caused by cervical muscle vibration (Rossi, et al., 1985), cervical muscle pain (Vuillerme and Pinsault, 2009), and cervical muscle fatigue (Schieppati, et al., 2003). Lekhel, et al. (1998) suggested that this phenomenon is a compensatory response as a result of postural control for kinesthetic illusion of head position sense. Therefore, it is assumed that trauma to cervical facet joints or muscles could increase altered afferent input from cervical receptors (Heikkila and Astrom, 1996) (Hinoki and Niki, 1975) (Taylor and Twomey, 1993).

A similar mechanism will happen in rugby players with cervical injuries. Furthermore, previous research also reported that rugby players had altered head position sense by accumulated microtrauma of cervical muscles, joints and nerves (Lark and McCarthy, 2007) (Pinsault, et al., 2010), though this current study did not measure the head position sense. Lark and McCarthy suggest that the head position sense in forwards was deteriorated by damage to the cervical proprioception due to high-energetic collisions in training and matches. Actually, this was also found in the current study; forwards tend to have greater sway than backs. In the future, it is required to verify whether there is a relationship between the head position sense and the postural control in rugby players who have sustained cervical injuries.

One limitation of the current study is that it is unclear if greater postural sway in standing in rugby players with a past history of cervical injuries could be clearly identified as a risk factor of balance disorder, because this study was a cross-sectional study, not a prospective cohort study. Further investigation such as longitudinal and long-term research is required to measure standing balance and position sense to identify the mechanism.

4.2.2. The influence on standing balance under eyes open or closed condition

In general, standing balance with eyes closed causes greater postural sway than with eyes open, because of a lack of visual information to keep balance. For instance, while the average enveloped area of Japanese general males in their early twenties was 1.8 ± 0.9 cm^2 with eyes open, it was 2.4 ± 1.3 cm^2 with eyes closed (Imaoka, et al., 1997). In the current study, the average enveloped area on standing was greater in comparison with that of the previous study for both eyes open and closed conditions. However, there is no significance of the average enveloped area between with eyes open and eyes closed. This result contains several assumptions: first, the influence of eyes closed condition might be decreased because of a stronger learning effect (Treleaven, 2008b) on standing afterward. Secondly, CI could have difficulty integrating visual, vestibular, and cervical proprioceptive signals to control standing balance (Sjöström, et al., 2003).

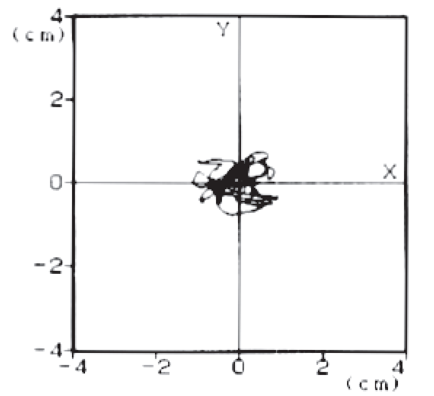
4.2.3. Sagittal sway

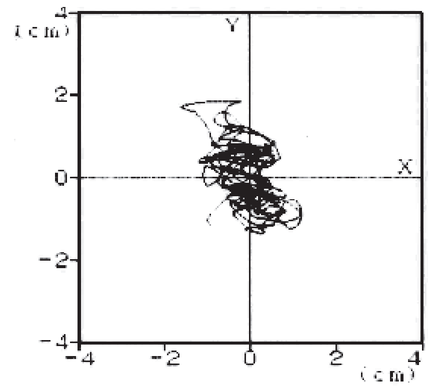
Static standing balance generally has larger postural sway in displacement along anterior-posterior axes than in displacement along medial-lateral axes (Michaelson, et al., 2003) (Sjöström, et al., 2003) (Vuillerme and Pinsault, 2009). Sagittal sway is controlled by ankle strategy, hip strategy or mixed hip-ankle strategy (Gatev, et al., 1999). However, Lekhel, et al. (1998) showed that postural sway in the anterior direction is stimulated by vibration of the dorsal cervical muscle in healthy subjects. In case of intact vestibular signals, the vibration to the dorsal cervical muscle causes kinesthetic illusion. It is assumed that displacement in the anterior direction of the center of gravity is caused by automatic postural response due to wrong information as the lower body shifts towards the posterior.

It was not clear which mechanisms affected the static standing balance in detail for our study because we didn't measure each joint movement and muscle activity around the head-neck, hips and ankles with electromyography during the postural sway measurement. In future, we should examine the correlation between postural muscle activity and postural sway, and how cervical disorder influences control of the displacement. This information would be helpful for physiotherapy approaches or conditioning of rugby players with cervical disorders.

4.3. Limitation

It is important to know whether any balance disorders existed before starting the research. Especially, head injuries might also have an influence on balance disorder, however, the research of





Example data in NI (subject: A) Age: 20 years old Height: 175.5cm, Weight: 83.6kg Position: FW		Example data in CI (subject: B) Age: 21 years old Height: 169.0cm, Weight: 81.0kg Position: FW	
Mean total path length (cm)	36.5	Mean total path length (cm)	76.6
Enveloped area (cm^2)	1.5	Enveloped area (cm^2)	3.8
Root mean square area (cm^2)	1.0	Root mean square area (cm^2)	2.5
Displacement along medial-lateral axes (cm)	0.5	Displacement along medial-lateral axes (cm)	0.3
Displacement along anterior-posterior axes (cm)	0.9	Displacement along anterior-posterior axes (cm)	1.8

Figure 3 Example data of center of foot pressure sway in NI and CI with eyes open condition

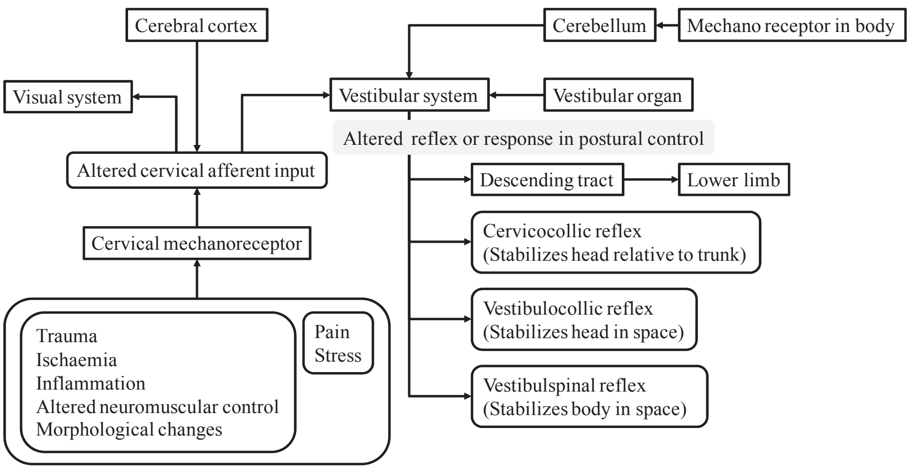


Figure 4 Relationship between cervical injuries and vestibular system (a quotation and modifications from the figure in previous study (Armstrong, et al., 2008) (Field, et al., 2008) (Treleaven, 2008a))

past injuries for each player has the limitation of occurrence in the past year. While the current study is a cross-sectional study, a longitudinal and long-term research scheme to measure standing balance and position sense with cervical injuries will be required to identify risk factors clearly.

5. Conclusion

Rugby players who had sustained cervical injuries might have balance disorders because they have significantly greater sway in displacement along anterior-posterior axes with eyes open or closed in standing. Cervical disorders in rugby players could influence the static standing balance as it changes in the sensorimotor control system. Major cervical injuries leading to the end of a player's career are a preventive problem for union rugby players, therefore we should pay more attention to minor cervical disorders and improve many physical dysfunctions in injured players, as soon as possible after injury occurrence.

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Name:
Yoshiyuki Imoo

Affiliation:
Mito Kyodo General Hospital, Tsukuba University Hospital Mito Medical Center

Address:
3-2-7, Miya-machi, Mito, Ibaraki, 310-0015, Japan

Brief Biographical History:
2007-2012 Doctoral Programs in Graduate School of Comprehensive Human Sciences
(Sports Medicine), University of Tsukuba
2010- Physiotherapist, Mito Kyodo General Hospital,
Tsukuba University Hospital Mito Medical Center
2012 Ph.D(Sports Medicine)

Main Works:
- Cervical intervertebral disc degeneration in collegiate rugby player. Japanese Journal of Clinical Sports Medicine, 20(1): 96-104, 2012.
- Neck muscle morphology of college rugby players. Bulletin of Institute of Health and Sport Science, the University of Tsukuba, 32: 61-69, 2009.

Membership in Learned Societies:
- Japanese Society of Science and Football
- Japanese Physical Therapy Association
- Japanese Society of Clinical Sports Medicine
- Japan Sports Association
- National Strength and Conditioning Association