

Shoulder joint position sense in judo athletes

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Abstract:

Background and Study Aim: *Kakari* practice, which is one of the methods of practicing such techniques, involves skilfully breaking *uke's* body balance and repeating techniques using accurate form. Accordingly, using both the pulling and lifting hand is important, the position of the upper limbs needs to be improved and the reproducibility ensured, and the sense of the shoulder joint position is thought to have a considerable influence. Sense of position refers to the perception of one's own body posture and where body parts are located, without relying on visual information. Many biomechanical studies report the focus on the pulling and lifting hand, but none examine the sense of position. The cognitive goal of this research is knowledge about the sense of the shoulder joint position in judo athletes.

Material and Methods: We observed 14 judo athletes: 7 represented the conventional lightweight group, including five 66kg and two 73kg, and 7 heavyweights, including two 81kg, one 90kg and two over 100kg. We used BIODEX (13BY6333, manufactured by Sakai Medical Co., Ltd.) in automatic and passive modes to measure both shoulder joints. The measurement items were flexion/extension (60°, 90°, 120°), abduction/adduction (60°, 90°, 120°), and external rotation/internal rotation (5°, 35°). The analysis was conducted from multiple perspectives.

Results: We succeeded in finding significant differences in comparison by body mass, *hikite* and *tsurite*, and target angle. In the comparison between lightweight and heavyweight athletes, the sense of shoulder joint position in heavyweight athletes may be superior as a whole. The comparison between *hikite* and *tsurite*, the *tsurite* side of the shoulder joint may have a better sense of shoulder joint position. Comparison by target angle established that the 120° target angle had the smallest error, suggesting that this angle had the superior sense of position.

Conclusions: Heavyweight athletes may have an overall superior sense of shoulder joint position. The comparison between the pulling and lifting hands revealed athletes are more likely to have a better sense in the former. Moreover, when comparing target angles between the two hands, the error for the target angles of 120° was the smallest in the pulling hand, thus suggesting a better sense of position.

Keywords: comparison by weight, *hikite*, kinesthesia, *kuzushi*, target angle, *tsurite*

Dictionary:

Jiyu-renshu (freestyle practice) – *noun* practice method in which both players attack and defend each other by freely performing techniques [4].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to other or in relation to personal goals or standards [5].

Hikite – *noun* Name used in Judo to grip the sleeve of an opponent [6].

Tsurite – *noun* Name for holding the opponent's collar in judo [6].

Isokinetic dynamometer – *noun* Equipment that performs measurement while controlling the speed of muscle contraction at a constant rate during joint movement [9].

Dan (dan'i) – a term used to denote one's technical level or grade [22].

1. Introduction

Judo became an official sport at the 1964 Tokyo Olympics, and continues to grow, with more than 200 countries becoming members of the International Judo Federation. Judo, which has evolved into a sport loved around the world, has its own unique teaching methods and techniques in each country, captivating spectators. An appeal of judo lies in one of its indispensable factors: the throwing technique.

The throwing techniques in judo consists of three phases: i) *kuzushi*, where the *tori* (the one executing the technique) breaks the balance of the *uke* (the one receiving the attack), ii) *tsukuri*, where the *tori* gets into the best position and posture for performing the technique, and iii) *kake*, where the *tori* applies the final decisive move [1]. Moreover, *kuzushi* is considered as the most significant factor that gets the *uke* thrown by the *tori* [2]; therefore, it can be considered an important movement [3,4]. In *kuzushi*, the centre of gravity of the *uke* should be raised above their natural body state and then moved outside the support surface [3].

Judo practice includes *jiyu-renshu* (freestyle practice), *kakari-renshu* (kakari practice), *yakusoku-renshu* (agreed-upon-move practice), and *kata* practice [5]. Among these, *kakari*, also called *uchikomi*, is a method of practicing techniques repeatedly without throwing the opponent, while *yakusoku* involves throwing the opponent using techniques [6]. These two are typical practice methods to confirm the rationality and reason of a technique, and to acquire the correct form to skilfully break the balance of the *uke*. The *tori's* *hikite* and *tsurite* become essential in this case. To properly break the *uke's* balance, the *tori* must be able to perceive the position of their upper limbs and improve reproducibility, which is considered to have a significant effect on the sense of motion in the shoulder joint.

Kinesthesia is the ability to perceive the position of the limbs of the body and the movement of the trunk, and is discussed in numerous reports [7]. Although the receptors that control position and movement have been assumed to be the same until now, recent studies have demonstrated that the receptors controlling position and movement vary depending on speed levels and fatigue state [8, 9]. Based on these, the ability to perceive the position and state of the limbs is called sense of position [10], and isometric muscle contraction at 20% of maximum effort is considered effective for muscle conditioning [11].

These are also used in sports to achieve accurate form and optimal performance [12,13]. In judo, the upper limbs are mainly used in the *kuzushi* phase when executing throwing techniques and taking the kinetic chain from the *kuzushi* to *tsukuri* phase into account, the shoulder joints are very important. In the *kakari* and *yakusoku* practices to acquire the throwing technique form in particular, since the *tori* must control their upper limbs in the proper direction in order to skilfully break the *uke's* balance, checking one's own sense of shoulder joint position plays an important role in improving future practice methods.

Although many biomechanical studies have investigated judo throwing techniques, specifically, regarding *hikite* and *tsurite*, none examine the sense of position. Having a sense of shoulder joint position may help athletes improve their throwing technique and provide an opportunity for instructors to explore their way of thinking and practice methods. Moreover, the essentiality of cultivating various senses in childhood, when the nervous system that controls forward and backward movements is rapidly developing [14], can be proposed as evidence to introduce training for

improving the sense of position. Hence, we measured the sense of shoulder joint position in judo athletes from various perspectives and aimed to verify it as a basic study.

The cognitive goal of this research is knowledge about the sense of the shoulder joint position in judo athletes.

2. Material and Methods

Subjects

The subjects were 14 male judo club members of university. A questionnaire indicating their attributes was administered prior to measurement. Questionnaire items included age, height, weight, years of competition experience, rank (this information is included in the first part of Table 1). The second part of the table monitors the weight category of each judo athlete and their preferred special throwing techniques. In addition, the questionnaire included answers to questions about presence and timing of injuries. The inclusion criteria in the measurements is those who did not have shoulder joint movement limitation due to injury. Moreover, the purpose of the study, the content of the experiment, the risks associated with the experiment, privacy protection, and the freedom to refuse participation or withdraw at any time were fully explained to the subjects orally and in writing in advance, and those whose signed consent were obtained were included in the study.

This study was conducted with the approval of the Research Ethics Committee of the Faculty of Health and Sports Science, Juntendo University (Jundai su rin No. 2023-111).

Table 1. General characteristics of judo athletes (n = 14) and profiles of their preferred special throwing techniques.

Variable (item) and indicator	Division into conventional weight categories	
	lightweight: 66kg 5;- 73kg 2 athletes	heavyweight: 81kg 2;-90kg 1;- 100kg 2;- over 100kg 2 athletes
Age (years)	19.1 ±1.1	20.0 ±1.5
Height (cm)	169.6 ±3.5	175.1 ±6.0
Weight (kg)	71.3 ±2.8	98.7 ±15.6
Competition experience (years)	12.7 ±1.6	12.0 ±2.4

Athlete initials	Preferred special throwing techniques		
	I (most used)	II	III (least often)
	lightweight (n = 7)		
T.K	<i>o-soto-gari</i>	<i>o-goshi</i>	<i>o-uchi-gari</i>
G.O	<i>uchi-mata</i>	<i>seoi-nage</i>	<i>o-uchi-gari</i>
R.K	<i>o-goshi</i>	<i>o-uchi-gari</i>	<i>uchi-mata</i>
S.U	<i>uchi-mata</i>	<i>o-goshi</i>	<i>ko-uchi-gari</i>
Y.D	<i>uchi-mata</i>	<i>o-soto-gari</i>	<i>ippon-seoi-nage</i>
H.N	<i>seoi-nage</i>	<i>ippon-seoi-nage</i>	<i>ko-uchi-gari</i>
H.I	<i>seoi-nage</i>	<i>o-soto-gari</i>	<i>ko-uchi-gari</i>

initials	heavyweight (n = 7)		
H.S	<i>o-soto-gari</i>	<i>uchi-mata</i>	<i>harai-goshi</i>
K.K	<i>o-soto-gari</i>	<i>ippon-seoi-nage</i>	<i>uchi-mata</i>
S.T	<i>seoi-nage</i>	<i>ko-uchi-gari</i>	<i>ippon-seoi-nage</i>
H.K	<i>o-uchi-gari</i>	<i>ippon-seoi-nage</i>	<i>ko-uchi-gari</i>
G.K	<i>uchi-mata</i>	<i>o-uchi-gari</i>	<i>o-uchi-gari</i>
Y.O	<i>o-soto-gari</i>	<i>o-uchi-gari</i>	<i>harai-goshi</i>
N.M	<i>harai-goshi</i>	<i>o-uchi-gari</i>	<i>o-goshi</i>

Measurement method

The sense of position of both shoulder joints was measured using the automatic and passive mode of the isokinetic dynamometer BIODEX (13BY6333, manufactured by Sakai Medical Co., Ltd.). In the automatic mode, the arm is manually moved to the set target angle, and this method was employed in the measurement of the sense of position in the shoulder of healthy subjects and those with traumatic shoulder instability conducted by Tsuda et al [15]. In the passive mode, the arm automatically stops when it reaches the set target angle, and this method was employed in the measurement of the knee position of female collegiate track athletes conducted by Koyanagi [16].

At the beginning of the measurement, the subjects were prepared through an isokinetic dynamometer, and were given eye masks to block visual information as well as a switch to operate the arm. The target angles were 60°, 90°, and 120° flexion/extension movements in a forward elevation with the line parallel to the floor passing through the acromion at 0° in the supine position (Figure 1A); 60°, 90°, and 120° abduction/adduction movements in a lateral raise with a perpendicular line to the floor passing through the acromion at 0° in the seated position (Figure 1B), and 5° and 35° external/internal rotations in a seated position with a perpendicular line to the forehead passing through the elbow joint at 0° (Figure 1C).

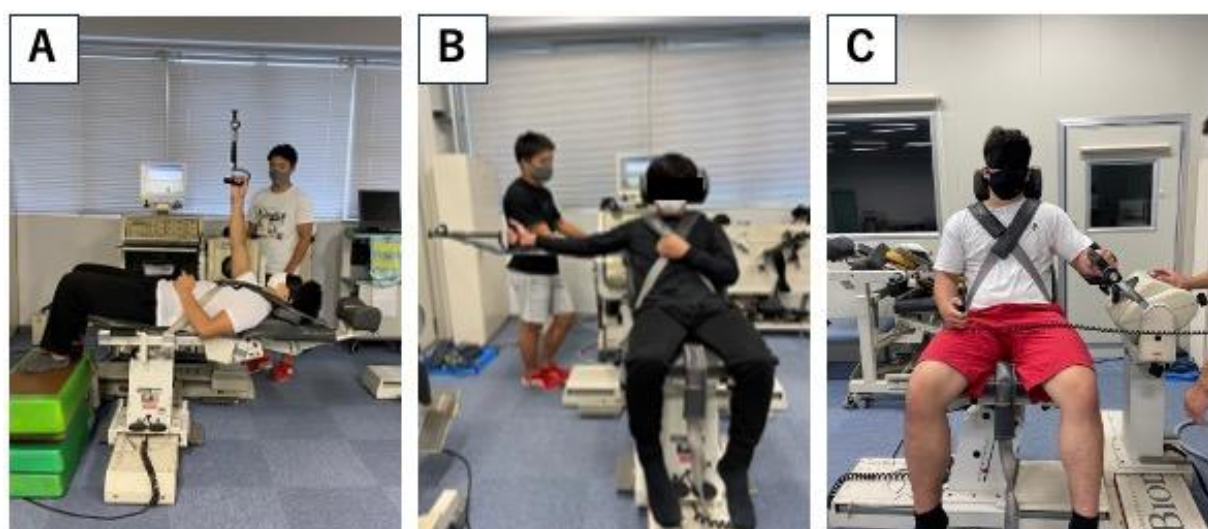


Figure 1. Measurement conditions.

Before taking measurements at each angle, the device was held at the target angle for five seconds to retain its memory. Subjects then pressed a switch on the moving arm to stop it when they deemed that the shoulder angle has reached the target angle. In automatic mode, the arm was set to move at an angular velocity of 500deg / s, moved automatically to the target angle, and was stopped by pressing the switch. In passive mode, the arm was set to an angular velocity of 10deg / s and was stopped when the self-propelled arm was deemed to have reached the target angle. These operations were performed three times for each target angle, and a method that calculates the sum of the absolute values of the difference between the angle of the shoulder joint at which the arm was stopped and the target angle was employed. The measurement time required for one movement task was approximately 50 mins, and taking the subjects' ability to concentrate into account, only one movement task was performed per day, and a total of three measurement days were set aside for the activity. Since measurement for each movement task and setting up the arm of the isokinetic dynamometer required considerable time, the order of the measurement items was the same for each subject.

Measurement criteria (survey design)

The measurement items for both shoulder joints performed on the isokinetic dynamometer are as follows.

- a. The target angles for flexion/extension were set to 60°, 90°, and 120°, and measurements were performed at angular velocities of 500deg / s for automatic mode, and 10 deg / s for passive mode.
- b. The target angles for abduction/adduction were set to 60°, 90°, and 120°, and measurements were performed at angular velocities of 500deg / s for automatic mode, and 10 deg / s for passive mode.
- c. The target angles for internal/external rotation were set to 5° and 35°, and measurements were performed at angular velocities of 500deg / s for automatic mode, and 10 deg / s for passive mode.

Statistical analysis

Each item was measured three times, and the total difference (absolute value) to the target angle was selected for analysis. The obtained values are expressed as mean and standard deviation ($\pm$). Statistics were calculated using SPSS Version 29 (IBM), and the significance level was set at $p < 0.05$. In the tables, statistically significant values (p-value) are in bold. Intra-subject reliability was evaluated for the absolute difference from the target angle in each passive measurement value. Unpaired t-test performed for those that showed normality, and Mann-Whitney U test or Wilcoxon's rank-sum test or alternatively Shapiro-Wilk test was performed for those that did not show normality. Therefore, due to this specificity of collecting empirical data, in the 'Results' section we inform about the nonparametric test used. The t value and variance (s^2) were recorded for unpaired.

Cohen's d coefficient and eta squared (η^2) was used to measures of experimental effect size. The strength of the effect d : 0.2 weak, 0.5 average, 0.8 strong; and η^2 : 0.01 weak, 0.06 average, 0.14 strong.

3. Results

In a comprehensive sense, the highest correlation coefficient values ($r = 0.686$ to 0.769) were found for the target 90° , automatic mode. The lowest individual value ($r = 0.275$) concerns the empirical variable 'external rotation', within the target 35° , automatic mode (Table 2).

Table 2. Intra-subject reliability for the absolute value of the difference from the target angle for the 5 measurements automatic and passive.

Mode	MD	IC	Min	Max	MD	IC	Min	Max
the target angles for set 60°					the target angles for set 5°			
Automatic	flexion	0.658	0.468	0.808	external rotation	0.554	0.339	0.739
	extension	0.699	0.521	0.833	internal rotation	0.769	0.62	0.875
	abduction	0.721	0.552	0.847				
	adduction	0.468	0.241	0.678				
Passive	flexion	0.626	0.427	0.788	external rotation	0.515	0.294	0.712
	extension	0.519	0.299	0.715	internal rotation	0.524	0.304	0.719
	abduction	0.619	0.418	0.783				
	adduction	0.747	0.589	0.863				
the target angles for set 90°					the target angles for set 35°			
Automatic	flexion	0.686	0.505	0.826	external rotation	0.275	0.047	0.524
	extension	0.769	0.62	0.876	internal rotation	0.65	0.457	0.803
	abduction	0.689	0.508	0.827				
	adduction	0.731	0.566	0.853				
Passive	flexion	0.626	0.427	0.788	external rotation	0.506	0.283	0.706
	extension	0.508	0.286	0.707	internal rotation	0.674	0.488	0.818
	abduction	0.566	0.353	0.747				
	adduction	0.683	0.5	0.824				
the target angles for set 120°								
Automatic	flexion	0.409	0.178	0.633				
	extension	0.643	0.448	0.798				
	abduction	0.418	0.188	0.641				
	adduction	0.418	0.188	0.641				
Passive	flexion	0.78	0.636	0.882				
	extension	0.733	0.569	0.854				
	abduction	0.445	0.216	0.661				
	adduction	0.344	0.112	0.582				

IC interclass correlation; **Max** maximum; **MD** movement direction; **Min** minimum

Comparison by body mass

The results indicated that the lightweight class had a value of $24.6 \pm 14.0^\circ$ and the heavyweight class a value of $14.1 \pm 16.1^\circ$ for 60° automatic abduction, with the test showing that the heavyweight class had a significantly lower value. Moreover, the lightweight class had a value of $19.8 \pm 12.8^\circ$ and the heavyweight class a value of $11.1 \pm 8.4^\circ$ for 90° automatic abduction, with the heavyweight class showing a significantly lower value. In addition, the lightweight class had a value of $23.4 \pm 14.4^\circ$ and the heavyweight class a value of $14.0 \pm 9.0^\circ$ for 35° passive external rotation, with the heavyweight class showing significantly lower values (Table 3). In the summarized data in Table 3, unpaired t-test performed for those that showed normality, and Mann-Whitney U test was performed for those that did not show normality. The t value and variance were recorded for unpaired t-test.

Table 3. Comparison of shoulder joint position sense by target angle in lightweight and heavyweight athletes.

MC	Mode & MD	Lightweight	Heavyweight	<i>t</i>	<i>s</i> ²	<i>p</i>	<i>d</i>	η^2
60°	Automatic flexion	23.5 ±13.3	32.4 ±24.3			0.482		0.14
	Automatic extension	26.9 ±20.2	30.1 ±22.3			0.8		0.05
	Passive flexion	29.9 ±15.6	24.5 ±15.9			0.265		-0.22
	Passive extension	27.9 ±17.2	33.9 ±21.6			0.571		0.11
90°	Automatic flexion	21.6 ±12.2	28.9 ±21.7			0.571		0.11
	Automatic extension	28 ±17.9	37.3 ±22.2	-1.22	24.84	0.235	-0.46	
	Passive flexion	25.3 ±11.6	23.9 ±14.3	0.28	24.91	0.785	0.104	
	Passive extension	17.4 ±10.6	19.7 ±10.6			0.454		0.14
120°	Automatic flexion	20.1 ±11.1	20.9 ±10.1			0.734		0.07
	Automatic extension	21.9 ±14.1	29.9 ±22.9			0.352		0.18
	Passive flexion	23.1 ±13.5	27.3 ±26			0.946		-0.01
	Passive extension	15.9 ±13	23.7 ±17.4			0.194		0.25
60°	Automatic abduction	24.6 ±14	14.1 ±16.1			0.021		-0.43
	Automatic adduction	20.3 ±13.8	16.8 ±14.3			0.227		-0.23
	Passive abduction	20.9 ±14	15.2 ±10	1.23	23.61	0.231	0.464	
	Passive adduction	30.9 ±21	23.4 ±21.4	0.94	25.99	0.358	0.354	
90°	Automatic abduction	19.8 ±12.8	11.1 ±8.4			0.019		-0.44
	Automatic adduction	14.8 ±12.3	17.4 ±14.6			0.734		0.07
	Passive abduction	18 ±11.9	11.7 ±8.7			0.085		-0.33
	Passive adduction	23.3 ±16.5	31.5 ±22.9			0.427		0.15
120°	Automatic abduction	14.1 ±8.5	16 ±11.9			0.91		0.03
	Automatic adduction	21.9 ±14.2	18.5 ±10.2	0.73	23.51	0.47	0.277	
	Passive abduction	23.1 ±12.6	22.9 ±15.1	0.05	25.19	0.957	0.021	
	Passive adduction	15.9 ±14	12.7 ±8.1			0.769		-0.06
5°	Automatic external rotation	18.79 ±12.23	20 ±15.04			0.874		0.04
	Automatic internal/rotation	19.5 ±16.64	16.29 ±15.38			0.511		-0.13

35°	Passive external rotation	12	±10.49	8.71	±6.99			0.511	-0.13
	Passive internal rotation	21.14	±12.29	18.43	±9.77	0.65	24.74	0.524	0.244
	Automatic external rotation	13.29	±8.05	17.36	±8.21	-1.32	25.99	0.197	-0.501
	Automatic internal rotation	19.71	±17.04	16.86	±12.7			1	0
	Passive external rotation	23.36	±14.38	14	±9			0.05	-0.37
	Passive internal rotation	19.5	±14.47	11	±6.88			0.15	-0.28

d Cohen's coefficient; **MC** measurement criteria (survey design); **MD** movement direction; **η²** experimental effect size; **s²** variance; **p** probability; **t** Student's *t*-distribution

The results established values of 26.7 ±13.6° lightweight class and 11.6 ±7.4° heavyweight class for 60° automatic abduction, 27.6±18.0° lightweight class and 8.7 ±4.6° heavyweight class for 35° passive external rotation, and lastly, 20.1 ±9.7° lightweight class and 7.4 ±5.6° heavyweight class for 35° passive internal rotation, with the test results indicating that the heavyweight class had significantly lower values for all three items (Table 4). Unpaired t-test performed for those that showed normality, and Mann-Whitney U test was performed for those that did not show normality. The t value and variance were recorded for unpaired t-test.

Table 4. Comparison of shoulder joint position sense by target angle in the *hikite* of lightweight and heavyweight athletes.

MC	Mode & MD	Lightweight		Heavyweight		<i>t</i>	<i>s</i> ²	<i>p</i>	<i>d</i>	η ²
60°	Automatic flexion	23.57	±8.24	25	±19.43	0.18	8.09	0.862	0.096	
	Automatic extension	17.86	±14.5	26.14	±18.47	0.93	11.36	0.37	0.499	
	Passive flexion	30	±12.36	29.14	±17.28	-0.11	10.87	0.917	-0.057	
	Passive extension	28.71	±24.25	33.71	±21.69	0.41	11.85	0.692	0.217	
90°	Automatic flexion	18	±7.94	30.43	±23.19	1.34	7.39	0.219	0.717	
	Automatic extension	22	±9.33	42.29	±22.45	2.21	8.01	0.058	1.18	
	Passive Flexion	27.57	±14.79	28.43	±15.97	0.1	11.93	0.919	0.056	
	Passive extension	15.43	±8.24	23	±12.38	1.35	10.45	0.207	0.72	
120°	Automatic flexion	17.14	±5.58	25.57	±10.94	1.82	8.93	0.103	0.971	
	Automatic extension	20.29	±13.4	34.86	±23.1			0.097		0.45
	Passive Flexion	25.86	±17.15	27.29	±32.12			0.71		-0.12
	Passive extension	16.14	±9.81	28.14	±18.27	1.53	9.19	0.159	0.818	
60°	Automatic abduction	26.7	±13.6	11.6	±7.4	-2.59	9.26	0.029	-1.384	
	Automatic adduction	19.7	±18.5	13.9	±8.3			0.71		-0.1
	Passive abduction	29.1	±13.7	19.7	±8.9	-1.53	10.3	0.157	-0.816	
	Passive adduction	43	±15	31	±25.7	-1.07	9.65	0.312	-0.571	
90°	Automatic abduction	26.3	±14.5	11.4	±11.7	-2.11	11.48	0.058	-1.127	
	Automatic adduction	22.4	±13.6	17.7	±9.8	-0.75	10.91	0.471	-0.399	
	Passive abduction	21.3	±15.3	16.3	±9.8			0.535		-0.17
	Passive adduction	31.1	±15.7	42.7	±26.6	0.99	9.73	0.346	0.529	
120°	Automatic abduction	19.4	±8.4	10.3	±7.6	-2.13	11.87	0.054	-1.141	

	Automatic adduction	27.1	±16.4	16.3	±11.3	-1.44	10.68	0.178	-0.771
	Passive abduction	19.1	±7.9	24.4	±15.7	0.8	8.84	0.446	0.426
	Passive adduction	13.4	±8.3	14	±7.6	0.13	11.91	0.895	0.072
5°	Automatic external rotation	22	±15	24.14	±18.36				0.12
	Automatic internal rotation	21.43	±20.12	20.43	±21.98				-0.12
	Passive external rotation	11.29	±9.57	4.86	±4.53	1.61	8.556	0.144	0.859
	Passive internal rotation	16.86	±12.03	17.43	±8.18	-0.1	10.571	0.919	-0.056
35°	Automatic external rotation	15	±12.5	16.71	±7.11	-0.32	9.514	0.759	-0.169
	Automatic internal rotation	19.29	±12.82	19.71	±10.86				0.07
	Passive external rotation	27.57	±17.99	8.71	±4.64	2.69	6.8	0.032	1.435
	Passive internal rotation	20.14	±9.67	7.43	±5.56	3.02	9.58	0.014	1.612

d Cohen's coefficient; **MC** measurement criteria (survey design); **MD** movement direction; **η²** experimental effect size; **s²** variance; **p** probability; **t** Student's *t*-distribution

Comparison of *hikite* and *tsurite*

Significant differences were observed in the comparisons by weight, between *hikite* and *tsurite*, and by target angle. The results revealed values of $24.4 \pm 12.1^\circ$ *hikite* and $11.6 \pm 8.8^\circ$ *tsurite* for 60° passive abduction, and $37.0 \pm 21.1^\circ$ *hikite* and $17.2 \pm 16.4^\circ$ *tsurite* for 60° passive adduction, with the tests establishing that *tsurite* had significantly lower values for all items. Moreover, the values were $18.8 \pm 12.6^\circ$ *hikite*, and $10.9 \pm 6.7^\circ$ *tsurite* for 90° passive abduction; $36.9 \pm 21.9^\circ$ *hikite* and $17.9 \pm 12.6^\circ$ *tsurite* for 90° passive adduction, with the test results indicating that *tsurite* had significantly lower values for all items (Table 5). Unpaired t-test was performed for those that showed normality, and Wilcoxon's rank-sum test was performed for those that did not show normality. The *t* value and variance were recorded for unpaired t-test.

Table 5. Comparison of shoulder joint position sense by target angle in *hikite* and *tsurite*.

MC	Mode & MD	<i>Hikite</i>		<i>Tsurite</i>		<i>t</i>	<i>p</i>	<i>d</i>	η^2
60°	Automatic flexion	24.29	±14.35	31.57	±24.01	-0.9	0.384	-0.241	
	Automatic extension	22	±16.52	34.93	±23.38	-1.37	0.193	-0.367	
	Passive flexion	29.57	±14.44	24.79	±17.13		0.552		-0.11
	Passive extension	31.21	±22.26	30.64	±17.01	0.08	0.937	0.022	
90°	Automatic flexion	24.21	±17.85	26.36	±18.05	-0.31	0.76	-0.083	
	Automatic extension	32.14	±19.58	33.14	±21.83	-0.12	0.907	-0.032	
	Passive flexion	28	±14.79	21.21	±9.79	1.53	0.151	0.408	
	Passive extension	19.21	±10.84	17.86	±10.44	0.32	0.754	0.086	
120°	Automatic flexion	21.36	±9.42	19.57	±11.63		0.834		-0.04
	Automatic extension	27.57	±19.65	24.21	±19.12		0.7		-0.07
	Passive flexion	26.57	±24.75	23.86	±15.79		0.572		-0.11
	Passive extension	22.14	±15.4	17.43	±16.01		0.53		-0.12

60°	Automatic abduction	19.14	±13.13	19.57	±18.48	−0.08	0.934	−0.022
	Automatic adduction	16.79	±14.08	20.29	±14		0.362	0.17
	Passive abduction	24.43	±12.13	11.64	±8.81	3.31	0.006	0.885
	Passive adduction	37	±21.14	17.21	±16.44	3.81	0.002	1.017
90°	Automatic abduction	18.86	±14.83	12.07	±5.62	1.96	0.072	0.523
	Automatic adduction	20.07	±11.61	12.07	±14.11		0.064	−0.35
	Passive abduction	18.79	±12.63	10.93	±6.73		0.009	−0.49
	Passive adduction	36.93	±21.86	17.86	±12.56	3.23	0.007	0.863
120°	Automatic abduction	14.86	±9.05	15.29	±11.63		0.777	−0.05
	Automatic adduction	21.71	±14.66	18.71	±9.59	0.77	0.455	0.206
	Passive abduction	21.79	±12.22	24.21	±15.27	−0.59	0.563	−0.159
	Passive adduction	13.71	±7.65	14.93	±14.4		0.916	0.02
5°	Automatic external rotation	23.07	±16.15	15.71	±9.32	1.44	0.173	0.385
	Automatic internal rotation	20.93	±20.25	14.86	±9.45		0.414	−0.15
	Passive external rotation	8.07	±7.93	12.64	±9.52	−1.65	0.122	−0.442
	Passive internal rotation	17.14	±9.89	22.43	±11.73	−1.58	0.138	−0.422
35°	Automatic external rotation	15.86	±9.81	14.79	±6.66	0.56	0.588	0.148
	Automatic internal rotation	19.5	±11.41	17.07	±17.96		0.314	−0.19
	Passive external rotation	18.14	±15.97	19.21	±8.9		0.695	0.07
	Passive internal rotation	13.79	±10.05	16.71	±13.79	−0.72	0.482	−0.194

d Cohen's coefficient; **MC** measurement criteria (survey design); **MD** movement direction; **η²** experimental effect size; **p** probability; **t** Student's *t*-distribution

Comparison by target angle

The analysis determined values of $30.9 \pm 19.4^\circ$, $18.5 \pm 10.5^\circ$, and $19.8 \pm 15.6^\circ$ for target angles of 60° , 90° , and 120° , respectively, in passive extension with test results indicating that the target angles of 90° and 120° had significantly lower values than that of 60° . Moreover, the values were $27.11 \pm 21.1^\circ$, $27.4 \pm 20.0^\circ$, and $14.3 \pm 11.3^\circ$ for target angles of 60° , 90° , and 120° , respectively, in passive adduction, with test results revealing that the target angle of 120° had a significantly lower value than those of 60° and 90° . In addition, comparison by target angle without considering arm movement mode and direction of motion established values of 28.6 ± 18.9 , $25.3 \pm 16.4^\circ$, and $22.8 \pm 16.8^\circ$ for 60° , 90° , and 120° , respectively, in flexion/extension, with test results indicating a significantly lower value at the target angle 120° than 60° (Table 6).

Table 6. Comparison of shoulder joint position sense by target angle: 60°, 90° and 120° (*p* probability, η^2 experimental effect size).

Mode	Movement direction	Measurement criteria (target angles)						<i>p</i>	η^2
		60°		90°		120°			
Automatic	flexion	27.93	±19.76	25.29	±17.65	20.46	±10.43	0.257	
	extension	28.46	±20.93	32.64	±20.36	25.89	±19.1	0.196	
Passive	flexion	27.18	±15.73	24.61	±12.78	25.21	±20.42	0.641	
	extension	30.93	±19.44	18.54	±10.47	19.79	±15.6	0.002	
The target angles for flexion/extension						60°-90°		<001	0.45
						60°-120°		0.013	0.33
						90°-120°		0.385	−0.12
Automatic	abduction	19.36	±15.73	15.46	±11.54	15.07	±10.23	0.596	
	adduction	18.54	±13.89	16.07	±13.31	20.21	±12.25	0.109	
Passive	abduction	18.04	±12.27	14.86	±10.71	23	±13.63	0.06	
	adduction	27.11	±21.14	27.39	±20.01	14.32	±11.33	0.05	
The target angles for abduction/adduction						60°-90°		0.845	−0.03
						60°-120°		0.045	0.27
						90°-120°		0.027	0.3
Automatic		28.63	±18.86	25.27	±16.38	22.84	±16.83	0.045	
Indistinct	the target angles for internal/external rotation					60°-90°		0.181	
						60°-120°		0.013	
						90°-120°		0.256	
Passive		20.76	±16.32	18.45	±15.09	18.15	±12.31	0.316	

Furthermore, the values were $10.36 \pm 8.9^\circ$ and $18.68 \pm 12.7^\circ$ for 5° and 35° target angles, respectively, for passive external rotation, with a significantly lower value for the 5° target angle (Table 7).

Table 7. Comparison of shoulder joint position sense by target angle: 5° and 35° (*p* probability, η^2 experimental effect size).

Mode	Movement direction	Measurement criteria				<i>p</i>	η^2
		5°		35°			
Automatic	external rotation	19.39	±13.47	15.32	±8.25	0.132	−0.2
	internal rotation	17.89	±15.81	18.29	±14.82	0.799	0.03
Passive	external rotation	10.36	±8.9	18.68	±12.7	0.001	0.43
	internal rotation	19.79	±10.98	15.25	±11.93	0.145	−0.2
The target angles for internal/external rotation							
Indistinct automatic/passive		16.86	±12.97	16.88	±12.1	0.937	0.01

For the data included in Table 6 and 7 non-parametric tests were used for all items as a result of the Shapiro-Wilk test. Friedman test was performed for bending/extension and abduction/adduction, and Wilcoxon's rank-sum test was performed for external rotation/internal rotation.

4. Discussion

Comparison by weight established significantly lower values for 60° and 90° automatic abduction and 35° passive external rotation. Moreover, the sense of shoulder joint position for *hikite* was significantly lower in heavyweight-class athletes during 60° automatic abduction, 35° passive external rotation, and 35° passive internal rotation. This suggests that lightweight-class athletes had a larger error in the sense of position relative to the target angle. In University J, where the study subjects were from, the seven heavyweight-class athletes were confirmed to use a wider variety of throwing

techniques in their daily practice and competitions compared to the seven lightweight-class athletes; therefore, these results may conceivably be attributed to the heavyweight class athletes' use of *hikite* and *tsurite* in multiple techniques. In *kakari* practice during training, the angle of *hikite* is highly likely to change according to the technique, and the shoulder joint is adjusted to the intended angle. Moreover, in terms of throwing techniques specialties, lightweight-class athletes often throw the *uke* forward (which in judo jargon means throwing the opponent off balance in the direction of their potential forward movement; the reverse is called a 'backward throw') with techniques such as *uchimata* and *seoi-nage*, while heavyweight-class athletes use many variations of backward throwing techniques, such as *osotogari* and *ouchigari*, and they have vlikely devised ways to use *hikite*.

In the instruction manuals on throwing techniques by Daigo [17-19], while *uchimata* and *seoi-nage* are described as 'pulling up and over towards the front', *osotogari* is described more concretely: 'the left hand (*hikite*) pulls the left hip, and breaks the balance of the *uke*'s body towards the right rear corner', and *ouchigari* is described in a similar concrete way: 'the left hand (*hikite*) lightly pushes up to the *uke*'s right elbow'. The significantly lower values for 60° automatic abduction, 35° passive external rotation, and 35° passive internal rotation in the sense of shoulder joint position for *hikite* may be due to its use in *osotogari* and *ouchigari*. This is only an assumption, but the quality of the sense of position may be greatly affected by the type of technique being used and the combination of specialty techniques. This is an issue that will be addressed in future research.

Comparison of *hikite* and *tsurite* showed that *tsurite* had significantly lower values for 60° and 90° passive abduction/adduction. This result suggests that errors in terms of sense of position are fewer and is therefore better with *tsurite*. A total of two types of *kumi-kata* (grip/stance) exist in judo: *ai-yotsu* (same stance) and *kenka-yotsu* (opposite stance). In *ai-yotsu*, both *tori* and *uke* grasp each other's left sleeve with the right hand or the right sleeve with their left hand; in *kenka-yotsu*, both the *tori* and *uke* use the opposite hands (right or left) from their natural dominant stance [20]. For *ai-yotsu*, the player grabs the opponent's *tsurite* as their own *hikite*, and their own *tsurite* is grabbed by the opponent as their *hikite*. For *kenka-yotsu*, both sides take the opposite stance to *ai-yotsu*, so it becomes a fight between the *tori* and *uke*'s *hikite* or their *tsurite*. The fight between two competitors' *tsurite* in *kenka-yotsu* is especially important during a competition, and this competition for the *tsurite* position may help to cultivate the athletes' sense of position. In judo athletes, upper limb muscle strength of the *tsurite* tends to be higher due to the struggle for the *tsurite* position mentioned earlier, and the shoulder muscle strength measurements conducted as preliminary experiment also indicated that the subjects had significantly higher strength in the shoulder they use for the *tsurite*. Meanwhile, there were also concerns about the effect of one side being the dominant or non-dominant side, rather than the effect of *tsurite* or *hikite*, but additional analysis performed showed that these had no effect.

Comparison by target angle revealed significantly lower values for 90° and 120° compared with 60° for passive extension. For passive abduction, significantly lower values were suggested for 120° compared to 60° and 90°. Even in the comparison that focused only on target angle without taking the movement mode or direction of motion into account, significantly lower values were obtained for 120° compared to 60°. The

common feature among these is that the larger the angle, the smaller the error in the sense of position with respect to the target angle. On the other hand, Tsutsui et al. reported that the errors in abduction movement with target angles of 60°, 90°, and 120° in normal adult males become larger as the target angle increases [21]. In explanations of judo throwing techniques, expressions such as 'lift upward with the right hand' and 'pull with the left hand diagonally upward with the elbow up' are often used to break the balance of the opponent [17-19]. To execute these, the angle of the shoulder joint must be increased. In particular, during *kakari* practice in daily training, since the direction and angle of *hikite* and *tsurite* must be carefully checked, sensitivity towards the sense of position in the 90° to 120° range of the shoulder joint may become more acute.

We analysed the sense of shoulder joint position of judo athletes, and this enabled the verification of the sensations that players and instructors have somehow experienced in the past. These knowledge and findings will help athletes improve their throwing techniques in the future, and should perhaps be included into the coaching methodology of instructors. To effectively break the balance of the *uke*, the *tori* must change the way they utilise their *hikite* and *tsurite* based on their opponent's frame and the type of technique they will use. In the field, many teaching methods such as setting the *hikite* at one's own eye or chin level have been presented, but the way the *uke's* balance is broken needs to be considered, and utilisation of the *hikite* and *tsurite* must be fine-tuned to suit the opponent. In this respect, the sense of positional awareness is important, and it is essential for athletes to conduct their *kakari* and *yakusoku* practices with various opponents to develop a sense of immediate adaptability.

This study is a pilot validation, and the number of subjects is not large. One limitation of the study is the fact that we were unable to block incoming information from being heard due to the progress of the experiment. Another is the fact that the relationship between instability and scapular dyskinesis could not be taken into account because the scapula movement and instability of the glenohumeral joint were not evaluated in advance. Although subjects were selected prior to the experiment on the condition that they had no limitation in shoulder joint movement due to injury, an orthopaedic test should have also been introduced prior to the measurement to obtain more accurate information. In the future, the number of subjects should be increased, as well as the information mentioned above further developed, taking the types of specialty techniques of the subjects and their athletic ability into account for comparison, to contribute to the further popularisation and development of judo.

5. Conclusions

The results suggested that heavyweight athletes may have an overall superior sense of shoulder joint position. The comparison between the pulling and lifting hands revealed athletes are more likely to have a better sense in the former. Moreover, when comparing target angles between the two hands, the error for the target angles of 120° was the smallest in the pulling hand, thus suggesting a better sense of position.

Data Availability Statement: The data supporting this study's findings are available from the corresponding author upon reasonable request.

Institutional Review Board Statement: This study was conducted with the approval of the Research Ethics Committee of the Faculty of Health and Sports Science, Juntendo University (Jundai su rin No. 2023-111, 9.26.2023).

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