© *Idōkan Poland Association*
"IDO MOVEMENT FOR CULTURE. Journal of Martial Arts Anthropology",
Vol. 20, no. 1–4 (2020), pp. 38–46
DOI: 10.14589/ido.20.1.6

HEALTH & REHABILITATION

Elnaz Sanati [1(BCEF)], Amin Kordi Yoosefinejad [2,3(ACDE)], Ali asghar Amiripanah [4(DF)], Saeid Parandavarfard [5(AF)], Frazaneh Yazdani [2(BE)]

Funding Sources: Vice chancellor of Shiraz University of Medical Sciences

1 Msc. of Sport Physical Therapy, Physical Therapy Department, Shiraz University of Medical Sciences, Shiraz (Iran)
2 Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences, Shiraz (Iran)
3 PhD of Physical Therapy, Physical Therapy Department, Shiraz University of Medical Sciences, Shiraz (Iran)
4 Jiyushinkai aikido director, Head of central (Takhti) Dojo, Shiraz (Iran)
5 Head of technical committee, Jiyushinkai aikido director, Head of Fajr Dojo, Shiraz (Iran)
Corresponding Author: Amin Kordi Yoosefinejad
Address: Chamran Blvd., Sheikh Abivardi 1, School of Rehabilitation Sciences, Physical Therapy Department, Shiraz University of Medical Sciences, Shiraz, Iran
e-mail: yoosefinejad@sums.ac.ir

Comparison of sense of wrist joint position between aikidokas and healthy people

Submission: 11.09.2019; acceptance: 2.02.2020

Key words: *aikido*, joint position sense, isokinetic strength, wrist

Abstract

Background. *Aikido* is a Japanese martial art developed by Morihei Ueshiba. Aikido techniques include throwing, falls and joint locks. The wrist joint usually undergoes extreme ranges of flexion and extension in aikido. There is scant evidence about the correlation between proprioception and muscle strength in wrist joints.

Problem and aim. The objective of this study was to compare wrist joint position sense (JPS) between aikidokas and healthy people and to evaluate the correlation between JPS and isokinetic strength of wrist muscles.

Methods. Thirty one aikidokas and 31 healthy people participated in this cross-sectional study. Active and passive JPS were assessed at 35˚ and 60˚ of wrist flexion and extension in both hands. The isokinetic strength of wrist flexors and extensors was assessed at an angular velocity of 90˚/sec.

Results. No significant difference was observed in wrist JPS between the groups. Average peak torque of wrist extension was significantly higher in aikidokas than the control group on the dominant side (P=0.03). Angle to peak torque was achieved sooner in aikidokas (P=0.01). Total work in extension (P=0.03) and average power of flexion (P=0.02) and extension (P=0.03) were significantly higher on the non-dominant side in aikidokas. No acceptable correlation was detected between JPS and isokinetic strength in aikidokas.

Conclusions. Despite the overstraining applied to the wrist, JPS was not impaired in aikidokas. Although we did not observe an acceptable correlation between JPS and muscle strength in aikidokas, some factors like higher peak torque, total work, and power might have supported wrist complex and prevented proprioception impairment in aikidokas.

Introduction

Aikido is a soft style Japanese martial art introduced and developed in twentieth century by *O-sensei, Morihei Ueshiba* [Reguli *et al.* 2016; Vodicka *et al.* 2016]. It is based on concentrating on balance, tranquility, and using the energy of the opponent. The main styles of *aikido* are *Aikikai*, *Yoseikan, Manseikan, Yoshinkan, and Shodokan* [Aikido-health.com]. *Jiyushinkai* is an independent style with roots in teaching methods of *Kano, Mifune, Ueshiba, Tomiki, Ohba, Nishioka*, and *Miyake senseis [Jiyushinkai*.org]. The main techniques of *aikido* include throwing, falls (*ukemi*), pin and locking the joints, and the art of combat with various weapons like knife, staff, and sword [Reguli *et al*. 2016; Foster 2015]. *Aikido* can be practiced with every person irrespective to physical properties, age, height, and weight [Reguli *et al*. 2016; Boguszewski *et al.* 2013; Vidqvist 2012]. The performance and incidence of injury was evaluated in 32 male *aikidokas* using functional movement screen. It was concluded that injuries like fractures, dislocations, sprains, and bursitis were more prevalent in amateur athletes who were under 25 years old, had less than 9 years of aikido experience, and had more than 3 sessions of exercise per week [Boguszewski *et al*. 2013]. Most injuries occurred due to overuse during the practice sessions or incorrect performance of the techniques or falls. Strenuous exercise without fascial awareness prevent the muscles from contracting with a proper timing during the performance of the techniques; this would affect the balance and proprioception of the athletes [Petersen 2015].

Extreme and violent flexion and extension of the wrist would happen during most of *aikido* techniques [Vodicka *et al*. 2016; Eckert and Lee 1993; Olson *et al.* 1996]. According to Eckert *et al.* [1993] and Olson *et al.* [1996], anatomical analyses of two locking techniques on wrist (*Nikyo and Gokyo*) revealed repetitive stress to the wrist and its supporting ligaments. *Aikidokas* require a combination of dynamic and static stability (ligaments and joint supporting structures) to maximize upper extremity performance and also to carry out a wide range of precise and strong movements. Dynamic stability is affected (mediated thorough) by proprioceptive pathways and neuro-muscular control [Salva-Coll *et al*. 2013; Skirven *et al.* 2011; Jerosch and Prymka 1996b; Hagert *et al*. 2009]. Three types of peripheral sensory efferents terminate on brain cortex and help processing of proprioception. They include mechanoreceptors of muscles, skin, and joints. Proprioception is comprised of joint position sense, kinesthesia, neuro-muscular control, and sense of force or resistance [Hagert 2010; Rombaut *et al*. 2010; Riemann and Lephart 2002a; Riemann and Lephart 2002b]. Moberg *et al*. anesthetized the skin over radio-carpal joint to evaluate the joint position sense of this joint. They concluded that irrespective of intact muscles and tendons, joint position sense was impaired [Hagert 2010]. Therefore, skin and joint receptors have an undeniable role in the wrist joint position sense. Among these receptors, *Ruffini* corpuscles have a specific role. Most of the above mentioned receptors are activated during the extreme ranges of wrist flexion and extension. Muscular receptors are more active at mid-position of joint. Trauma and other injurious activities would impair this feedback system (joint position sense) which would predispose limbs to more potential injuries [Jerosch and Prymka 1996a; Baker et al. 2002].

Another important component of exercise, which has a major role in athletic performance, his/her success, and injury prevention, is muscle strength [Brown 2000; Luk *et al.* 2014]. Strength is one of the most affective parameters in athlete performance allow them to confront external forces and to produce motion [Niespodziński et *al.* 2018]. Strength is defined as torque produced by group of muscles acting on a special joint and is measured through vertical applied force to vector arm around joint axis [Kroemer 1986]. Isokinetic measurement of muscle force is concerned with factors like the type of contraction and muscle activity (concentric vs. eccentric), range of motion, speed of test, and limb position during the test. Other factors including age, weight, sex, sport experience, height, injury history, and limb dominancy influence the obtained results [Brown 2000; Reichard *et al.* 2010]. Muscles have the best performance while they are at the optimal length and over-lengthening or over-shortening would impair muscle function [Olson *et al.* 1996]. Over-straining would occur during locking techniques on the wrist joint secondary to extreme range of wrist movements in *aikidokas*. Isokinetic strength studies on upper limbs are not yet available in *aikidokas* and most studies on martial arts have been carried out in *Judo* [Vodicka *et al*. 2016; Eckert and Lee 1993; Olson *et al.* 1996]. There is scant evidence on the correlation between joint position sense and muscular strength especially on wrist joint [Niespodziński *et al.* 2018]. It seems rational that joint position sense impairment secondary to injury, would be compensated by adequate muscular strength [Van der Esch *et al*. 2007]. Proper functioning is mainly affected by impaired joint position sense and muscle weakness [Salles *et al.* 2015]; so, muscle strengthening would provide dynamic stability and ultimately, the joint position sense. Previous studies investigated the correlation between muscle strength and isokinetic exercise and proprioception at shoulder [Salles *et al.* 2015, knee [Hurley *et al.* 1997; Hazneci *et al.* 2005], and ankle joint [Sekir *et al.* 2007] have concluded that increased sensitivity of muscle spindles, as the main receptor of joint position sense [Craske 1977; Gandevia 1985; Lackner and Taublieb 1984; Merton 1964], following strenuous strengthening exercise would result in the augmentation of proprioception. Nevertheless, no correlation was found between decreased muscle strength and impaired joint position sense in patients with osteoarthritis.

The vital role of muscle receptors in reinforcement of joint position sense has been confirmed previously [Hagert 2010]. There is a limited number of studies evaluated the wrist joint position sense in *aikidokas*. The objectives of this study were: 1) to compare muscle strength and wrist joint position sense between *aikidokas* and matched healthy people and 2) to evaluate the correlation between wrist joint position sense and muscle strength in *aikidokas*. If wrist joint position sense would be impaired due to forceful techniques in *aikido*, it would be mandatory to consider a proprioception training program within their practice sessions.

Materials & Methods:

It was a cross-sectional study conducted between April 2019 and July 2019 at Rehabilitation research center of *Shiraz University of Medical Sciences*. The study was approved by the Ethics Committee of the vice chancellor of *Shiraz University of Medical Sciences* (Ethics code: IR. SUMS. REHAB. REC. 1397. 020). The sample size was calculated based on a previous study with considering a power of 80% and an alpha equal to 0.05 as 30 in each group. Thirty one male *aikidokas* (*Jiyushinka*i style) participated in our study using sample of convenience method. A healthy non-athlete control group was matched on age, weight, and height with *aikidokas* group.

The hand dominancy was determined asking the subjects about their hand side preference when throwing a ball. Inclusion criteria for *aikido* group were as follows: 1) Practicing for at least 3 times a week and 1.5 to 2 hours per session [Reguli *et al.* 2016; Boguszewski *et al.* 2013] and 2) Age over 18 years old. Exclusion criteria for both groups were as any congenital disease impacting musculoskeletal or nervous systems, chronic musculoskeletal disorders, hematologic and inflammatory disorders, and positive *Phalen* test [Huang *et al.* 2008; Andersen *et al.* 1996]. All the participants signed an informed consent prior to beginning of the study.

Testing equipment

Active and passive joint position sense and also isokinetic strength of wrist flexors and extensors were evaluated using Biodex system 3 *(Biodex Medical Systems*, Inc, Shirley, New York) with an acceptable reliability and repeatability to investigate athletic performance [Rojas *et al.* 2005; Fabis *et al.* 2016].

Preparation of individuals:

Participants were asked to refrain from heavy load activities twenty four hours before the test [Hazneci *et al.* 2005]. They sat on chair while using headphone and blindfold [Rombaut *et al.* 2010]. The trunk was fixed with straps to stabilize the participant during the trials. The elbow was fixed in pronation and 60 degrees of flexion on arm rest and the shoulder was in 20 degrees of abduction. The tests were performed bilaterally as techniques are performed with both dominant and non-dominant hands in *aikido*.

Testing sequence:

– Position sense assessment

Both active and passive joint position senses were evaluated. The center of the wrist joint was aligned with the actuator of dynamometer [Andersen *et al.* 1996; Forthomme *et al.* 2002]. The distance between machine arm and distal of ulna was set at 1.5 cm. The range of motion was evaluated within inner half (35 °) and outer half (60°) of flexion and extension [Andersen *et al.* 1996]. The gravity correction was applied. To familiarize the participants with tests, each participant performed 3 active trials from full flexion to full extension range [Hazneci *et al.* 2005]. For safety, participants were advised how to stop the test if necessary. To evaluate active joint position sense, wrist joint was in initial neutral position. Then, the participant was asked to move the wrist to pre-determined angle actively either to extension or flexion. The actuator stopped at the predetermined angle for 3 seconds and the participants was asked to record it in their mind. Then, the actuator returned to the initial position and the participant would move the wrist to pre-determined angle actively. This trial was repeated twice [Gay *et al.* 2011]. To evaluate passive joint position sense, the participant actively moved the wrist to predetermined angles, and the actuator stopped there for 5 seconds (Atalay *et al.* 2008]. After returning to the initial position, the actuator moved with an angular velocity of 4 °/sec to predetermined angle. The participant was asked to press stop bottom whenever the predetermined angle was achieved. The trial was repeated three times [Lee *et al.* 2009]. Wash out period between the tests was 30 seconds [Gay *et al.* 2011]. Mean absolute error score of repositioning of pre-determined angles was calculated for the final analysis.

– Isokinetic strength assessment

The dynamometer was calibrated according to the instruction. The position of the participants during isokinetic tests was the same as before. The assessments were carried out within 100 degrees of range of motion (50 degrees of flexion and 50 degrees of extension) with an angular velocity of 90°/sec. We evaluated the eccentric contraction of wrist extensors and the concentric contraction of wrist flexors. Five submaximal contractions were performed as warm up [Andersen *et al.* 1996]. The participants were asked to exert maximal effort during the test and they received visual and auditory feedback during the test. They started the test as soon as they saw green light on the screen or hearing a beeb. The rest period was 15 seconds between the trials [Kaminski *et al.* 2003].

The extracted and evaluated parameters were peak torque, peak torque normalized to weight, average peak torque, average of total work, average power, and angle to peak torque as the most commonly used indices to assess weakness and injury of muscles [Call, Chandler 1996; Brinks *et al.* 1995; Horvat *et al.* 1999; Mayer *et al.* 1994]. The tests were repeated if the coefficients of variation (CV) were more than 10%.

– Statistical analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 25.0 for Windows (PASW Statistics for Windows, Chicago: SPSS Inc., IL, U.S.A). The normality of data was confirmed using Shapiro- Wilk test. To compare the position of sense and isokinetic strength data between the groups, independent sample *t*-test was used. To evaluate the correlation among isokinetic and position of sense parameters (dependent variables) and independent variables including age and *aikido* experience, Pearson correlation coefficient was used. The correlations were interpreted as very weak if r= 0- 0.19, weak if r=0.2- 0.39, moderate if r= 0.4- 0.69, strong if r= 0.7- 0.89, and very strong if r= 0.9-1 [Cacchio *et al.* 2012]. Significance level was considered as P<0.05.

Results

The demographic data of the participants is summarized in Table 1.

Table 1. Demographic data of the participants

Variables	*Aikidoka* group (n=31)	Control group (n=31)	P-value
Age (years)	34.70± 11.72	32.77± 11.03	0.35
Height (cm)	173.63± 5.52	176.54± 7.30	0.09
Weight (Kg)	78.13± 13.03	75.38± 13.89	0.4
Aikido experience (years)	8.33± 5.23	-------	------

Data are presented as mean± SD

As can be observed in Table 1, there was no significant difference in demographic data between the groups.

Active and passive mean absolute joint repositioning error of both dominant and non-dominant sides, at 35° and 60° during flexion and extension were compared between the groups. The related data are summarized in Table 2.

As can be observed, there was no significant difference for all the evaluated conditions of joint repositioning error between the groups.

Comparing isokinetic strength data between the groups revealed that mean of peak torque of dominant side in extension was significantly more in *aikidokas* in comparison to control group (P=0.03). Also, angle to peak torque on dominant side was achieved significantly sooner in *aikidokas* rather than control group (P=0.01). Maximum work during extension of the non-dominant side, mean power of the non-dominant side during both flexion and extension were all significantly higher in *aikidokas* comparing with control group. The related data of dominant and non-dominant sides are summarized in Tables 3 and 4 respectively.

Correlations among joint position sense with age and *aikido* experience were not acceptable. Table 5 summarized the correlations.

Table 6, summarized the correlation among isokinetic contraction parameters with age and *aikido* experience. As can be observed the obtained correlations were not within acceptable values.

Discussion

Most of the isokinetic studies have been performed on knee joint [Forthomme *et al.* 2002]. In *aikido*, there are various locking techniques on wrist joint including maximum extremes of flexion and extension; however, there is no evidence on isokinetic assessment of upper extremities in *aikidokas*. Previous studies mostly evaluated *judo* [Vodicka *et al.* 2016]. The main objective of this study was to compare isokinetic strength of wrist flexors and extensors and also passive and active joint position senses between *aikidokas* and a group of healthy matched people. The obtained results showed that the average power of extensors, total work of the extensors of non-dominant hand, and mean of peak torque in

Table 2. Comparison of mean absolute error of joint repositioning between aikidokas and control group

variables			*Aikidokas* group (n=31) (mean± SD)	Control group (n=31) (mean± SD)
Dominant hand	Active	35° flexion	5.72 ± 3.21	5.96 ± 4.03
		60° flexion	8.27 ± 3.97	8.55 ± 4.99
		35° extension	6.40 ± 3.36	5.63 ± 2.87
		60° extension	8.01± 6.39	6.19 ± 3.19
	Passive	35° flexion	4.24 ±1.95	4.59 ± 2.17
		60° flexion	5.70 ± 3.57	7.33 ± 4.68
		35° extension	5.02 ± 3.57	4.51 ± 2.01
		60° extension	4.91 ± 3.0	4.95 ± 2.82
Non-dominant hand	Active	35° flexion	5.76 ± 3.15	7.15 ± 4.79
		60° flexion	7.11 ± 3.38	8.32 ± 4.10
		35° extension	5.29 ± 3.47	6.00 ± 4.18
		60° extension	6.69 ± 3.64	7.08 ± 4.49
	Passive	35° flexion	3.26 ± 1.73	4.03 ± 2.32
		60° flexion	5.51 ± 2.99	5.52 ± 3.16
		35° extension	3.78 ± 2.41	4.92 ± 2.81
		60° extension	4.13 ± 1.96	3.98 ± 2.59

Table 3. Comparison of the parameters of isokinetic strength of dominant side

Variables	Movement direction	*Aikidokas* group (n=31) Mean ± SD	Control group (n=31) Mean ± SD	P-value
Peak torque/ Body weight (%)	Flexion	38.74 ± 9.30	37.34 ± 10.82	0.49
	Extension	43.92 ± 7.47	42.03 ± 9.22	0.38
average Peak torque (Nm)	Flexion	26.21 ± 7.42	23.38 ± 7.13	0.13
	Extension	30.00 ± 6.13	26.15 ± 7.57	**0.03***
Total work (Joule)	Flexion	149.33 ± 51.03	135.83 ± 61.04	0.35
	Extension	180.27 ± 38.69	168.63 ± 52.34	0.33
average power (watt)	Flexion	17.85 ± 5.74	15.49 ± 6.85	0.15
	extension	28.38 ± 3.51	25.74 ± 6.91	0.07
Angle to peak torque	Flexion	36.46 ± 16.12	44.70 ± 9.76	**0.02***
	Extension	20.83 ± 14.36	22.29 ± 16.52	0.71

*: P<0.05

Table 4. Comparison of the parameters of isokinetic strength of non-dominant side

Variables	Movement direction	*Aikidokas* group (n=31) Mean ± SD	Control group (n=31) Mean ± SD	P-value
Peak torque/ Body weight (%)	Flexion	38.96 ± 9.43	36.88 ± 11.94	0.87
	Extension	42.81 ± 8.55	40.44 ± 10.38	0.46
average Peak torque (Nm)	Flexion	24.73 ± 5.06	23.94 ± 7.57	0.13
	Extension	29.26 ± 5.55	26.53 ± 7.85	0.69
Total work (Joule)	Flexion	138.02 ± 43.72	126.49 ± 52.49	**0.03***
	Extension	190.72 ± 34.70	168.15 ± 43.35	0.49
average power (watt)	Flexion	14.51 ± 3.78	12.02 ± 4.72	**0.02***
	extension	29.70 ± 4.92	24.97 ± 6.80	**0.003***
Angle to peak torque	Flexion	42.06 ± 16.10	40.10 ± 15.68	0.32
	Extension	24.30 ± 15.92	22.76 ± 16.07	0.12

*: P<0.05

Table 5. Pearson correlation coefficient among joint position sense with age and *aikido* experience

Side	Movement type	Movement direction	Age (years)	P-value	*Aikido* Experience (years)	P-value
Dominant	active	35° flexion	-0.02	0.90	- 0.11	0.55
		60° flexion	0.01	0.95	0.04	0.82
		35° extension	-0.15	0.42	-0.24	0.18
		60° extension	0.05	0.76	0.26	0.15
	Passive	35° flexion	-0.05	0.76	0.13	0.49
		60° flexion	-0.10	0.57	0.10	0.59
		35° extension	-0.01	0.95	0.04	0.81
		60° extension	0.07	0.69	-0.08	0.65
Non-dominant	Active	35° flexion	0.07	0.69	0.14	0.44
		60° flexion	-0.02	0.88	0.17	0.34
		35° extension	-0.29	0.11	-0.26	0.15
		60° extension	-0.23	0.20	0.02	0.89
	Passive	35° flexion	0.11	0.53	-0.03	0.84
		60° flexion	-0.21	0.26	-0.27	0.13
		35° extension	0.01	0.95	0.11	0.55
		60° extension	0.001	0.99	-0.07	0.69

extensors were significantly higher in *aikidokas* in comparison to control group. Furthermore, mean of angle to peak torque in flexors of dominant side was lower in *aikidokas* rather than control group.

Vodicka *et al.* [2016] who showed less strength of wrist extensor muscles in *aikidokas* in comparison to that of other martial arts such as *judo*, boxing, wrestling, and Brazilian *jiujitsu*. They did not compare their findings with those of healthy control group. We selected speed as 90 °/sec as the participants were unable to do trials at higher velocities (120, 180 °/sec). Therefore, it might be possible that the selected speed had more effects on eccentric contraction of extensors rather than concentric contraction of flexor muscles. The smaller average angle to peak torque in comparison to control group might be due to the application of more explosive mechanical

Table 6. Pearson correlation coefficient among isokinetic contraction with age and aikido experience

Side	Variable	Movement direction	Age (years)	P-value	*Aikido* Experience (years)	P-value
Dominant	Peak torque/ Body weight (%)	flexion	-0.09	0.61	0.02	0.89
		Extension	-0.18	0.32	-0.04	0.82
	Average peak torque (Nm)	Flexion	-0.21	0.24	-0.15	0.42
		extension	-0.34	0.05	-0.23	0.20
	Total work (joule)	Flexion	-0.01	0.95	-0.28	0.13
		extension	-0.09	0.63	-0.34	0.06
	Average power (watt)	Flexion	0.21	0.25	-0.05	0.77
		extension	-0.24	0.19	-0.37	0.05
Non-dominant	Peak torque/ Body weight (%)	flexion	-0.08	0.65	0.09	0.61
		Extension	-0.14	0.45	0.12	0.49
	Average peak torque (Nm)	Flexion	-0.03	0.84	-0.02	0.90
		extension	-0.27	0.14	-0.17	0.36
	Total work (joule)	Flexion	-0.12	0.50	-0.14	0.45
		extension	-0.20	0.29	-0.23	0.21
	Average power (watt)	Flexion	-0.23	0.21	-0.30	0.10
		extension	-0.26	0.16	-0.26	0.15

force in *aikidokas*. Having more muscular strength in *akidokas* in comparison to control group revealed that although *aikido* art is not based on strengthening exercises, it has beneficial effects on strength gain. Moreover, higher strength of eccentric contraction of extensors rather than concentric contraction of flexors indicated stabilizing role of these group of muscles which might be effective in preventing injuries of wrist joint.

According to Eckert *et al.* [1993] and Olson *et al.*[1996], *aikido* techniques exert a great stress on ligaments and tendons of wrist joint especially *Ruffini* and Golgi-like tendon receptors. We did not find any difference in active and passive joint position senses between the *aikidokas* and the control group. It might be attributed to stabilizing role of the wrist extensors which prevented injury to proprioceptors. *Ruffini* receptors are widely distributed in wrist ligaments [Hagert *et al.* 2005; Hagert *et al.*, 2007]. These receptors respond to slow speeds between 0.5 and 2°/sec [Lephart *et al.* 1997; Riemann *et al.* 2002]. On the other hand, isokinetic is preset at a rate of 4°/sec during the assessment of joint position force. This might elucidate the lack of difference in active and passive joint position senses between the groups. Unaltered joint position sense in *aikidokas* showed that despite the great stress on wrist joints during the performance of techniques, joint position sense did not disturbed even in *aikidokas* with more than 7 years of experience.

It was shown that amateurs intentionally concentrate on closed loop system to improve their function, while expert athletes use sensory checking to have better performance [Provins 1997; Han *et al.* 2014]. Investigating ankle joint in soccer players revealed that the augmentation of proprioception had a positive correlation with performance. Also, expert athletes allocate less central capacity to control movement during the processing of data related to proprioception. Consequently, they had more concentration to locate teammates or opponents or to have better opportunity to pass or shoot the ball [Han *et al.* 2014; Yogev-Seligmann *et al.* 2008]. Better proprioception was strongly correlated with competition level of soccer players and no correlation was observed between proprioception and time spent in sport [Han *et al.* 2014; Han *et al.* 2015]. As forty percent of the *aikidokas* in our study were practicing for less than 5 years, this might have contaminated our results about the lack of difference in proprioception between the *aikidokas* and the control group. It is also worth noting that we did not evaluate the correlation between proprioception and competition level of the *aikidokas.*

It could not be hypothesized that joint repositioning error could be considered as the only indicator of proprioception deficit [Bayramoglu *et al.* 2007]. Other factors like the occupation, genetic, and strenuous exercise might be so effective on proprioception [Han *et al.* 2015; Baker *et al.* 2003]. As the muscle spindles are the main receptors of proprioception [Proske 2005], we assumed a positive correlation between muscle strength and the joint position sense but we did not find any accepted correlation. It was in line with findings of Selles *et al.* They evaluated the effects of eight-week training program on shoulder proprioception [Salles *et al.* 2015]. They found that the obtained joint repositioning error during the evaluation of active proprioception was related to the intensity of exercises and strenuous exercise had beneficial effects on proprioception. As *aikido* do not contain strenuous strengthening training, we did not find a correlation between strength and proprioception parameters.

This was the first study comparing wrist joint position sense between *aikidokas* and a matching group of healthy people. Also, the first one evaluated the correlation among joint position sense and isokinetic contraction parameters with age and *aikido* experience. Our study had some limitations. Firstly, our sample contained only male *aikidokas*; so we cannot generalize our findings to all the *aikidokas*. Secondly, our participants were from *jiyushimka*i style. Similar studies on other styles such as *aikikai, yoshinkan,* or else are required to see if the same results would be obtained. Also, future studies are warranted to compare the proprioception of other joints which are vulnerable to overstrain or overpressure in *aikidokas.*

Conclusion

Despite the overstraining applied to the wrist during aikido techniques, joint position sense was not impaired in *aikidokas*. Although no acceptable correlation was found between joint position sense and isometric muscle strength in *aikidokas*, it seems that some factors like higher peak torque, total work, and power might have supported wrist complex and prevented any proprioception impairment in *aikidokas.*

Acknowledgment

This study was supported by a grant from vice chancellor of research of *Shiraz University of Medical Sciences*. We appreciate all the subjects for their kind participation in our study.

References

1. Andersen H., Poulsen P.L., Mogensen C.E., Jakobsen J. (1996), *Isokinetic muscle strength in long-term IDDM patients in relation to diabetic complications*, "Diabetes", vol. 45, pp. 440-445.
2. Atalay N., Ersoz M., Eser F., Kumbara F., Akyuz M. (2008), *Evaluation of Proprioception of Wrist in the Cases of the Hemiplegia After Cerebro Vascular Event (CVE) by Using Isokinetic System*, "Turk J Phys Med Rehab", vol. 54, pp. 46-49.
3. Baker J., Horton S., Robertson-Wilson J., Wall M. (2003), *Nurturing sport expertise: factors influencing the development of elite athlete,* "Journal of sports science & medicine", vol. 2, p. 1.
4. Baker V., Bennell K., Stillman B., Cowan S. Crossley K. (2002), *Abnormal knee joint position sense in individuals with patellofemoral pain syndrome*, "Journal of Orthopaedic Research", vol. 20, pp. 208-214.
5. Bayramoglu M., Toprak R. Sozay S. (2007), *Effects of osteoarthritis and fatigue on proprioception of the knee joint*, "Archives of physical medicine and rehabilitation", vol. 88, pp. 346-350.
6. Boguszewski D., Suchcicka B., Adamczyk J.Z., Bialoszewski D. (2013), *The functional efficiency and incidence of injuries in men practicing aikido. Pilot study*, "Journal of Combat Sports & Martial Arts", vol. 4., no. 1, pp. 67-73.
7. Brinks K., Delong R., Stout T. (1995), *The relationship among isokinetic knee parameters and three functional tests.* Master Thesis, 237.
8. Brown L.E. (2000), *Isokinetics in human performance*, Human Kinetics. Florida Atlantic University, Florida, pp. 3-25.
9. Cacchio A., Necozione S., Macdermid J.C., Rompe J. D., Maffulli N., Di orio F., Santilli V. Paoloni M. (2012), *Cross-cultural adaptation and measurement properties of the Italian version of the Patient-Rated Tennis Elbow Evaluation (PRTEE) questionnaire*, "Physical therapy",vol. 92, pp. 1036-1045.
10. Call L., Chandler S. (1996), *Relationships Among Isokinetic Knee Flexion and Extension Parameters, Three Functional Tests, and Subjective Knee Scores in ACL Reconstructed Patients*. Masters theses. 266. Grand Valley State University.
11. Craske B. (1977), *Perception of impossible limb positions induced by tendon vibration*, "Science", vol. 196, pp. 71-73.
12. Eckert J.W., Lee T.K. (1993), *The anatomy of Nikyo (Aikido's second teaching),* "Perceptual and motor skills",vol. 77, pp. 707-715.
13. Fabis J., Rzepka R., Fabis A., Zwierzchowski J., Kubiak G., Stanula A., Polguj M., Maciej R. (2016), *Shoulder proprioception–lessons we learned from idiopathic frozen shoulder*, "BMC musculoskeletal disorders", vol. 17, p. 123.
14. Forthomme B., Croisier J.L., Foidart-Dessalle M., Crielaard J.M. (2002), *Isokinetic assessment of the forearm and wrist muscles*, "Isokinetics and exercise science", vol. 10, pp. 121-128.
15. Foster D. (2015), *Fighters who don't fight: The case of aikido and somatic metaphorism*, "Qualitative Sociology", vol. 38, pp. 165-183.
16. Gandevia S.C. (1985), *Illusory movements produced by electrical stimulation of low-threshold muscle afferents from the hand*, "Brain", vol. 108, pp. 965-981.
17. Gay A., Harbst K., Hansen D.K., Laskowski E.R., Berger R.A., Kaufman K.R. (2011), *Effect of partial wrist denervation on wrist kinesthesia: wrist denervation does not impair proprioception*, "The Journal of Hand Surgery", vol. 36, pp. 1774-1779.
18. Hagert E. (2010), *Proprioception of the wrist joint: a review of current concepts and possible implications on the rehabilitation of the wrist*, "Journal of Hand Therapy", vol. 23, pp. 2-17.
19. Hagert E., Forsgren S., Ljung B.O. (2005), *Differences in the presence of mechanoreceptors and nerve structures between wrist ligaments may imply differential roles in wrist stabilization*, "Journal of Orthopaedic Research", vol. 23, pp. 757-763.
20. Hagert E., Garcia-Elias M., Forsgren S. Ljung B.O. (2007), *Immunohistochemical analysis of wrist ligament innervation in relation to their structural composition*, "The Journal of hand surgery", vol. 32, pp. 30-36.
21. Hagert E., Persson J. K., Werner M., Ljung B.O. (2009). *Evidence of wrist proprioceptive reflexes elicited after stim-*

ulation of the scapholunate interosseous ligament, "The Journal of Hand Surgery", vol. 34, pp. 642-651.

22. Han J., Anson J., Waddington G., Adams R. (2014), *Sport attainment and proprioception*, "International Journal of Sports Science & Coaching", vol. 9, pp. 159-170.
23. Han J., Waddington G., Anson J., Adams R. (2015), *Level of competitive success achieved by elite athletes and multi-joint proprioceptive ability*, "Journal of Science and Medicine in Sport", vol. 18, pp. 77-81.
24. Hazneci B., Yildiz Y., Sekir U., Aydin T., Kalyon T.A. (2005), *Efficacy of isokinetic exercise on joint position sense and muscle strength in patellofemoral pain syndrome*, "American journal of physical medicine & rehabilitation", vol. 84, pp. 521-527.
25. Horvat M., Croce R., Pitetti K. H., Fernhall B. (1999), *Comparison of isokinetic peak force and work parameters in youth with and without mental retardation*, "Medicine and science in sports and exercise", vol. 31, pp. 1190-1195.
26. Http://www.aikido-health.com (access Jan. 2020).
27. Http://www.Jiyushinkai.org (access Jan. 2020).
28. Huang C.C., Yang Y.H., Chen C.H., Chen T.W., Lee C.L., Wu C.L., Chuang S.H., Huang M.H. (2008), *Upper extremities flexibility comparisons of collegiate "soft" martial art practitioners with other athletes*, "International journal of sports medicine", vol. 29, pp. 232-237.
29. Hurley M.V., Scott D.L., Rees J., Newham D.J. (1997), *Sensorimotor changes and functional performance in patients with knee osteoarthritis*, "Annals of the rheumatic diseases", vol. 56, pp. 641-648.
30. Jerosch J., Prymka M. (1996a). *Knee joint proprioception in patients with posttraumatic recurrent patella dislocation*, "Knee surgery, sports traumatology, arthroscopy", vol. 4, pp. 14-18.
31. Jerosch J., Prymka M. (1996b), *Proprioception and joint stability*, "Knee surgery, sports traumatology, arthroscopy", vol. 4, pp. 171-179.
32. Kaminski T., Buckley B., Powers M., Hubbard T., Ortiz C. (2003), *Effect of strength and proprioception training on eversion to inversion strength ratios in subjects with unilateral functional ankle instability*, "British Journal of Sports Medicine", vol. 37, pp. 410-415.
33. Kroemer K.H. (1986), *Human muscle strength: definition, generation and measurement*, "Proceedings of the Human Factors Society Annual Meeting", vol. 22, no. 1, pp. 977-981.
34. Lackner J.R., Taublieb A.B. (1984), *Influence of vision on vibration-induced illusions of limb movement,* "Experimental neurology", vol. 85, pp. 97-106.
35. Lee H.M., Cheng C.K., Liau J.J. (2009), *Correlation between proprioception, muscle strength, knee laxity, and dynamic standing balance in patients with chronic anterior cruciate ligament deficiency*, "The Knee", vol. 16, pp. 387-391.
36. Lephart S.M., Pincivero D.M., Giraido J.L., Fu F.H. (1997), *The role of proprioception in the management and rehabilitation of athletic injuries*, "The American Journal of Sports Medicine", vol. 25, pp. 130-137.
37. Luk H.Y., Winter C., O'neil L.E., Thompson B.A. (2014), *Comparison of muscle strength imbalance in powerlifters and jumpers*, "The Journal of Strength & Conditioning Research", vol. 28, pp. 23-27.
38. Mayer F., Horstmann T., Kranenberg U., Rocker K., Dickhuth H.H. (1994), *Reproducibility of isokinetic peak torque and angle at peak torque in the shoulder joint*, "International Journal of Sports Medicine", vol. 15, pp. S26-S31.
39. Merton P. (1964), *Human position sense and sense of effort*, "Symposia of the Society for Experimental Biology", pp. 387-400.
40. Niespodzinski B., Kochanowicz A., Mieszkowski J., Piskorska E., Zychowska M. (2018), *Relationship between joint position sense, force sense, and muscle strength and the impact of gymnastic training on proprioception.* "BioMed research international", vol. 2018: 5353242. doi: 10.1155/2018/5353242.
41. Olson G.D., Seitz F.C., Guldbrandsen F. (1996), *An Inquiry into Application of Gokyo (Aikido's Fifth Teaching) on Human Anatomy,* "Perceptual and motor skills", vol. 82, pp. 1299-1303.
42. Petersen S. (2015), *The secret of fascia in the martial arts* [in:] R. Schleip [ed.], *Fascia in sport and movement*, Handsprong Publishing, Edinburg, pp. 153-160.
43. Proske U. (2005), *What is the role of muscle receptors in proprioception*?, "Muscle & Nerve: Official Journal of the American Association of Electrodiagnostic Medicine", vol. 31, pp. 780-787.
44. Provins K. (1997), *The specificity of motor skill and manual asymmetry: A review of the evidence and its implications*, "Journal of Motor Behavior", vol. 29, pp. 183-192.
45. Reguli Z., Bernacikova M., Kumstat M. (2016), *Anthropometric Characteristics and Body Composition in Aikido Practitioners,* "International Journal of Morphology", vol. 34, no. 2, pp. 417-423.
46. Reichard B., Katz-Leurer M., Rubinstein M., Croisier J.L., Dvir Z. (2010), *Short range of motion isokinetic testing of wrist flexor and extensor strength in normal subjects and patients with carpal tunnel syndrome,* "The Journal of Strength & Conditioning Research", vol. 24, pp. 1866-1873.
47. Riemann B.L., Lephart S. M. (2002a), *The sensorimotor system, part I: the physiologic basis of functional joint stability*, "Journal of Athletic Training", vol. 37, no. 1, pp.71- 79.
48. Riemann B.L., Lephart S.M. (2002b), *The sensorimotor system, part II: the role of proprioception in motor control and functional joint stability*, "Journal of Athletic Training", vol. 37, no. 1, pp. 80-84.
49. Riemann B.L., Myers J.B., Lephart S.M. (2002), *Sensorimotor system measurement techniques*, "Journal of Athletic Training", vol. 37, no. 1, pp. 85-98.
50. Rojas R.G., Zarco R.C., Garcıa M.D. (2005), *Evaluacion cuantitativa de propiocepcion en hombro: Sentido de posicion, umbral y repeticion de velocidad de movimiento*, "Revista mexicana de medicina fısica y rehabilitación", vol. 17, pp. 77-83 [in Brazilian].
51. Rombaut L., De Paepe A., Malfait F., Cools A., Calders P. (2010), *Joint position sense and vibratory perception sense*

in patients with Ehlers–Danlos syndrome type III (hypermobility type), "Clinical Rheumatology", vol. 29, no. 3, pp. 289-295.

52. Salles J.I., Velasques B., Cossich V., Nicoliche E., Ribeiro P., Amaral M.V., Motta G. (2015), *Strength training and shoulder proprioception,* "Journal of Athletic Training", vol. 50, no. 3,pp. 277-280.
53. Salva-Coll G., Garcia-Elias M., Hagert E. (2013), *Scapholunate instability: proprioception and neuromuscular control,* "Journal of Wrist Surgery", vol. 2, no. 2, pp. 136-140.
54. Sekir U., Yildiz Y., Hazneci B., Ors F., Aydin T. (2007), *Effect of isokinetic training on strength, functionality and proprioception in athletes with functional ankle instability*, "Knee surgery, sports traumatology, arthroscopy", vol. 15, no. 5, pp. 654-664.
55. Skirven T.M., Osterman A.L., Fedorczyk J., Amadio P.C. (2011), *Rehabilitation of the hand and upper extremity, 2-volume set E-book: expert consult*, Elsevier Health Sciences.
56. Van Der esch M., Steultjens M., Harlaar J., Knol D., Lems W., Dekker J. (2007), *Joint proprioception, muscle strength, and functional ability in patients with osteoarthritis of the knee*, "Arthritis Care & Research: Official Journal of the American College of Rheumatology" , vol. 57, no. 5, pp. 787-793.
57. Vidqvist E. (2012), *Knee Problems among Iaido Practitioners*, Degree Programme in Physiotherapy, Thesis.
58. Vodicka T., Pieter W., Reguli Z., Zvonar M. (2016), *Isokinetic strength of the wrist in male aikido athletes*, "Ido Movement for Culture. Journal of Martial Arts Anthropology", vol. 16, no. 2, pp. 48-54.
59. Yogev-Seligmann G., Hausdorff J. M., Giladi N. (2008), *The role of executive function and attention in gait,* "Movement disorders: official journal of the Movement Disorder Society", vol. 23, no. 3, pp. 329-342.

Porównanie czucia pozycji stawu nadgarstka u zawodników aikido i zdrowych osób

Słowa kluczowe: aikido, czucia pozycji stawu nadgarstka, siła izokinetyczna, nadgarstek

Streszczenie

Tło. Aikido to japońska sztuka walki stworzona przez Morihei Ueshibę. Techniki aikido obejmują rzuty, upadki i blokady stawów. W aikido staw nadgarstkowy zwykle ulega ekstremalnym zakresom zgięcia i wydłużenia. Nie ma wielu opracowań naukowych dostarczających dowodów na związek między proprioceptem a siłą mięśni w stawie nadgarstkowym.

Problem i cel. Celem pracy było porównanie czucia pozycji stawu nadgarstka (JPS) u zawodników aikido i zdrowych osób oraz ocena korelacji między JPS a siłą izokinetyczną mięśni nadgarstka.

Metody. W badaniu przekrojowym wzięło udział trzydzieści jeden aikidoków i 31 osób zdrowych. Aktywne i bierne JPS oceniano przy 35˚ i 60˚ zgięcia i rozciągnięciu nadgarstka po obu stronach. Wytrzymałość izokinetyczną zginaczy i ekstensorów nadgarstka oceniono przy prędkości kątowej 90˚/sec.

Wyniki. Nie zaobserwowano istotnej różnicy w JPS nadgarstka między grupami. Średni szczytowy moment obrotowy rozciągnięcia nadgarstka był istotnie większy u zawodników aikido niż w grupie kontrolnej po stronie dominującej (P=0,03). U zawodników aikido kąt do punktu szczytowego momentu obrotowego osiągnięto wcześniej (P=0,01) niż w grupie kontrolnej (P=0,03). Całkowita praca w rozciągnięciu (P=0,03) oraz średnia siła zgięcia (P=0,02) i rozciągnięcia (P=0,03) były istotnie większe po stronie niedominującej u zawodników aikido. Nie stwierdzono dopuszczalnej korelacji pomiędzy JPS a siłą izokinetyczną u zawodników aikido.

Wnioski. Pomimo nadmiernego obciążenia nadgarstka, JPS u zawodników aikido nie był zaburzony. Chociaż nie zaobserwowano akceptowalnej korelacji pomiędzy JPS a siłą mięśni u zawodników aikido, niektóre czynniki, takie jak większy szczytowy moment obrotowy, praca całkowita i siła mogły wspierać kompleks nadgarstka i zapobiegać zaburzeniom propriocepcji u zawodników aikido.