ORIGINAL ARTICLE

Three-dimensional assessment of the judo throwing techniques frequently used in competition

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Abstract

Background & Study Aim: Although the judo throwing techniques are not considered as injurious to the attacker, repetition of these techniques might cause repetitive strain type injuries. The goal of the study was knowledge about the degrees of flexion and extension and abduction and adduction of the main locomotive joints, performing the most employed throwing techniques in high-level competition.

Material & Methods: Two world-class judoists, under the supervision of an elite Japanese expert, performed seoi-nage, uchi-mata, osoto-gari, ouchi-gari and kouchi-gari. They were analysed using three-dimensional technology.

Results: Data of performance throws obtained from expert 1 and 2 respectively were very similar. Results indicate that systematic repetition of seoi-nage, uchi-mata and o-soto-gari can produce shoulder tendon pathologies. Long-term seoi-nage and uchi-mata practice might generate epicondylitis. Judokas who have suffered anterior cruciate ligament injuries must be careful when executing techniques that demand explosive knee extension (i.e. seoi-nage) against a great resistance. Judokas are not exposed to overuse injuries when they perform ouchi-gari and kouchi-gari throws.

Conclusions: Systematic practice of the most employed judo throwing techniques in high-level judo can cause injuries by overuse in the upper-body joints (shoulder, elbow). Nevertheless, the lower-body joints (knee, ankle) do not seem to be at risk of injury by overuse.

Keywords: combat sports • injuries • overuse • prophylactic training • rehabilitation programme

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Introduction

Kata – formal movement pattern exercises containing idealized model movements illustrating specific combative principles [20]

Kodokan Goshinjutsu – a set of Kodokan Judo formal exercises (kata) designed to teach ways and means of self defense using throwwing, grappling, and striking techniques [20]

Nage no Kata – a set of Kodokan Judo formal exercises (kata) illustrating the principles of throwing, including three representative techniques each from the categories of hand, hip, foot, supine sacrifice, and side sacrifice techniques [20]

Ju no Kata – the Ju no Kata feature many movements designed to stretch and extend the body and so serve as a supplement to general physical education regimen. They also incorporate many slow, relatively gentle movements designed to give practitioners a clear understanding of the principles of judo [20]

Over-use syndrome – the pathological signs and symptoms created by repeated use of the body in physically stressful conditions [21]

Prophylaxis – any preventive treatment of disease [21]

Judo is a combat sport included in the Olympic and Paralympic programme. It is an intermittent exercise, short in duration, and high in intensity [1]. Competitors are in close contact, wearing a specific uniform (*judogi*), trying to throw their opponent to the floor [2]. Besides, physiological, psychological, emotional and tactical components, technical skills are indispensable for success in training and competition [2, 3]. During the 2010 Judo World Championships, *seoi-nage, uchi-mata* and *osoto-gari* were the most frequently executed throwing techniques [4]. Their effectiveness resulted from their massive use in training, since "World Championships and Olympic Games are the moments that best summarize many years of training" [5, 51]. Gawronski [6] distinguishes two types of sport injuries: acute which are caused by a sudden and single trauma, and chronic injuries following a long-lasting, repeated impact of a traumatic factor. Both types are manifestations of tissue wear. A single stimulus has certain physiological effects, but multiple repetitions of the same stimulus can produce an injury. Although judo throwing techniques do not hold a traumatic factor, their massive used may produce chronic injuries. Moreover, technical errors of judo athletes executing a technique might also generate these chronic injuries. Judo is the combat sport with the highest percentage of injuries [7], but the injury risk was medium in male (10.9%) and female (12.4%) judo athletes during Olympic tournaments [8] According to Kurppa [9], each sport ought to develop its specific preventive injury measures. Witkowski et al. stated that: "effective prevention and rehabilitation in the future are determined by the ability of researchers studying these phenomena, and combat sports coaches to implement relevant measures in practice" [10]. Thus, building on the study of Rukasz et al. [11] who demonstrated the risk of injury during *ippon-seoi-nage* throw, judo coaches and researchers have tried to assess judo techniques to detect possible risks arising from their daily practice in order to prescribe prophylactic trainings and motor rehabilitation tasks for their *judokas*. Hence, it seems necessary to analyze the way judo athletes execute the different throwing techniques to avoid injuries caused by excessive repetitions.

Based on the aforementioned, the main goal of the present study was knowledge about the degrees of flexion and extension (F/E) and abduction and adduction (Abd/Add) of the main locomotive joints, expressed when performing the most employed throwing techniques in high-level competition: seoi-nage, uchi-mata, osoto-gari, ouchi-gari and kouchi-gari. The second goal was useful information to develop specific prophylactic training.

Material and methods

Participants

The study was based on two world-class judo athletes: age: 49 and 50 years, height: 174 and 176 cm, body mass: 73.2 and 73.4 kg, respectively, and a Japanese judo expert. All were selected because of their expertise in judo (over 40 years as coaches and/or competitors). The *judokas* were top-level athletes: both of them hold currently the 6th Dan degree, they had been *kata* national champions in *nage-no-kata*, *ju-no-kata* and *goshin-jitsu-no-kata* in several occasions, and European champions in *goshin-jitsu-no-kata*. They possess the *osameru* degree (top level) from Kodokan Judo Kata School (the most important institution of judo in the world) in the three mentioned *kata* specialities. Furthermore, they are active competitors that train eleven months a year. Their weekly training programme includes 5-6 days (90 minutes each session), 3-4 days focused on technical training, and 2-3 on conditioning. The Japanese judo master holds the 9th Dan degree. He is a disciple of Master Toshiro Daigo (Japanese 10th Dan degree), one of the most important judo masters in the world. Therefore, all participants were high-level *judokas*. In order to conduct the research project, permission from the Ethics Committee of the researchers' University was obtained prior to the beginning of the study. Participants were fully informed, they agreed to participate and signed a written consent.

Experimental procedure

All data collection was carried out in the Motor Skills Laboratory of the School of Sports Medicine of the University of Oviedo (Spain). CLIMA technology was used throughout the whole project. It is a complete equipment of motion, capture and analysis, which provides results in graphics and three-dimensional reports. This technology was eveloped by STT Engineering and Systems (San Sebastián, Spain). CLIMA is based on a computer and a variable number of video cameras. In our project, four VGA motion capture cameras were employed to capture an area of 5x5 metres. CLIMA software consists of a database, display modules motion images, three-dimensional sights and interactive curves. In order to collect any data, it is necessary to place several reflective markers on the subject under study. The recording of a capture motion allows to store in the computer the three-dimensional trajectories of all reflective markers. CLIMA technology requires the

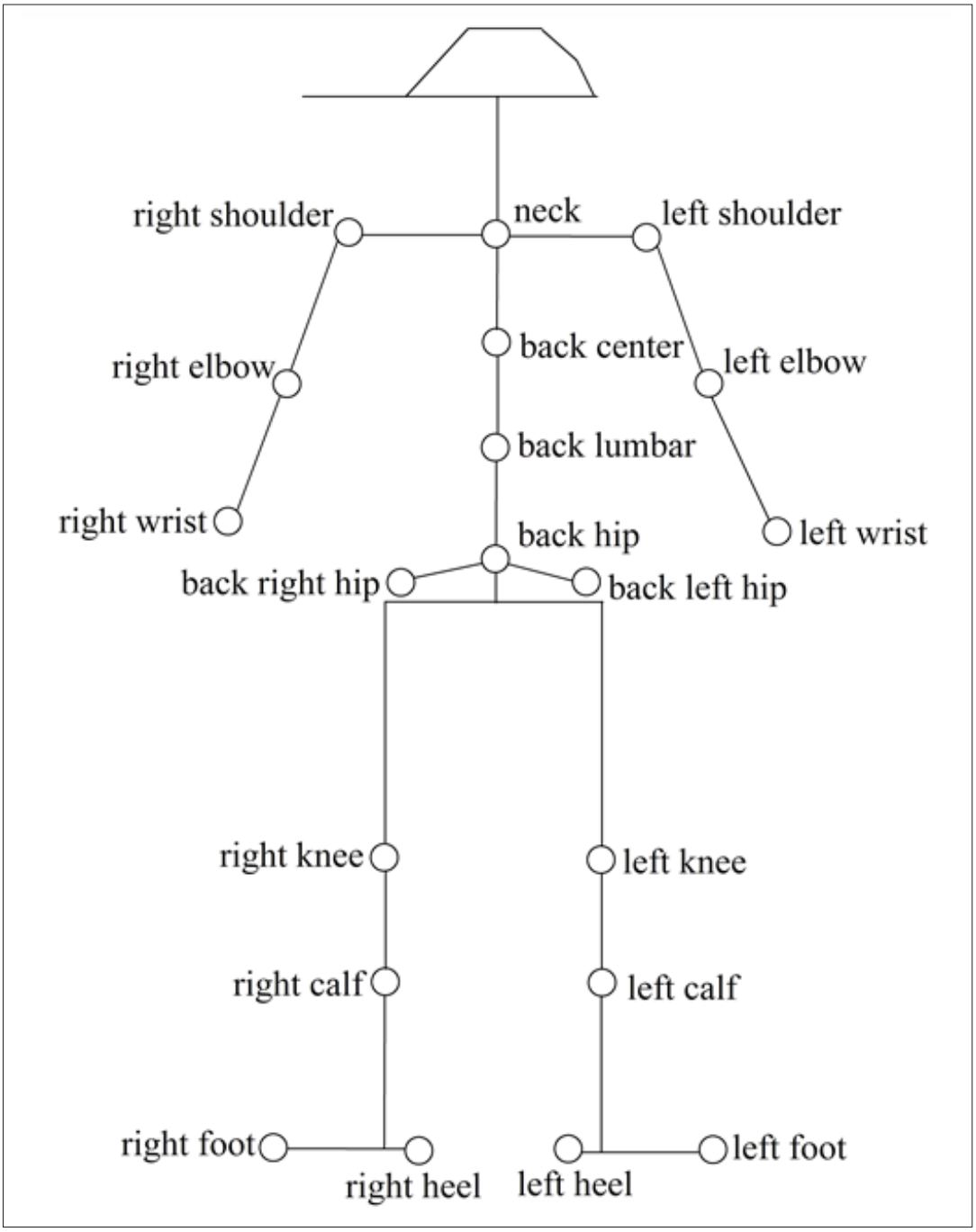

Figure 1. Anthropometric model

selection of a specific anthropometric model to collect data. Hence, a model able to show all human movements involved in the sport of judo was developed. This anthropometric model is based on the data of 20 reflective markers placed on the subjects' body (see Figure 1). In our study, aiming at the highest specificity in the experts' movements, the markers were placed directly on the athletes' *judogi*, avoiding any type of extra movement during the whole process. This model demands set landmarks at these specific locomotive areas: (1) right shoulder (humerus head), (2) back neck (seventh cervical vertebra), (3) left shoulder (humerus head), (4) right elbow (epicondyle), (5) left elbow, (epicondyle), (6) right wrist (1/3 dorsal medium), (7) left wrist (1/3 dorsal medium), (8) back centre (sixth thoracic vertebra), (9) back lumbar (third lumbar vertebra), (10) back hip (charnel lumbo-sacra), (11) back right hip (over back belt),

(12) back left hip (over back belt), (13) right knee (external femoral condyle), (14) left knee (external femoral condyle), (15) right calf (21 cm up to right heel marker), (16) left calf (21 cm up to left heel marker), (17) right heel (Achilles tendon's distal insertion), (18) left heel (Achilles tendon's distal insertion), (19) right foot (third metatarsal head), and (20) left foot (third metatarsal head).

In this research project, the judo throwing techniques most frequently employed in high-level competition were analysed: *seoi nage, uchimata, osoto gari, ouchi-gari and kouchi-gari* [4]. Every throwing technique can be divided in three phases: (1) *kuzushi*: *uke* (judo athlete who receives the judo technique) is unbalanced by *tori* (judo athlete who develops the judo technique); (2) *tsukuri*: the proper fitting of *tori's* body to generate strength to throw (3) and *kake*: *uke* is thrown by *tori*. In the present study, we analyzed *tori's* body alignment in the beginning phase of *kake*, when the locomotive system suffers the highest muscular and tendinous stress. *Tori* generates a high amount of strength in a very short period of time against a great resistance (*uke* opposition and weight) trying to throw *uke* to the floor. According to Daigo [12], the beginning phase of *kake* in *seoi-nage* takes place when *tori* holds *uke´s* left collar with his right hand, pushes in *uke´s* right armpit, pulls with his left hand covering *uke´s* right arm, and puts the back of his waist tight against the front of *uke´s* thighs and waist, loading *uke* onto his back. In *uchi-mata,* when *tori* supports his body on the left leg lowering his body, inserts his right leg between *uke´s* legs, and puts the back of his right thigh on the inside of *uke´s* left thigh. In *osoto-gari,* when *tori´s* back part of the right knee meets the back of *uke´s* right knee. In *ouchi-gari* when *tori* reaps *uke´s* left foot open towards *uke´s* left side (facing *uke*). Finally, in *kouchi-gari,* when *tori* supports his body on the left foot while reaps the inside of *uke´s* right heel in the direction he is stepping with his right foot. In addition, it is necessary to remember that data interpretation of the present study requires considering the anatomical standing position (Figure 2). It is widely accepted as the point of reference for any body movement, where the anterior view of the human body is shown standing with legs slightly apart, feet forward and palms facing forward [13].

The present project's goal was to carry a three-dimensional assessment of the beginning of the *kake* phase of these specific techniques. Participants were asked to perform two attempts of each throwing technique (always on the right side), and the judo master chose the best performance to be analysed. The goal was to achieve the highest level of performance, avoiding the influence of tiredness in the participants or the master. Subjects performed all techniques in a dynamic posture (as in competition), but without resistance from the partner (opponent).

RESULTS

The performances selected by the judo master from expert 1 and expert 2 of each judo throwing technique under assessment produced very similar data: differences were <4º in any joint or throwing technique. This data showed the validity of the assessment process (Table 1). In addition, intra-subject comparisons (the two executions both experts performed of each one of the five techniques under assessment), showed almost identical scores. Differences between the first and the second execution in each joint were ±0.5º.

Table 1 shows degrees of flexion and extension, as well as abduction and adduction of the main joints (shoulder, elbow, knee, hip and ankle) of two world-class judo athletes expressed during the beginning phase of *kake* of *seoi nage, uchimata, osoto-gari, kouchi-gari and ouchi-gari.* Flexions and abductions are expressed in positives values and extensions and adductions in negative.

Data obtained from expert 1 were: in *seoi-nage*: F/E right shoulder: -07.15º, F/E left shoulder: 85.31º, Abd/Add right shoulder: 94.87º, Abd/Add left shoulder: 41.77º, F/E right elbow: 52.48º, F/E left elbow: 78.01º, F/E right hip: 94.15º, F/E left hip: 92.94º, Abd/Add right hip: 37.10º, Abd/Add left hip: 39.66º, F/E right knee: 97.91º, F/E left knee: 95.22º, F/E right ankle: 78.01º, F/E left ankle: 79.88º. Data obtained in *uchi-mata* were: F/E right shoulder: -15.71º, F/E left shoulder: 92.33º, Abd/Add right shoulder: 22.66º, Abd/Add left shoulder: 92.08º, F/E right elbow: 42.97º, F/E left elbow: 82.52º, F/E right hip: 180.00º, F/E left hip: 137.07º, Abd/Add right hip: 22.73º, Abd/Add left hip: 18.11º, F/E right knee: 171.79º, F/E left knee: 168.03º, F/E right ankle: 136.12º, F/E left ankle: 82.03º. Data obtained in *osoto-gari* were: F/E right shoulder: -02.12º, F/E left shoulder: 11.51º, Abd/Add right shoulder: 81.38º, Abd/Add left shoulder: 07.91º, F/E right elbow: 66.48º, F/E left elbow: 91.64º, F/E right hip: 132.03º, F/E left hip: 147.28º, Abd/Add right hip: 21.68º, Abd/Add left hip: 09.15º, F/E right knee: 152.73º, F/E left knee: 165.27º, F/E right ankle: 137.02º, F/E left ankle: 88.44º. Data obtained in *ouchi-gari* were: F/E right shoulder: 58.46º, F/E left shoulder: 23.18º,

Abd/Add right shoulder: 38.47º, Abd/Add left shoulder: 23.39º, F/E right elbow: 96.53º, F/E left elbow: 81.44º, F/E right hip: 143.31º, F/E left hip: 161.49º, Abd/Add right hip: 37.74º, Abd/Add left hip: 13.62º, F/E right knee: 171.43º, F/E left knee: 136.18º, F/E right ankle: 134.04º, F/E left ankle: 83.01º. Data obtained in *kouchi-gari* were: F/E right shoulder: 17.63º, F/E left shoulder: 02.64º, Abd/Add right shoulder: -04.37º, Abd/Add left shoulder: 00.00º, F/E right elbow: 99.69º, F/E left elbow: 82.03º, F/E right hip: 147.19º, F/E left hip: 171.78º, Abd/Add right hip: -01.35º, Abd/Add left hip: 02.28º, F/E right knee: 180.00º, F/E left knee: 166.78º, F/E right ankle: 117.66º, F/E left ankle: 88.42º.

Data obtained from expert 2 were: in *seoi-nage*: F/E right shoulder: -06.98º, F/E left shoulder: 88.14º, Abd/Add right shoulder: 95.06º, Abd/Add left shoulder: 43.54º, F/E right elbow: 53.04º, F/E left elbow: 76.49º, F/E right hip: 97.63º, F/E left hip: 95.78º, Abd/Add right hip: 38.66º, Abd/Add left hip: 41.31º, F/E right knee: 98.01º, F/E left knee: 96.87º, F/E right ankle: 76.56º F/E left ankle: 78.32º. Data obtained in *uchi-mata* were: F/E right shoulder: -17.03º, F/E left

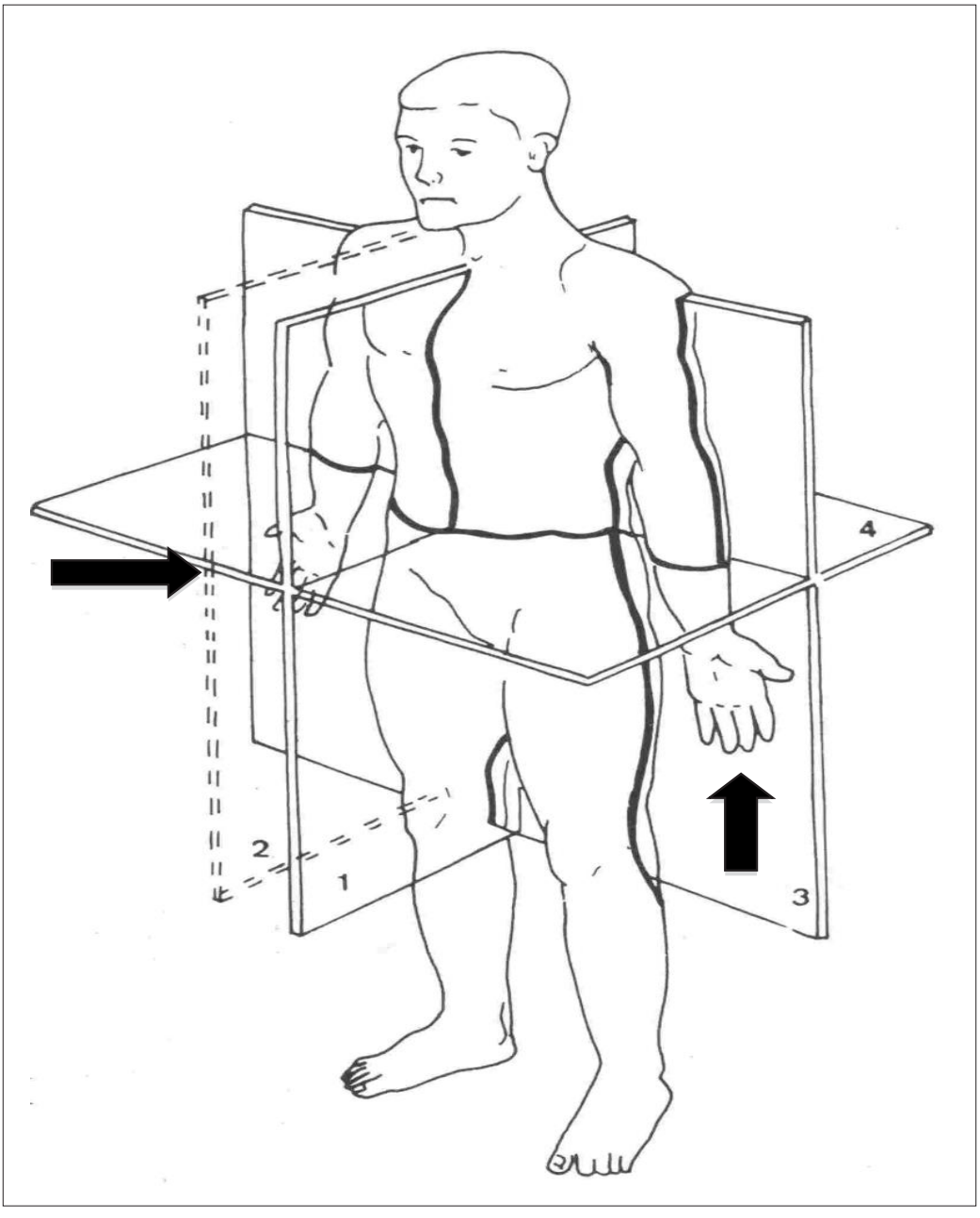

Figure 2. Anatomical standing posture

shoulder: 94.17º, Abd/Add right shoulder: 24.84º, Abd/Add left shoulder: 94.66º, F/E right elbow: 45.44º, F/E left elbow: 85.02º, F/E right hip: 180.00º, F/E left hip: 139.58º, Abd/Add right hip: 21.99º, Abd/Add left hip: 19.22º, F/E right knee: 173.52º, F/E left knee: 169.33º, F/E right ankle: 137.27º, F/E left ankle: 85.87º. Data obtained in *osoto-gari* were: F/E right shoulder: -03.44º, F/E left shoulder: 13.81º, Abd/Add right shoulder: 80.03º, Abd/Add left shoulder: 09.18º, F/E right elbow: 65.91º, F/E left elbow: 93.11º, F/E right hip: 133.89º, F/E left hip: 148.00º, Abd/Add right hip: 22.37º, Abd/Add left hip: 11.74º, F/E right knee: 154.97º, F/E left knee: 165.99º, F/E right ankle: 136.71º, F/E left ankle: 89.05º. Data obtained in *ouchi-gari* were: F/E right shoulder: 59.92º, F/E left shoulder: 24.37º, Abd/Add right shoulder: 40.68º, Abd/

Table 1. Participants' flexion and extension (F/E) and abduction and adduction (Abd/Add) at joints in the beginning phase of kake.

Anatomical Movements	Judo Throwing Techniques				
	Seoi-nage	Uchi-mata	Osoto-gari	Ouchi-gari	Kouchi-gari
F/E Right shoulder					
Expert 1	–07.15º	–15.71º	–02.12º	58.46º	17.63º
Expert 2	–06.98º	–17.03º	–03.44º	59.92º	19.39º
F/E Left shoulder					
Expert 1	85.31º	92.33º	11.51º	23.18º	02.64º
Expert 2	88.14º	94.17º	13.81º	24.37º	04.55º
Abd/Add Right shoulder					
Expert 1	94.87º	22.66º	81.38º	38.47º	–04.37º
Expert 2	95.06º	24.84º	80.03º	40.68º	–05.12º
Abd/Add Left shoulder					
Expert 1	41.77º	92.08º	07.91º	23.39º	00.00º
Expert 2	43.54º	94.66º	09.18º	25.61º	02.33º
F/E Right elbow					
Expert 1	52.48º	42.97º	66.48º	96.53º	99.69º
Expert 2	53.04º	45.44º	65.91º	95.74º	97.72º
F/E Left elbow					
Expert 1	78.01º	82.52º	91.64º	81.44º	82.03º
Expert 2	76.49º	85.02º	93.11º	84.20º	85.79º
F/E Right hip					
Expert 1	94.15º	180.00º	132.03º	143.31º	147.19º
Expert 2	97.63º	180.00º	133.89º	145.88º	148.90º
F/E Left hip					
Expert 1	92.94º	137.07º	147.28º	161.49º	171.78º
Expert 2	95.78º	139.58º	148.00º	161.94º	170.96º
Abd/Add right hip Expert 1	37.10º	22.73º	21.68º	37.74º	–01.35º
Expert 2	38.66º	21.99º	22.37º	36.59º	–03.73º
Abd/Add left hip					
Expert 1	39.66º	18.11º	09.15º	13.62º	02.28º
Expert 2	41.31º	19.22º	11.74º	13.06º	02.81º
F/E Right knee					
Expert 1	97.91º	171.79º	152.73º	171.43º	180.00º
Expert 2	98.01º	173.52º	154.97º	170.21º	180.00º
F/E Left knee					
Expert 1	95.22º	168.03º	165.27º	136.18º	166.78º
Expert 2	96.87º	169.33º	165.99º	137.56º	164.41º
F/E Right ankle					
Expert 1	78.01º	136.12º	137.02º	134.04º	117.66º
Expert 2	76.56º	137.27º	136.71º	135.48º	120.56º
F/E Left ankle					
Expert 1	79.88º	84.03º	88.44º	83.01º	88.42º
Expert 2	78.32º	85.87º	89.05º	84.53º	89.23º

Add left shoulder: 25.61º, F/E right elbow: 95.74º, F/E left elbow: 84.20º, F/E right hip: 145.88º, F/E left hip: 161.94º, Abd/Add right hip: 36.59º, Abd/Add left hip: 13.06º, F/E right knee: 170.21º, F/E left knee: 137.56º, F/E right ankle: 135.48º, F/E left ankle: 84.53º. Data obtained in *kouchi-gari* were: F/E right shoulder: 19.39º, F/E left shoulder: 04.55º, Abd/Add right shoulder: -05.12º, Abd/Add left shoulder: 02.33º, F/E right elbow: 97.72º, F/E left elbow: 85.79º, F/E right hip: 148.90º, F/E left hip: 170.96º, Abd/Add right hip: -03.73º, Abd/Add left hip: 02.81º, F/E right knee: 180.00º, F/E left knee: 164.41º, F/E right ankle: 120.56º, F/E left ankle: 89.23º.

Discussion

Judo athletes execute an enormous number of their special throwing techniques (the ones that judo athletes perform best) in training and competition. Therefore, they are exposed to injuries by overuse. Our results indicate that systematic repetition of *seoi-nage, uchi-mata* and *osoto-gari* can produce shoulder tendon pathologies. Long-term *seoi-nage* and *uchi-mata* practice could generate epincondylitis. *Judokas* who have suffered anterior cruciate ligament injuries must be careful when executing techniques that demand explosive knee extensions (i.e., *seoi-nage*) against a great resistance. At the shoulder, tendon pathologies are frequent in repetitive activities that involve ≥ 90º shoulder abductions [14]. One of the most frequent shoulder pathologies is the impingement syndrome [13] which involves the tendinous portion of the rotator cuff by the coraco-acromial ligament and the anterior third of the acromion. In addition, the impingement may also involve the tendon of the long head of the biceps. Hypertrophic lipping at the acromio-clavicular joint may impinge the supraspinatus tendon when the arm is in 60º-120º abduction. Table 1 shows that none of the throwing techniques assessed in the present study exceed the 90º in abduction except: *seoi-nage*: 94.87º, 95.06º right shoulder (expert 1 and 2 respectively), and *uchi-mata:* 92.08º, 94.66º left shoulder (expert 1 and 2 respectively). In addition, another one is inside of the 60-120º noxious rank (*osoto-gari*: 81.38º, 80.03º right shoulder, expert 1 and 2 respectively). At the elbow, epicondylitis is the most frequent injury. Scientific literature suggests that the disorder's primary etiology is a repetitive stress or overuse of the flexor-pronator musculature [15]. Degenerative changes in the musculotendonous region of the medial epicondyle are the result of chronic repetitive concentric and eccentric contractile loadings of the flexor-pronator group. Results of the present study show that *seoi-nage* left elbow flexion expresses 78.01 and 76.49 degrees (expert 1 and 2 respectively), and the next anatomical movement to finish the execution of the throw is an explosive extension of the arm that holds the *uke´s* sleeve. Hence, specialists in this throwing technique are at risk of epicondylitis by overuse. When you use this technique, and others like *ude-garami* (a joint technique), twisting forces can cause a crooked forearm. These forces can lead to damage to the ulnar collateral ligament, pain disorders and chronic inflammatory. The summit of the medial epicondyle of the humerus can suffer medial epicondylitis [16] due to the constant pulling by the ulnar collateral ligament and the bending muscles. These symptoms are similar to the ones described by tennis players and golfers [16]. Our *judokas* expressed 82.52 and 85.02 degrees (expert 1 and 2 respectively), at the left elbow flexion performing *uchi-mata* and the next anatomical movement to finish the execution of the throw is an explosive extension of the arm that holds the *uke´s* sleeve. Thus, specialists in this technique are also at risk of epincodylitis by overuse. Moreover, in the case of *uchi-mata*, the risk of epicondylitis is added to the previously mentioned shoulder tendon pathologies' risk (*uchi-mata* left shoulder abduction expressed 92.08 and 94.66 degrees – expert 1 and 2 respectively). Nevertheless, our data do not show risk of epicondylitis in *osoto-gari, ouchi-gari* and *kouchi-gari.* At the knee, the iliotibial band syndrome produces a localized pain in the lateral area of the knee. It is produced by the friction between the rear edge of the iliotibial band and the outer rim of the femoral epicondyle of the femur. The friction is maximum around 30º of knee flexion. Table 1 also shows that all throwing techniques analysed in the present study expressed knee flexion larger than 30º (all of them are above 80º). Hence, the iliotibial band syndrome is not related to throwing techniques assessed in the present study. Data collected on shoulder F/E, hip F/E, hip Abd/Add and ankle F/E of *seoi-nage, uchi-mata, osoto-gari, ouchi-gari* and k*ouchi-gari* do not hold a direct relationship with the pathologies described in the references. Nevertheless, judo is a highly complex technical-tactical sport that requires years of training. Hence, *judokas*' locomotive system is exposed to constant articular and muscular injury, and the risk increases with age and number of years of exposure [9]. Some injuries appear after lifting heavy objects as in judo throwing techniques. One of them is the subacromial bursitis that is an inflammation of the synovial liquid at the bursa, which stands between the cuff and the acromion. This tendonitis is produced by the continuous mechanic irritation of the bursa against the acromion produced during arm elevation. Judo throwing techniques involve this type of actions. Considering

those *judokas* who have suffered an anterior cruciate ligament injury, knee extension exercises can produce undesirable loads in their injuries [17]. Hence, specialists in judo throwing techniques that demand an explosive knee extensions against a great resistance (in *seoi-nage* our *judokas* expressed a knee flexion of 97.91º and 95.22º – expert 1 – and 98.01º and 96.87º – expert 2 – right and left knee respectively) must pay special attention to elements such as number of repetitions, *uke´s* weight, degrees of their knees' extension just prior to the throw, etc, as well as their feelings (muscular disturbances or pain) to avoid overloads. Results from the present study can be used as a guide to develop prevention programs aimed at the reduction of injuries in judoists [18]. The judo athletes' prophylactic basic training might follow these general guidelines: (1) appropriate strength-training workouts for the main muscle groups with three goals: achieve the eutony muscular tone, muscular symmetry, and the adaptation of tendons, (2) muscular flexibility improvement, and (3) specific technical training to avoid noxious movements. In addition, solo practice (*tandoku renshu*) to improve forms of art, might be also considered as a preventive training. Unfortunately, there are no other research works that have biomechanically studied judo throwing techniques to compare them with the results obtained in the present study. Nevertheless, although goals and methodology are different, we would like to mention Kuo [19] who studied if changing the knee from extended to flexed would make the sweep more powerful and effective in *osoto-gari*. He found that the knee-flexed style was more effective. Our results indicate that: (1) systematic repetition of *seoi-nage, uchi-mata* and *osoto-gari* can produce shoulder tendon pathologies because they demand 90º or higher shoulder abductions, (2) long-term *seoi-nage* and *uchi-mata* practice could generate epincondylitis because they demand a strong extension of the arm that holds *uke´s* sleeve (78.01º and 82.52º - expert 1 - and 76.49º and 85.02º - expert 2 - left elbow flexion respectively), (3) repeated execution of judo throwing techniques that demand arm elevation can cause subacromial bursitis (for instance, *seoi-nage, uchi-mata* and *osoto-gari*) due to the continuous bursa's mechanic irritation against the acromion during arm elevation, (4) judo athletes who have suffered anterior cruciate ligament injuries must be careful when executing techniques that demand explosive knee extensions against a great resistance to avoid overloads and new injuries (for instance, *seoi-nage*). To our knowledge, this is the first study to show data of the main joints expressed by two world-class judo athletes performing the throwing techniques most employed in high-competition at present. Thus, it provides information that can be employed to improve the performance of the techniques, and to design specific strength and flexibility training protocols. This study presents several limitations. Firstly, participants were only two. However, they were world-class judoists and their throwing techniques should be considered high-mechanical effective models. Secondly, technology employed cannot collect data from all the joints. However, it allowed us to collect data from the most important joints involved in judo. Thirdly, as previously mentioned, the markers of the 3D technology were placed directly on the athletes' *judogi*. The aim was to obtain the highest specificity in the experts' movements. Nevertheless, our experts performed all the judo techniques in a free-resistance *uke* context, to avoid the *judogi´s* displacement and minimize mistakes in data collection. In addition, experts were asked to set their jackets following the guidelines of the anthropometrical model just after executing each judo technique. Fourthly, the execution of a judo throwing technique depends of several aspects: *uke´s* height, distance between *tori* and *uke,* etc. However, the anthropometric characteristics of the judo athletes are quite similar except in the categories +100 kg for men, and +78 kg for women who select special techniques for them [5]. Thus, data from the present work can be considered as a valid reference.

Conclusions

In conclusion, the three-dimensional analyses of the throwing techniques most employed in competition by judo athletes (*seoi-nage, uchi-mata, osoto-gari, ouchi-gari* and *kouchi-gari*) shows that their systematic practice can cause injuries by overuse at the upper extremity joints (shoulder, elbow). On the contrary, the lower locomotive joints (knee, ankle) do not seem to be at risk of injury due to overuse. This information should be considered to design prophylactic trainings for judoists who use these techniques and for rehabilitation programs.

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Conflict of interest

The authors declare that they have no financial or personal relationships with any people or organizations that could influence this paper's content in any form.

References

1. Degoutte F, Jouanel P, Bèguer RJ et al. Food Restriction, Performance, Biochemical, Psychological, and Endocrine Changes in Judo Athletes. Int J Sports Med 2006; 27: 9-18
2. Pierantozzi E, Muroni R. Judo high-level competitions injuries. Medit J Musc Surv 2009; 17: 26-29
3. Franchini E, Del Vecchio FB, Matsushigue KA et al. Physiological profiles of elite judo athletes. Sports Med 2011; 41: 147-166
4. Adam M, Smaruj M, Tyszkowski S. The diagnosis of the technical-tactical preparation of judo competitors during the World Championships (2009 and 2010) in the light of the new judo sport rules. Arch Budo 2011; 7(1): 5-9
5. Sterkowicz S, Sacripanti A, Sterkowicz-Przybycien K. Techniques frequently used during London Olympic judo tournaments: A biomechanical approach. Arch Budo 2013; 9(1): 51-58
6. Gawroński W. Uraz, obrażenie a kontuzja. Medicina Sportiva 1998; 2(4): 343-344 [in Polish]
7. Raschka C, Parzeller M, Banzer W. 15 years insurance statistics of incidents and accident types of combat sports injuries of the Rhineland-Pfalz Federal Sports Club. Sportverletz Sportsc 1999; 13(1): 17-21
8. Engebretsen L, Soligard T, Steffen K et al. Sports injuries and illnesses during the London Summer Olympic Games 2012. Br J Sports Med 2013; 47: 407-14.
9. Kurppa K, Viikari-Juntura E, Kuosma E et al. Incidence of tenosynovitis or peritendinitis and epicondylitis in a meat-processing factory. Scan J Work Env Hea 1991; 17(1): 32-37
10. Witkowski K, Maslinski J, Stefaniak T et al. Causes of injuries in young female judokas. Arch Budo 2012; 8(2): 109-116
11. Rukasz W, Sterkowicz S, Kłys A. Causes and types of injuries during *ippon-seoi-nage* throw. Arch Budo 2011; 7(1): 17-19
12. Daigo T. Kodokan Judo. Judo throwing techniques. Tokyo: Kondansha International Ltd.; 2005, 10
13. Neer C. Anterior Acromioplasty for the Chronic Impingement Syndrome in the Shoulder. A Preliminary Report, J Bone Joint Surg Br 1972; 54: 41-50
14. Matsen FA III, Fehringer EV, Lippitt SB et al. Rotator cuff. In: Rockwood CA Jr, Matsen FA III, Wirth MA, Lippitt SB, (eds.): The Shoulder. 4th ed. Philadelphia, Pa: Saunders Elsevier, 189; 2009
15. Ciccotti MG, Lombardo SJ. Lateral and medial epicondylitis of the elbow. In: Jobe FW, Pin MM, Glousman RE et al, editors. Operative techniques in upper extremity sports injuries. St. Louis (MO): Mosby-Year Book; 1996, 431-446
16. Field LD, Savoie FH. Common Elbow Injuries in Sport. *Sports Medicine* 1998; 26 (3): 193-205
17. Jurist KA, Otis JC. Anteroposterior tibiofemoral displacements during isometric extension efforts. The roles of external load and knee flexion angle. Am J Sports Med 1985; 13(4): 254-258
18. Tenvergert EM, Ten Duis HJ, Klasen HJ. Trends in sports injuries, 1982-1988: an in-depth study on four types of sport. J Sport Med Phys Fit 1992; 32(2): 214-220
19. Kuo Kwei-Bin. Comparison between knee-flexed and knee-extended styles in the major outer leg sweep. Biomechanics Symposia, University of San Francisco, 2001
20. Kawamura T, Daigo T. Kodokan New Japanese-English Dictionary of Judo. The Foundation of Kodokan Judo Institute, Kyodo Printing Co., Tokyo, 2000
21. Kent M. The Oxford Dictionary of Sports Science and Medicine. Oxford – New York – Tokyo: University Press; 1994

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