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Injury assessment of common nage-waza judo techniques for amateur judokas

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Abstract

There are few detailed publications that allow performing associations between the technical aspects and the occurrence of injuries. The purpose of this study was to apply a methodology based in recording material to assess the injury risk factors. Common nage-waza judo techniques during regular training of amateur judokas were used as a case study. Novice students (n=193; 100 men and 93 women) from the University of Vigo during five academic years (2003 to 2008) were filmed during the ordinary training period of the technical execution of ten nage-waza techniques. The obtained data were evaluated using descriptive statistics and t-patterns analysis. Thus, it was possible to identify the presence of typical inaccuracies during execution of the technique uncovering the main temporal sequence of errors allowing us to link our findings with the injury occurrence. In order to narrow the unexpected causes of accidents regarding poor technique performance in regular training, this research provides the hidden temporal sequence of errors of common throw techniques, helping professionals to correct the key technical errors in order to prevent diverse type injuries. The methodology developed here could be easily extended to other martial sports.

Keywords: *Judo nage-waza techniques; accidents; injury; regular amateur training; t-pattern analysis; chain of errors; risk assessment; prevention.*

1. Introduction

Considering the recent increase of interest in sports, the knowledge regarding injury and illness as a result of sport activity is an essential public health priority (European Commission, 2007). A very important aspect is that judo is one of the most practiced martial art sports in the world (Parkkari et al. 2004), present in many educational programs from a diversity of institutions such as school, universities, military, police, etc. Moreover, judo is an activity characterized by an abundant number of techniques

that involve changes in direction, twisting, lifting, and landing from falls and throws (Kujala and Taimela 1995).
Under these circumstances, several studies have showed judo as a sport with higher amount of injury occurrences, presenting a concerning rate of 18.3 occurrence records per 1,000 hours of practice (Rodriguez et al. 1998; Parkkari et al. 2004; Green et al. 2007). The need for further measures to help trainees to prevent not only deadly situations but also other circumstances that may cause different forms of health problems, such as minor, major, and chronic injuries, is also supported by the publication of several reports (Kulthanan 1992; Leavitt 2003; Salanne et al. 2010; Kamitani et al. 2013) analyzing the deaths of judokas, all of them occurred because instructors did not properly implement and apply the adequate safety measures.

Although judo is a sport that emphasizes the use of proper techniques and mechanics, there are few detailed publications (Barsottini et al. 2006; Sherker et al. 2008) that allow the identification of a causal correlation between the technical aspects and the risks of injuries. Most studies focused on tournaments (James and Pieter 2003; Souza et al. 2006; Pierantozzi and Muroni 2009), perhaps due to the greatest chance of injury in tense situations, availability of detail information about the injuries and the easy access to video-recorded material for deep analysis. The data obtained from such studies cannot be extrapolated to other practicing areas, in which most judokas are amateurs as part of schools and other institutions, and never have participated in competitions (Sterkowicz 1997). Amateur judokas are less skillful and trained and are more likely to suffer risky situations that can cause different types of injuries (Barsottini et al. 2006; Yard and Knox 2007).

Many injuries are attributed to doing repetitive actions (Zakynthinaki et al. 2010), which can increase the pressure on particular joints or muscles, especially when these actions are associated with inadequate techniques. For example, the damage in the elbow of tennis players is often caused by having poor backhand technique (Maffulli 2005). Over time, symptoms of injuries caused by bad technique can be exacerbated and lead to degenerative changes (Maffulli 2005). Moreover, characteristic injuries for a particular group of different martial art styles were identified and presented in several scientific studies (Birrer and Halbrook 1988; Kujala and Taimela 1995; Pieter 2005; Zetaruk et al. 2005; Yard and Knox 2007).

The present study refers to judo, which is a dangerous contact sport (Uchida 2011) that involves ground and standing fighting and is mainly based on unbalancing and throwing techniques, besides arm locks and strangling. Previous studies suggested that most of injuries in judo with novice students occur performing *nage-waza* (throwing) judo techniques (Yard and Knox 2007) even if most throws are not performed until the student has demonstrated an ability to execute correctly some of them.

Recently, studies have been conducted in order to ensure the proper conditioning of muscles and the biomechanics that are necessary for preventing risks of injuries affecting the knee, ankle, elbow and finger joints (Majewski et al. 2006) of professional and amateur judokas. However, the identification of the causes of injuries (Bahr and Krosshaug 2005; Meeuwisse et al. 2007) and the development of injury prevention strategies (Steffen et al. 2010) are very important for the optimization of the health

benefits of sports. For this purpose, several methodological approaches have been extensively used to identify the mechanism of injuries, including: interviews, video recordings analysis, clinical studies, modeling and simulation of injury situations. In this regard, a very detail review (Krosshaug et al. 2005) assessed the strengths and weaknesses of the available research approaches to uncover the mechanism that caused injuries. The study indicates that systematic video analysis of injuries can potentially provide information on the sports situation and athlete movement patterns, which can be used directly to prevent injuries, and also highlights the need for a standard procedure.

Various methodologies were developed for the study of the injury caused by sport activities, including the Krosshaug model-based technique of three-dimensional reconstruction of human motion (Krosshaug 2005), which uses the images recorded by one or more video cameras to estimate the parameters of the movement and identify the cause of the injury. An interesting technique was developed by McIntosh (2010) to study the rugby tackle events that resulted in injuries by correlating the frequency of the injuries with the risk factors, the tackle technique, and number of tacklers. Previously, Quarrie et al. (2002) recommended the well-designed epidemiological studies for the identification of the injury risk factors in rugby. Another technique for analyzing the injury situations from videos was prepared by Andersen et al. (2003) by adapting the methods used in football for performance analysis.

Fernandez et al. (2009) successfully used the systematic observation for the identification and analysis of basketball offensive plays techniques. Gabin et al. (2012) described LINCE, a new multiplatform application that enhances the analysis of sports performance. These techniques were used during the present research, together with the statistical tools represented by the Cohen's Kappa coefficient (k) (Cohen 1968), which is interpreted as a very good strength of agreement between two sets of observations when $k>0.80$, and by GSEQ software (Bakeman and Quera 2001) used for calculating the mentioned coefficient. Recommended for detecting temporal patterns (Magnusson 2000a), another software used for the present research, namely THEME, is extremely effective for the study of team and individual sports (Fernandez et al. 2009; Gutiérrez-Santiago et al. 2011). The temporal patterns (t-patterns) obtained with the mathematical algorithm guides to reveal the hidden structures and unobservable aspects of errors in judo techniques identifying the most significant error sequences (Magnusson 2000b). One of the advantages of using specific software to produce the t-patterns is that the individual ability of researchers to identify temporal sequences is not needed anymore and therefore its application is free from the typical controversial aspects in this type of studies (Krosshaug et al. 2005).

Judo throwing techniques are comprised of three main phases: *kuzushi,* which is the preparatory phase defined as breaking an opponent's balance or simply preparing them for a throw, *tsukuri,* which is the process of fitting into the throw, and *kake,* which is the acceleration phase describing the execution of the throw itself (Kano 1994). The gripping (kumikata) standard positions are characterized by both persons having the right feet extended one step forward while the right hand grips the opponent's left lapel and the left hand grips the opponent's right sleeve (Nishioka and West 1979). According to the authors, by constantly shifting position during the attack, the judoka aims to precipitate mistakes while the opponent is off-balance. Their recommendations

regarding the correct positions include keeping the bodyweight evenly distributed over the base of support and avoiding to cross the feet or to bring feet together when moving. Throwing techniques include hand techniques, hip techniques, foot techniques, back sacrifice techniques, and side sacrifice techniques (Dopico et al. 2014). The authors specify that the legs and arms techniques are not performed only with the legs and arms, respectively, and their success does not depend exclusively on that limb and the techniques in the groups are heterogeneous. During the throwing techniques, the control over own body is very important, causing the opponent's fall while the maintaining own balance (Witkowski et al 2014).

The present paper proposes a new methodological procedure based on the joint action of three different but well established techniques: identification of common technical errors based on video records, descriptive statistics of the obtained data and temporal sequences recognition using t-patterns analysis. As an illustrative case study, the video records of the performance of ten common *nage-waza* judo techniques by novice students during five years were used. Thus, significant risks factors that could cause injury were identified, providing information in the prevention of accidents occurrence during regular training due to poor technique.

2. Material and methods

2.1. Judo techniques, participants and duration of the study

Considering the fact that the analysis of all *nage-waza* techniques is infeasible, ten of the most common taught throwing techniques to novice judokas were selected for this study (Table 1).

During five academic years (2003 to 2008), novice students (n=193; 100 men and 93 women) from a judo course at the Faculty of Sciences of Education and Sport from the University of Vigo, with an age range between 21 and 30 years (an average of 24.02±3.98), were used as the target of study. Each group of ~40 novice students was taught the ten different basic *nage-waza* techniques (Table 1) in a special tatami-room and video records from different angles were analyzed. All the ethical standards throughout the study were in accordance with the American Psychological Association (APA), in which all students gave their written consent for the use of the derived recording material for research purposes.

Table 1. Nage-waza (throwing techniques) study group.

TECHNIQUE	CLASSIFICATION *	DESCRIPTION	STUDY GROUP		
			Male	*Female*	*Total*
WITH A ROTATION ACTION PRIOR TO THE THROW					
O-goshi (OG)	*Koshi-waza*	Large hip throw	24	30	54
Uki-goshi (UKI)	*Koshi-waza*	Floating hip throw	21	23	44
Koshi-guruma (KG)	*Koshi-waza*	Hip wheel	18	27	45
Seoi-nage (SN)	*Te-waza*	Shoulder throw	29	17	46
Ippon-seoi-nage (IP)	*Te-waza*	One arm shoulder throw	18	24	42
Tai-otoshi (TAI)	*Te-waza*	Body drop	19	21	40
WITHOUT A ROTATION ACTION PRIOR TO THE THROW					
Osoto-gari (OSG)	*Ashi-waza*	Large outer reap	30	25	55
Osoto-guruma (OSGU)	*Ashi-waza*	Large outer wheel	21	24	45
Ouchi-gari (OU)	*Ashi-waza*	Large inner reap	15	16	31
Deashi-harai (DAH)	*Ashi-waza*	Forward foot sweep	25	25	50

* Kodokan Judo classification of trowing techniques: *Te-waza* (hand); *Koshi-waza* (hip); *Ashi-waza* (foot).

2.2. Observational instrument

Table 2 describes the observation instrument developed for this study (named as OBSJUDO), which combines a field format with a category system. In general, it seems that the OSBJUDO instrument isolated and summarized during the present paper includes all common areas of error during the performance of the selected *nage-waza* judo techniques. The methodological model used for the teaching-learning process of both performance and observation is based on the indications from Kodokan (Kodokan, s.f) school.

Table 2. OBSJUDO observational instrument.

CRITERION	ID	DESCRIPTION OF THE ERROR*
GRIP	GR	During the performance of the technique *Tori* grips the *judogi* of *uke* at the level of the middle portion of the arm or forearm. The appropriate location would be at the elbow level with the exception of *seoi-nage* (which is below the elbow) and *ippon-seoi-nage* (which is above the elbow).
OFF-BALANCE	OB	*Tori* does not put *uke* off balance in the first part of the technique. His/her arms maintain the initial grip and serve only to accompany the action.
RIGHT-FOOT POSITION	RFP	Considering the description of the applied technique, the position of *Tori's* right foot after the *kuzushi* is incorrect.**
RIGHT ARM POSITION	RAP	Considering the description of the applied technique, *Tori* does not properly positioned his right arm in the projection phase of *tsukuri*.**
LEFT-FOOT POSITION	LFP	Considering the description of the applied technique, the position of *Tori's* left foot after the initial displacement of the judo-technique is incorrect. **
HIP-TRUNK POSITION	HTP	Considering the description of the applied technique, the location of the *tori's* hip and trunk is incorrect in order to adequately perform the technique.**
LEGS ACTION	LA	During the projections with rotation prior to the execution as described in the literature, an error related to the absence of an optimal bending (OG-SN-IP) or excessive bending of the legs (KG-UKI-TAI) can occur.
MOTOR ACTION	MA	There is a problem in the execution of the motor action. The usual error in the techniques that requires loading the opponent is the absence of it or sustained load on his back (OG-SN-IP). The error in the techniques with a reaping or a blockage motor action (OSG-OSGU-DAH-OU) refers to the execution with little intensity or inadequate height, or to the absence of it. In techniques with a blockage motor action (KG-UKI), the error refers to the lack of blockage load or that *tori* loads the body of *uke* instead performing the corresponding motor action.
ARM ACTION	ARM	During the final stage of the throw, *tori* does not apply sufficient power or performs the action towards a wrong direction when throwing *uke's* body to the floor with his arms.
THROW STAGE	LP	*Tori* throws *uke* around the side of his body instead of over the top and toward the front of his hip (OG-KG-UKI) or over its shoulder (SN-IP). This error is not detected when performing techniques without rotation.
	ITF	Insufficient trunk flexion (OG-OSG-SN-IP) at the end of the throw (*tori* maintains a position of between 10º and 60º). In other techniques (such as UKI and TAI), this error shows an excessive trunk flexion at the end of the throw.
	ITT	The *tori* does not turn his trunk left enough in the *kake* stage of the technique
CONTROL STAGE	FC	During the final stage of the technique, *tori* performs no action with his/her left hand and therefore fails to control the fall of the opponent's body.
	FAC	During the guiding stage, *tori* uses his/her right arm to accompany *uke's* fall to the floor.
	KTB	During the final stage of the throw, *tori* bends his/her trunk to around 90º with respect to the vertical plane, maintaining this position once the throw is complete.
REBALANCING	RE	After performing the throw, *tori* loses his/her balance and regains it with the right, left or both foots.
GLOBALITY	SL	The throw is executed slowly and without any continuity.

* For a right hand *judoka.*

** As a function of the technique, location of each part of the body mentioned (foot, arm, hip or trunk). For a more detail information check the Kodokan ideal model (Kano, 1994).

2.3. Injury registration and evaluation

The analysis of the injuries of judokas was performed during the entire training period using a record of the following elements: name of subject, sex, type of injury, projection and role of the judoka (*tori* / *uke*). If the injury exceeded a simple bruise, wound or abrasion (minor injuries), the diagnosis was concluded by a doctor. The results were used for analyzing the frequency of the injuries under the conditions of the present research.

2.4. Procedure, recording, editing and data collection

The technical execution of the ten *nage-waza* techniques was filmed during the ordinary training period (~ 4 months with 3 hr of practice per week) in a special tatami-room recorded from different angles with static digital cameras. The filmed material was obtained by recording each participant performing the techniques, without opposition and from a static position (technical), excluding these in which judokas were not size-balanced (based in weight and height). Table 1 presents the selected projections, their description, their classifications and number of suitable judokas that performed each technique.

To assist the analysis of the projections recorded, the filmed material was edited with the software Pinnacle Studio v.12, shortening the video material and keeping only the relevant material. Afterwards, the software LINCE v.1.0, a multimedia interactive program that allows viewing and registering the filmed material at the same time in a computer, was used to support systematically the observational analysis, which also made the data collection more simple.

The observational analysis using the SOBJUDO instrument was performed independently by two different researchers in two occasions. The quality control of the data recorded by the two observers is performed by the Cohen's Kappa coefficient (k), which was calculated with the GSEQ software. Once this quality control test is achieved a first descriptive analysis of frequencies and percentages of occurrence of technical errors is conducted.

After applying the previous steps to all selected projections, the results were recorded in an Excel file for each *nage-waza* technique with its sequence of errors.

2.5. Data analysis

The obtained Excel files were used for analyzing the frequencies of all registered codes. They are exported into the software THEME v.5 with the aim of detecting temporal patterns. In addition, the frequency of occurrence of the different errors made when performing the selected *nage-waza* technique was determined by means of a descriptive analysis using SPSS 15, the results of which are shown in Table 3.

Table 3. Frequency of errors found for each technique as a function of the OBSJUDO observational instrument designed (codes for the studied techniques are presented in Table 1 and 2).

TECHNIQUE	*OBSJUDO OBSERVATIONAL INSTRUMENT.*																
	GR	*OB*	*RFP*	*RAP*	*LFP*	*HTP*	*LA*	*MA*	*ARM*	*LPIT*	*FIT*	*TIT*	*FC*	*FAC*	*KTB*	*RE*	*SL*
WITH A ROTATION ACTION PRIOR TO THE THROW																	
OG	27,8	42,6	27,8	61,1	59,3	35,2	48,1	37	-	-	-	-	27,8	24,1	42,6	40,7	3,7
KG	24,4	66,7	46,7	20	75,6	73,3	11,1	42,2	53,3	71	46,7	15,6	-	22,2	28,9	31	4,4
UKI	13,6	65,9	45,5	65,9	63,6	63,6	25	75	45,5	77,3	54,5	22,7	13,6	27,3	13,6	38,6	0
SN	47,8	63	56,5	19,6	71,3	54,3	69,6	63	30,4	69,6	17,4	10,9	23,9	69,6	21,7	32,6	4,3
IP	45,2	61,9	59,5	9,5	73,8	42,9	81	66,7	47,6	85,7	21,4	4,8	45,2	-	26,2	61,9	0
TAI	35	87,5	40	57,5	75	52,5	10	72,5	60	-	2,5	25	10	27,5	-	12,5	4,3
WITHOUT A ROTATION ACTION PRIOR TO THE THROW																	
OSG	18,2	72,7	-	-	34,5	74,5		72,7	47,3	-	49,1	-	21,8	40	16,4	27,3	0
OSGU	28,9	80	-	-	55,6	6,7		17,8	42,2	-	-	33,3	11,1	20	4,4	13,3	4,4
OU	29	80,6	-	51,6	41,9	61,6		71	90,3	-	-	-	12,9	12,9	-	22,6	3,2
DAH	20	68	-		42	-		64	68	-	-	-	22	8	-	34	4

3. Results

3.1. Typical errors and common sequences found for each technique. T-pattern determination

The obtained value of the Cohen's Kappa coefficient for the present study was k=0.85, allowing the further analysis of the injury frequency.

Table 3 shows the percentage of participants that committed any of the errors in the observation tool of OBSJUDO, which combines the different aspects of the three phases of *nage-waza* techniques (*kuzushi*, *tsukuri* and *kake*).

In those techniques that involve a rotation action prior to the execution (Table 1) - ignoring the particularities- in general, the most frequent errors are represented by the initial imbalance, the position of the feet and hip-trunk, motor action, the action of arms and projection phase. Additionally, depending on the type of technique, there are particular common errors, as it is common in *o-goshi*, *uki-goshi* and *tai-otoshi* to observe an error related to the position of the right arm. In *seoi-nage* and *ippon-seoi-nage*, *it* is common that novice judokas make an incorrect grip which is related to the location of that grip at the elbow level. Those techniques that require the bending of legs to effectively execute the projection (such as *o-goshi*, *seoi-nage*, *ippon-seoi-nage* or *tai-otoshi*) have a repeating error associated with scarce flexion of *tori's* knees. The projections that require to lift of the opponent's body before the throw (*o-goshi*, *seoi-nage* and *ippon-seoi-nage*) have higher error rates in controlling the opponent fall than those whose driving action is a blocking (*koshi-guruma* and *uki-goshi*) or crashing action (*tai-otoshi*).

In turn, in those techniques in which there is a lack of rotation action (Table 1) prior to the execution, the most frequent errors detected are the imbalance of the supporting foot, motor action (except *osoto-guruma*) and arm action. The body position prior to the

final stage of the technique is incorrect in many techniques such as *osoto-gari* and *ouchi-gari*, but not in *deashi-harai* and *osoto-guruma*. Unlike the techniques with a prior rotation action, there are no evidences of errors associated with the direction in which the *uke's* body is projected (TS) in the control of the fall (CS) or in the rebalancing (RE). In contrast, the values related to the imbalance are higher than in the other sub-division. The techniques in which the motor action is a reaping (*osoto-gari* and *ouchi-gari*) had much higher error frequencies (474.5 and 477.6, respectively) compared to those with a sweep (*deashi-harai*) or blockage (*osoto-guruma*) action (317.7 and 330, respectively).

Through the analysis of t-patterns, the common sequences of errors are found for each of the projections. The so-called chain of errors reveals the hidden mechanistic behaviour of judokas for each technique, involving the presence of an apparently minor technical error at the beginning of the execution of a particular technique that will cause the occurrence of major and dangerous later ones. For example, Figure 1A shows footages of the errors when performing the *seoi-nage* judo technique by novice students during regular training, while Figure 1B shows the main t-pattern found, where the left-hand box depicts the relationship between the different categories (i.e. the technical errors, as listed in the OBSJUDO observation instrument). This tree diagram should be read from top to bottom, thus the first category to appear is at the top (red rectangle). The right-hand box indicates how many times each of these relationships occur by means of lines that run from top to bottom (blue rectangle). In the dendrogram of examples, we can see how the improper position of the feet (LFP and RFP) results in an incorrect positioning of the hip and trunk (HTP). Similarly, the last two categories are associated with the fact that *tori* does not flex his legs optimally (LA) and therefore, does not properly load the body of his opponent (MA), performing the action through the side instead above and in front of the shoulder (TS). This action is initiated with an incorrect initial imbalance (OB) which is normally associated with the lack of arm's action.

A:

B:

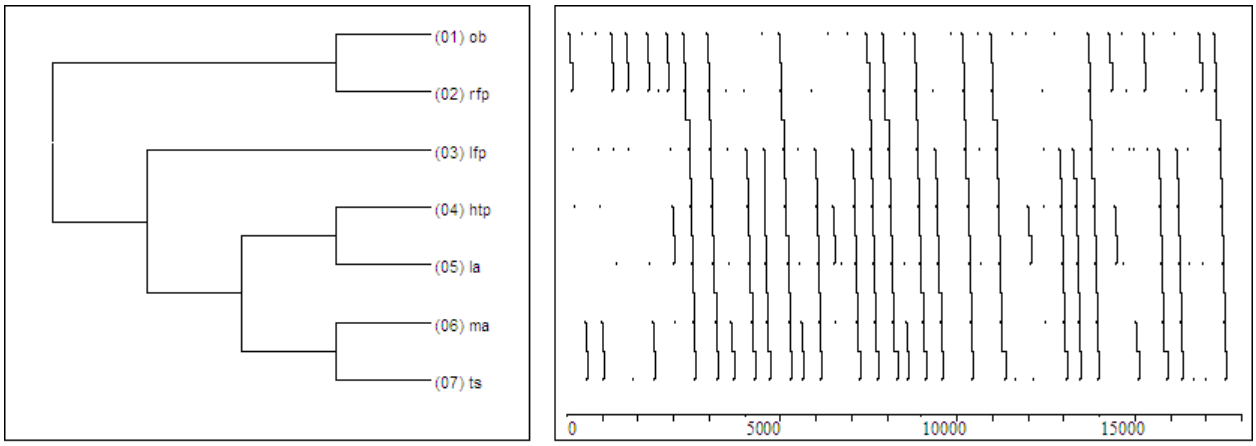

Figure 1. Figure 1A show a footage example of the errors when performing the *seoi-nage* judo technique by novice students during regular training. Figure 1B show the main t-pattern, in which the left-hand box depicts the relationship between the different categories and the right-hand box indicates how many times each of these relationships occur.

After performing such analysis for each technique, the typical sequence of errors of all projections was determined and presented in the first part of Table 4. All t-patterns for each technique are located in the supplemental material section (Figure A1-4).

Table 4. The association of the sequence of errors detected between the injuries occurred during the study are presented. For each of the ten techniques analyzed the global and particular sequences of error are presented and connected with the type injuries detected as a function of the role of the judoka (*T: tori, U: uke*). For the global sequences the percentage risk factor of each type of injuries is shown and for each of the particular sequences only a mark note is shown in order to indicate at which exactly point the risk takes place.

GLOBAL AND PARTICULAR SEQUENCE OF ERRORS OF *NAGE-WAZA* TECHNIQUES			INJURIES OCCURRED DURING THE STUDY																													
			A1		B1		C1		C2		C3		D1		D2		E1		F1		F2		F3		F4		F5		F6	
			T	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*
OG	*GLOBAL*	LFP-HTP-LA-MA	--	--	--	--	--	--	--	--	--	--	2.6	--	--	1.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PARTICULAR	LFP-HTP LA-MA	--	--	--	--	--	--	--	--	--	--	X	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
KG	*GLOBAL*	OB-LFP-HTP-MA-LP	--	--	--	1.1	--	--	--	--	--	--	--	--	--	1.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PARTICULAR	OB-RAP - (LFP-HTP-MA-LP)	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		MA-LP	--	--	--	X	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
UKI	*GLOBAL*	LFP- HTP-LA-MA-ARM-LP	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.1	--	--	--	--	--	--	--	--	--	--	--	--	--
	PARTICULAR	LFP-HTP-LA-MA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--
SN	*GLOBAL*	OB-RFP-LFP-HTP-LA-MA-LP	--	--	--	--	--	0.5	--	--	1.1	0.5	2.1	--	--	2.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PARTICULAR	GR-OB - (RFP-LFP-HTP-LA-MA-LP)	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		HTP-LA-MA-LP	--	--	--	--	--	X	--	--	--	X	X	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
IP	*GLOBAL*	OB-LFP-HTP-LA-MA-LP-FC	--	--	--	--	--	1.6	0.5	1.6	--	--	2.1	--	--	2.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PARTICULAR	GR-OB - (LFP-HTP-LA-MA-LP-FC)	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		MA-LP-CS	--	--	--	--	--	X	--	X	--	--	X	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TAI	*GLOBAL*	OB-LFP-HTP-LA-MA-ARM	--	1.1	--	--	--	--	--	--	--	--	--	--	--	2.6	--	--	--	--	--	--	1.1	--	--	--	--	--	--	--	--	--
	PARTICULAR	OB-LFP-HTP	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--
		HTP-LA-MA-ARM	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
OSG	*GLOBAL*	OB-LFP-HTP-ARM-MA	--	--	--	--	--	--	--	--	--	--	--	--	--	1.6	--	--	--	--	2.1	--	--	--	--	--	--	--	--	--	--	--
	PARTICULAR	ARM- MA-FC	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
OSGU	*GLOBAL*	OB-LFP-MA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
OU	*GLOBAL*	OB-HTP-MA-ARM-ITF-RE	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PARTICULAR	HTP-MA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--
DAH	*GLOBAL*	OB-RFP-MA-ARM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3.1	4.1	--	2.6	--	2.1	--	--
	PARTICULAR	RFP-MA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	X	--	X	--	X	--	--

3.2. Types of injuries occurred

In this study, head injuries occurred only in *tai-otoshi* techniques. They were characterized by a frequency of 1.1% and were caused by a poor gripping action of tori with his right arm during the execution. They were fairly minor injuries and were caused by a hard collision (against the surface or opponent).

During the study, minor neck hyperflexion and hyperextensions occurred only when the students were performing the *koshi-guruma* technique (1.1%). Even if the students were taught specifically that when they were playing as *tori* they cannot follow the throw, this type of injuries occurred occasionally, provoking a critical situation.

At the upper limb body parts, the typical injuries were the acromioclavicular sprain, dislocated shoulder and wrist sprain. The acromioclavicular sprains occurred only in *ippon-seoi-nage* (1.6%) and *seoi-nage* (0.6%) and were caused by a bad fall when *tori* throwed *uke* on the *tatami* directly on their shoulder or performed incorrectly the arm action pressuring the collarbone and resulting in a sprain. The dislocated shoulder injury was identified when performing the *ippon-seoi-nage* in both *uke* (1.6%) and *tori* (0.6%) positions. All of occurred wrist sprains were minors (grade 1) and mostly found when performing *seoi-nage* in both positions as *tori* (1.1%) and *uke* (0.6%).

Back injuries occurred mainly when performing techniques that involve a rotation action (as subdivided in Table 1) such as *o-goshi* (2.6% as *tori*; 1.1% as *uke*), *seoi-nage* (2.1% as *uke* or *tori*) and *ippon-seoi-nage* (2.1% as *uke* or *tori*).

Injuries in the lower limb body parts were the most common ones and were mainly sprains, contusions and cuts. The most serious injuries occurred in *tori* knee joint after a rotation on the vertical axis. When performing *uki-goshi,* a sprained knee ligament can occur when trying to keep the supporting foot steady. A bad support of the ankle is a mistake that can lead to a sprained ankle when performing *tai-otoshi.* Finally, contusions and cuts at the ankle, tibia or foot level were very common when performing *deashi-harai* (4.2%, 2.6%, and 2.1%, respectively, as *uke*), mostly due to the improper performance of the sweeping action.

3.3. Frequency of injuries occurred

Judo is a sport that focuses primarily on body contact and fast paced turning and twisting and, as in all risky situations, the repetition of such maneuvers increases the likelihood of an accident putting judokas at edge of suffering various types of injuries. Table 5 shows the injuries that occurred during the regular training period of novice students during the five-year period. The injuries were subdivided according to the affected body parts. In our case, the rate of injuries found was 8 per 1000 hours of practice, lower than other studies. The frequency of injuries of *uke* is clearly greater than *tori* (17 versus 9 types of injuries for all the performed techniques). Generally, most types of injuries were minor (such as contusions or cuts) and occurred in almost all techniques randomly, *deashi-harai* has a high frequency of minor injuries compared to other techniques (12). More serious injuries occurred in the techniques *ippon-seoi-nage* and *seoi-nage* (acromioclavicular sprain, wrist and dislocated shoulder) in *uki-goshi* (sprained knee) and *koshi-guruma* (whiplash), basically techniques in which the rotation action was prior to the execution.

Table 5. Percentage of the injuries occurred during the study as function of the technique and the role of the judoka during the execution action. T-*tori*; U-*uke*; studied techniques codes –see Table 2.

LOCATION	TYPE OF INJURIE	ID	*NAGE-WAZA* JUDO TECHNIQUES																			
			OG		***UKI***		***KG***		***SN***		***IP***		***TAI***		***OSG***		***OSGU***		***OU***		***DAH***	
			T	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*	*T*	*U*
HEAD	Bruise on the nose	A1	--	--	--	--	--	--	--	--	--	--		1.1	--	--	--	--	--	--	--	--
NECK	Cervical hyperflexion and hyperextension	B1	--	--	--	--	--	1.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
UPPER LIMB	Acromioclavicular sprain	C1	--	--	--	--	--	--	--	0.6	--	1.6	--	--	--	--	--	--	--	--	--	--
	Shoulder dislocation	C2	--	--	--	--	--	--	--	--	0.6	1.6	--	--	--	--	--	--	--	--	--	--
	Wrist sprain	C3	--	--	--	--	--	--	1.1	0.6	--	--	--	--	--	--	--	--	--	--	--	--
BACK	Contracture	D1	2.6	--	--	--	--	--	2.1	--	2.1	--	--	--	--	--	--	--	--	--	--	--
	Contusion	D2	--	1.1	--	--	--	1.1	--	2.1		2.1	--	2.6	--	1.6	--	--	--	--	--	--
GENITALS	Contusion	E1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.1	--	--
LOWER LIMB	Knee sprain	F1	--	--	1.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Biceps femoris strain	F2	2.1	--	--	--	--	--	--	--	--	--	--	--	--	2.1	--	--	--	--	--	--
	Sprained ankle	F3	--	--	--	--	--	--	--	--	--	--	1.1	--	--	--	--	--	--	--	--	--
	Ankle contusion	F4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3.1	4.2
	Tibia contusion	F5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.6
	Foot cuts	F6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.1

3.4. Linking the errors and its sequences with the occurred injuries in regular training. A starting point to re-dimension the risk analysis of judo techniques

In the second part of Table 4, the data association as a function of the judoka role on the projection is shown, linking the typical sequence of errors determined by t-patterns analysis of the studied techniques with the injuries occurring during the regular training period. For more information about t-patterns and footage representations check the supplemental material (Figure A1-4).

In general terms, for these techniques that involve a rotation action prior to execution, most of the injuries occurred (contractures, contusions, sprains) have to do with the sequence of errors LFP-HTP-LA-MA-LP. *Tori* puts his left foot badly after the turn, resulting in incorrect positioning of the hip, thus, tori doesn't make a proper leg action, then the load or the block action is incorrectly performed and subsequently the projection is uncontrolled. As example, in *ippon-seoi-nage,* this sequence is combined with the lack of control, which can cause greater risk situations for judokas (shoulder dislocation, cervical hyperflexion and hyperextension or acromioclavicular sprain). For these techniques that don't involve a rotation action prior to execution, were related with errors detected in some particular sequences such as thes produced in *deashi-harai* (RFP-MA), *ouchi-gari* (THP-MA) or *osoto-gari* (ARM-MA-FC).

4. Discussion and perspective

In specific terms, the typical injuries in the head of judokas during amateur training, are located in the nose (Salanne et al. 2010) because it is the more vulnerable part. In this study, these injuries occurred only in *tai-otoshi* techniques. Neck injuries are very serious and they are normally rare, but they happen in martial arts sports more often than they should (Nagahiro et al. 2011; Kamitani et al. 2013). During the study, minor neck injuries occurred only when the students were performing the *koshi-guruma* technique. In general, for this type of injury, it is very important that novice judokas acquire habits of properly throwing and falling (Leavitt 2003).

At the upper limb body parts, the typical injuries occurred were the acromioclavicular sprain, dislocated shoulder and wrist sprain. In general they are well documented injuries in the bibliography (Elliott 1972; James and Pieter 2003). The dislocated shoulder injury is usually caused by an excessive rotation of the arm when it is out to the side of the body, which pushes the top of the humerus forwards and provokes an anterior dislocation of the joint caused by a bad fall of *uke* when *tori* keeps grapping the arm of *uke* or when *tori* lifts an excessive weight over the shoulder. A sprain in the wrist is a very common injury. The ligaments that connect these bones can be torn by an extreme twist, bend or impact that suddenly forces the wrist into a position beyond its normal range of motion. All of occurred wrist sprains were minors (grade 1) and mostly found when performing *seoi-nage* in both positions as *tori* and *uke*.

The back injuries are very common in judo, the majority of judokas experience back problems due to some type of contracture or minor contusions caused by overwork or errors on the performance of some techniques (Sterkowicz 1997). Most of problems were identified when performing techniques that involve a rotation action (as subdivided in Table 1). There are two main concerns with less experienced judokas: poor falling technique and inadequate throwing or lifting (Sterkowicz 1997).

Injuries in the lower limb body parts were the most frequent injuries. A knee and ankle sprains are common injuries (Yamamoto et al. 1993; Majewski et al. 2006), mostly caused by the focus on physical contact and fast movements, when the ligaments are stretched too far beyond its normal range of motion (Koshida et al. 2010).

Even if judo is a sport that emphasizes the use of proper technique and mechanics, there are few detailed publications (Barsottini et al. 2006) that allow performing a causal correlation between

the technical aspects and the percentage picture of the injuries. The problems of describing the technical errors and its potential sequences have been solved previously by other authors (Mifune 2004; Daigo 2005) and in our department, we have successfully applied similar tools (Gutiérrez et al. 2009; Gutiérrez-Santiago et al. 2013; Prieto et al. 2013). However, it is difficult to conduct an associative research between technical error and injury occurrence. For instance, the type maneuvers vary every time, with no two throws ever exactly alike, which is why injuries are difficult to assess, and as all risky situations, the repetition of such maneuvers increases the likelihood of an accident. Additionally, the frequency of injuries that occurs in a training context is low, and studies that aim to link injuries with the poor technique performance are uncommon because they need to be extended during many years, managing a voluminous recording material on a daily basis. Thus, such observations are made by experienced trainers that assess the risk of each technique, based on the typical problems encountered with that experience. Unfortunately, this empirical analysis is limited and in many occasions would not allow uncovering critical situations that help to develop a more detailed guide that correctly assesses the risks of performing a poor technique.

In this research, we have selected those situations in which an injury had occurred as a result of a single action and caused by a poor technical execution, by analyzing a period of five years of recorded material and 193 novice judokas. Further research is necessary to determine the causal relationships between technical error and the occurred injuries. This research provides the hidden temporal sequence of errors of common throw techniques, helping the teaching-learning process of judo techniques and guiding professionals to use them as a tool to correct technical errors in the prevention of diverse type injuries in judo initiation. The methodology applied here could be easily extended to all judo techniques and possible to many other sports. In conclusion, the methodological procedure of video recordings combined with statistical and t-pattern analysis proposed can provide detailed descriptions of the mechanisms of sports injuries, but studies must be patiently performed to obtain representative video samples.

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Supplemental material

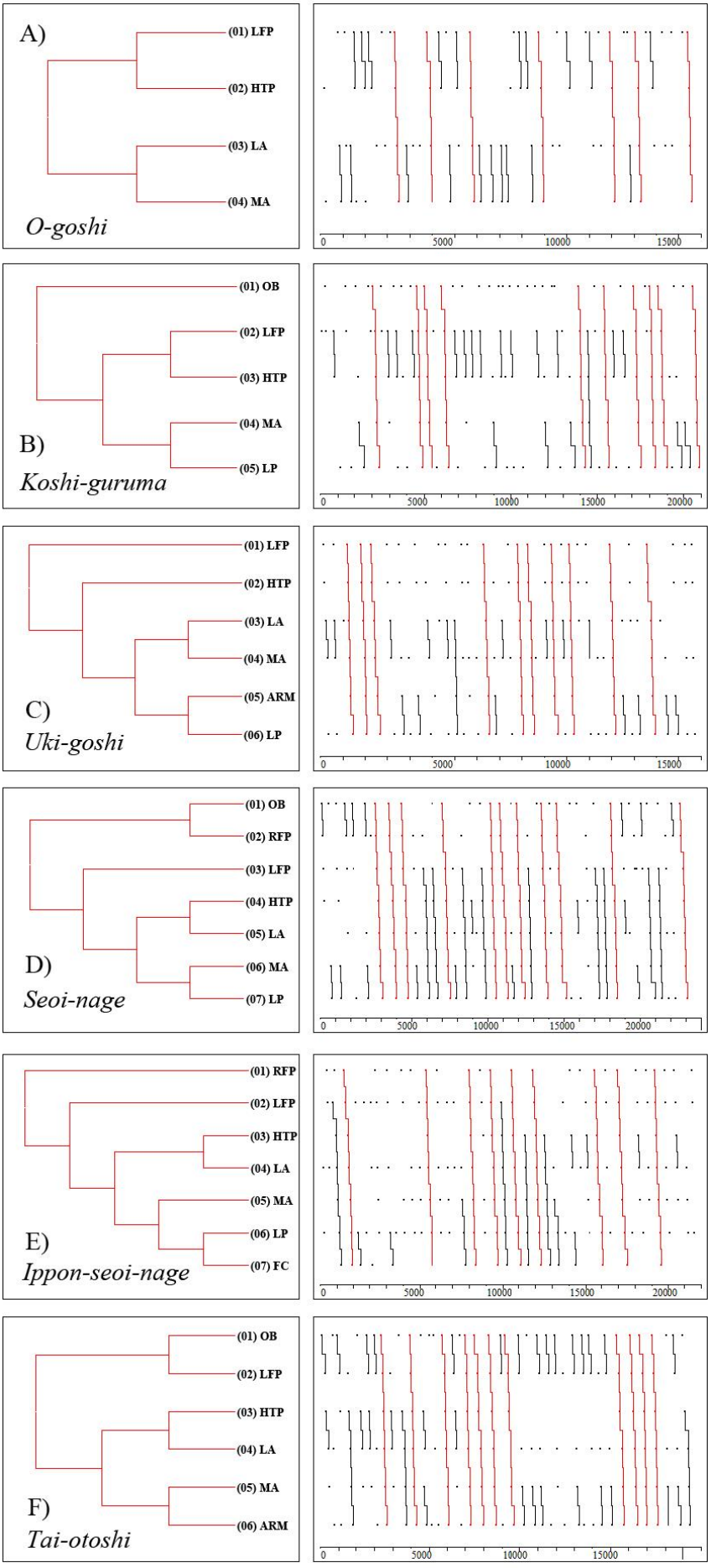

Figure A1. T-patterns obtained for the techniques that involve a rotation action prior to the throw. The left-hand box depicts the relationship between the different categories and the right-hand box indicates how many times each of these relationships occur.

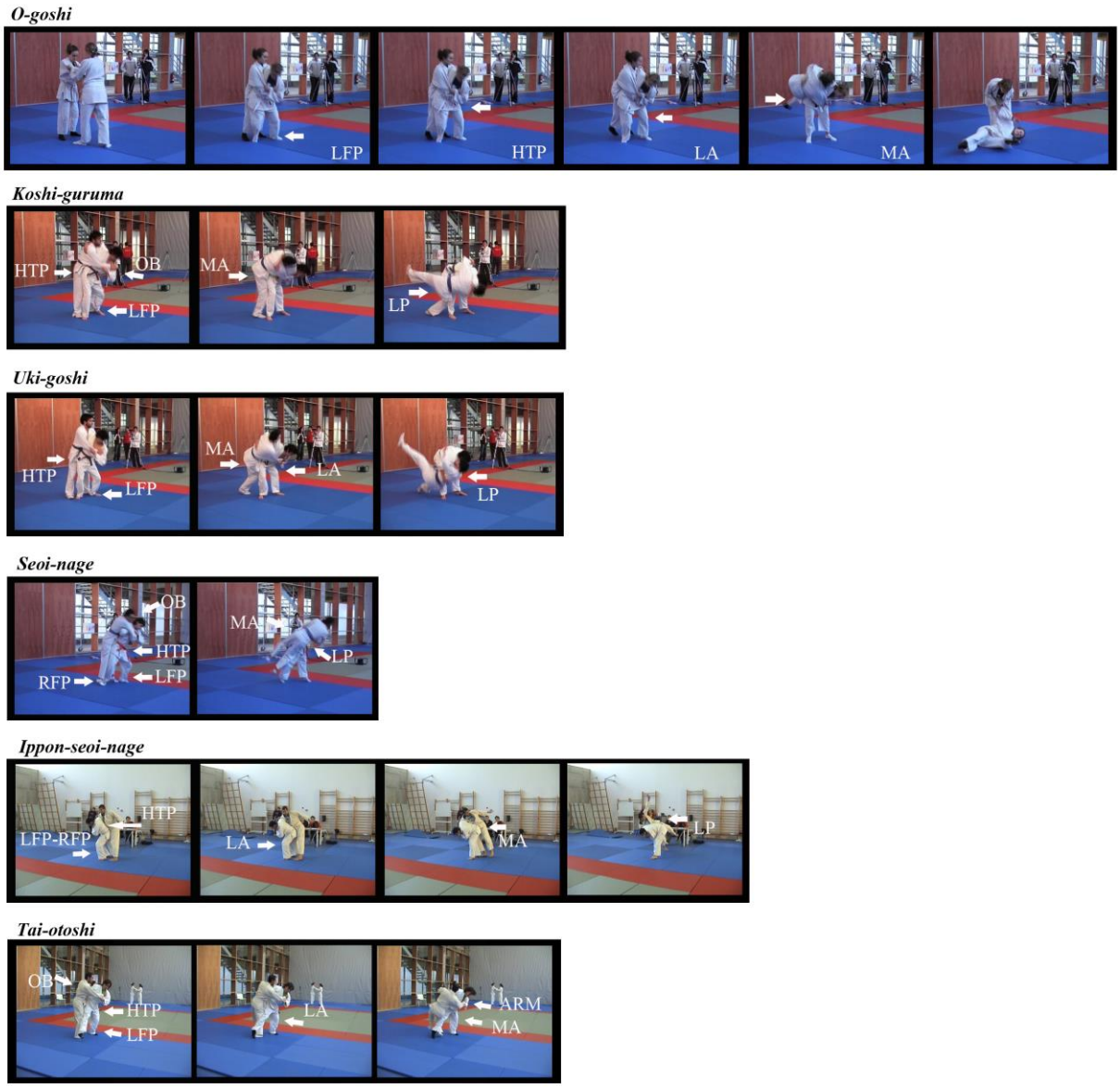

Figure A2. Footage representation showing the errors when performing the techniques that involve a rotation action prior to the throw by novice students during regular training.

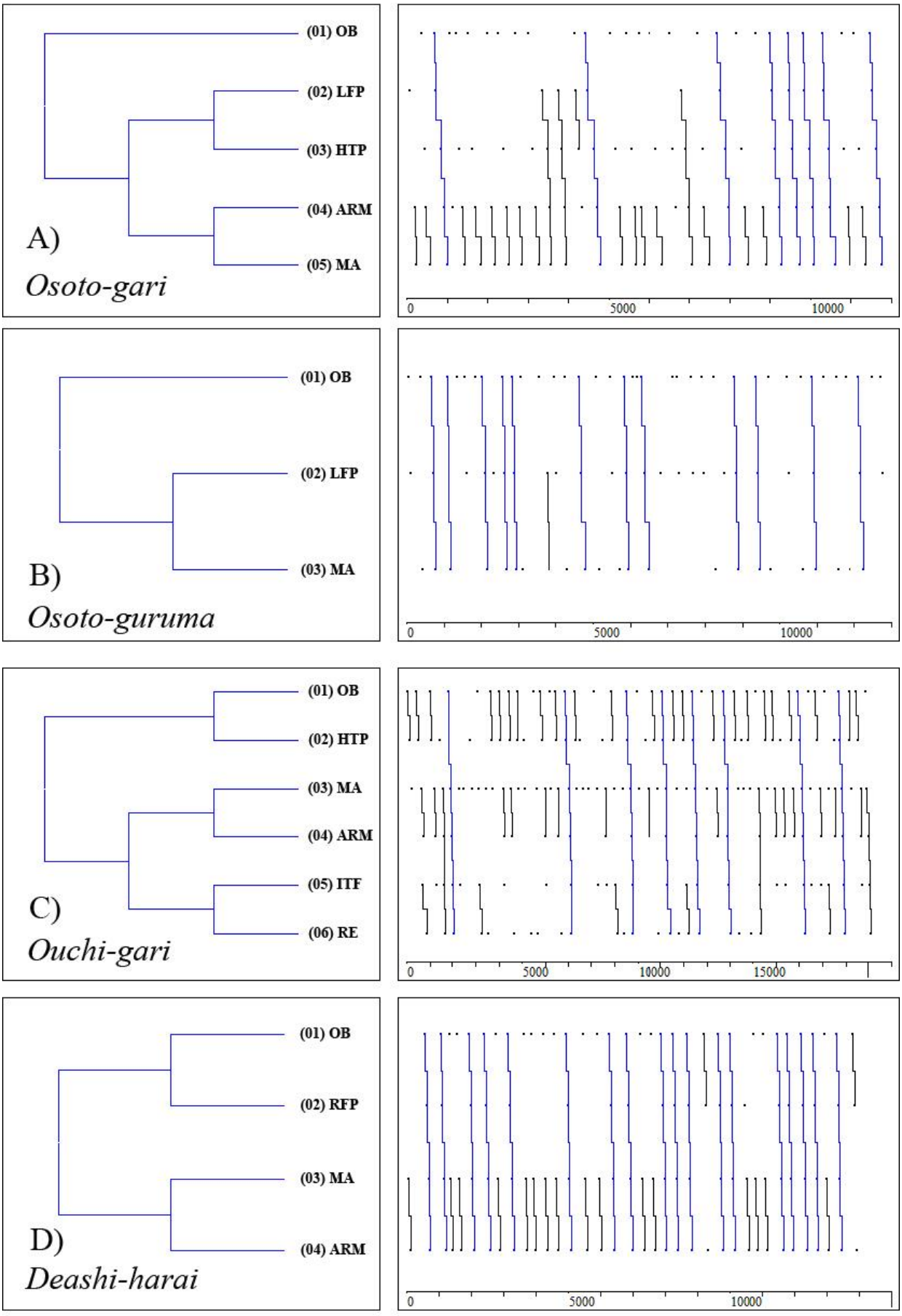

Figure A3. T-patterns obtained for the techniques that don't involve a rotation action prior to the throw. The left-hand box depicts the relationship between the different categories and the right-hand box indicates how many times each of these relationships occur.

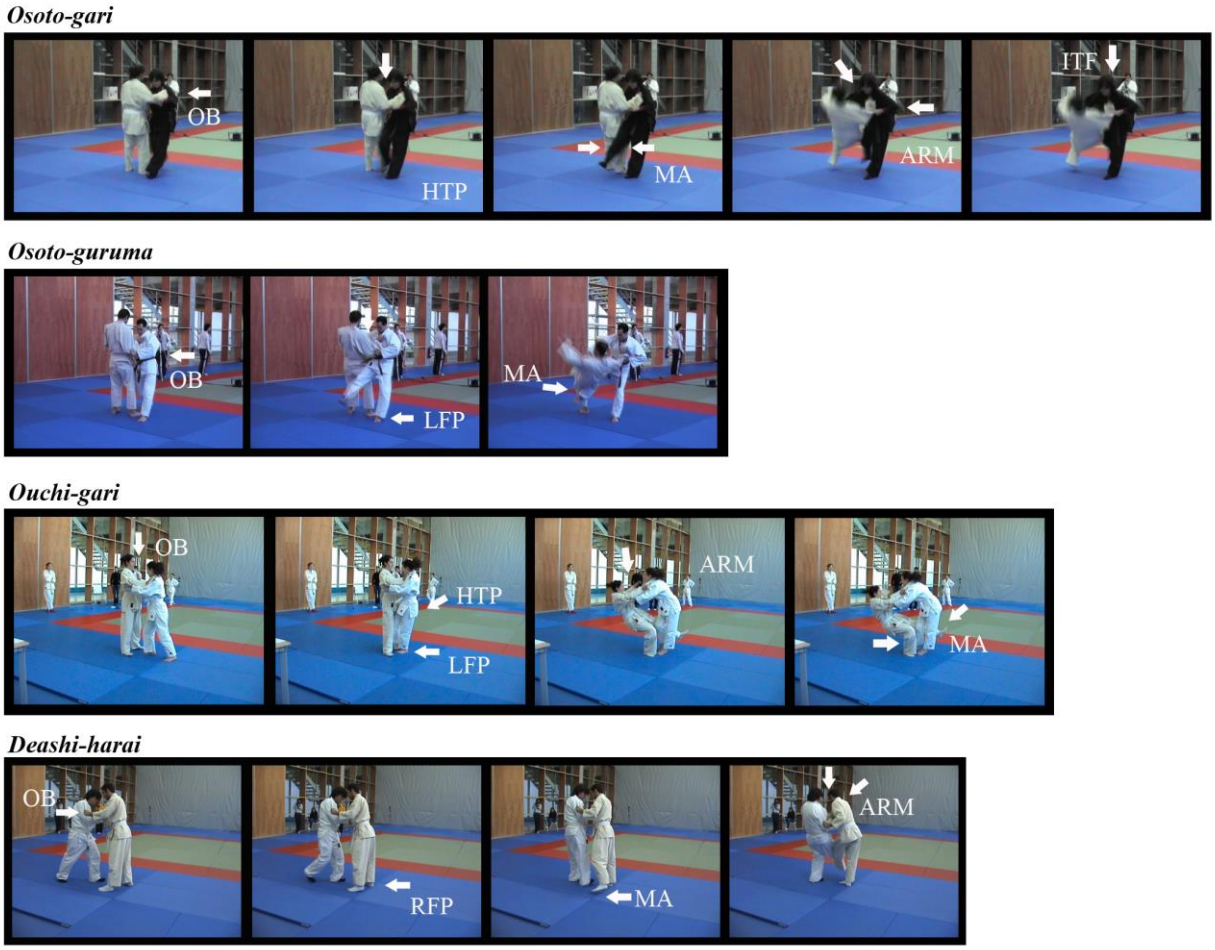

Figure A4. Footage representation showing the errors when performing the techniques that don't involve a rotation action prior to the throw by novice students during regular training.