EFFECTS OF A SPECIFIC TRAINING PROTOCOL ON POSTUROGRAPHIC PARAMETERS OF A TAEKWONDO ELITE ATHLETE AND IMPLICATIONS ON INJURY PREVENTION: A CASE STUDY

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ABSTRACT

Introduction*: Taekwondo elite athletes should have excellent qualities in several aspects of fitness, as well as peculiar postural characteristics in terms of balance and postural control, to achieve the best possible results during competitions. Moreover, it is known that taekwondo shows high risk of injury. The aim of this case study is to evaluate the effects of a specific training protocol on posturographic parameters of a taekwondo elite athlete in order to prevent the risk of injury.*

Materials and methods*: The specific training protocol provided 2 months of general strength conditioning, which included pre-conditioning in the first 2 weeks, physical training to improve explosive strength, balance and postural control and athletic training to improve the combat technique. The experimental design included three assessment times: the pre-test (T_0), the intermediate-test (T_1) and the post-test (T_2). Each test provided the same evaluations: anthropometric measurements, cervical ROM assessment and posturographic evaluation.*

Results*: Stabilometric parameters showed a good balance and postural control both in T_0 and T_2. Baropodometric parameters showed a physiological load pressure distribution between the left and the right foot in T_0 (left foot 54% - right foot 46%) as well as in T_2 (left foot 45% - right foot 55%). The left forefoot-rearfoot ratio pressure showed no differences between T_0 and T_2 ($p>0.05$); we found an improvement on the right forefoot-rearfoot ratio ($p<0.05$). Cervical range of motion evaluation showed no significant variations from T_0 to T_2 ($p>0.05$) on rotation and lateral bending movements; we found an improvement on the extension movement from T_0 to T_2 ($p<0.05$), while the flexion movement decreased ($p>0.05$).*

Conclusion*: The presented case study showed that the experimental protocol improved the postural parameters of this taekwondo elite athlete. We believe that other athletes may adopt this protocol in order to improve own sports performance and to prevent injuries.*

Keywords*: taekwondo, balance, postural control, training.*

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Introduction

Taekwondo is a Korean military art used in the past for military purposes[(1)]. This combat sport is the most practiced martial art in the world[(2)]. Taekwondo athletes are required significant aerobic capacity, peak of anaerobic power and, moreover, high levels of muscular strength, flexibility and agility[(1)].

Furthermore, in order to obtain the best possible results during competitions, taekwondo athletes should have peculiar postural characteristics in terms of balance and postural control as well as muscle symmetries. In fact, tonic postural system interferes negatively on posture when produces asymmetrical muscular tensions[(3)] and this, moreover, may increase the risk of injury[(4)]. It is known that the tonic postural system is controlled by the

nervous system, using feedback and feedforward strategies to maintain the postural control during quite stance[5]. These mechanisms entail the integration of proprioceptive, auditory and vestibular afferences as well as impulse sensory from visual and the stomatognathic systems[6, 7]. These sensory information's, integrated at the level of the central nervous system, influence the tonic postural system, deputy at stabilizing the skeletal structure and at the alignment of the human body[3].

In order to maintain body balance, the postural chains must ensure musculoskeletal stabilization of the body segments and self-adjustments to compensate for postural disorders[8]. Postural balance strategies also include the "hip strategy" and the "ankle strategy"[9]. Gorgy et al. reported that athletes of martial arts show high levels on postural reaction control after perturbation and, moreover, they frequently use the ankle joint compared to athletes of other sports-category or sedentary people[10]. For this reason, the authors[10] suggest that the good control of body balance in these subjects is related to a fine control of the lower limbs.

It is known that taekwondo training improves balance control and, moreover, that athletes of this martial art show a better postural control compared to age-related subjects who practice other sports[11]. Several studies have reported that many sports included balance exercises in their training programs in order to prevent the risk of injuries and to improve postural control and body balance[12, 13]. It has also been demonstrated that a poor postural control is related to an increased risk of ankle and knee injury[14].

The aim of this case study was to evaluate the effects of a specific training protocol on sports performance and posturographic parameters of a taekwondo elite athlete in order to prevent injuries.

Case presentation

We report a case of a young athlete of the Italian Taekwondo National Team who performed a 12-months specific training protocol, from September 2015 to August 2016, to improve balance and postural control. The athlete of the study was a 17 years old male (height: 1.80 m; weight: 65 kg), second Dan black belt, belonging to the A.S.D. Taekwondo Trinacria Team.

The young athlete has won 4 bronze medals at the Italian Junior Championship, 1 gold medal at the Italian Cup, 1 silver medal at the Italian Senior Championship, 1 bronze medal at the Greece International Open. He had participated at numerous meetings with the Italian Taekwondo National Team and participated at the European Championship with the Italian Taekwondo National Team in Latvia. All medals won by the athlete refer to national and international sports competitions according to W.T.F regulations. The training protocol took into account the athlete's calendar of competitions, the seasons and the loading and unloading periods of workouts. It is appropriate to report that the athlete started the training protocol after many meetings with the Italian Taekwondo National Team during the summer, the seasonal rest period for an athlete. Moreover, the athlete took part in a pre-European Championship rally with Italian Taekwondo National Team in October 2015 and participated at/in the European Championship in Latvia, representing Italy in the 63 kg-category.

The training protocol provided: 2 months of general conditioning of all the body muscles and joints which included pre-conditioning in the first 2 weeks. The protocol continued with physical training to improve explosive strength, balance and postural control. Subsequently, the athlete performed an athletic training to improve the combat technique with a rest period in the summer season of 2016 (at the end of the training protocol). Training was suspended 1-week before any sports competition and the athlete focused himself on fighting combinations.

All the experimental training protocol was performed barefoot on the tatami and fitness room, alternately.

The experimental design included three assessment times: the pre-test (T_0) in November 2015 (after 2 months of conditioning), the intermediate-test (T_1) in March 2016 and the post-test (T_2) in August 2016. During each test, the subject performed the same evaluations: anthropometric measurements, cervical Range of Motion (ROM) assessment and posturographic evaluation.

Anthropometric measurements

Height and body weight measurements were performed with the subject in a standing position, barefoot and wearing intimate clothing. Height was measured using a standard stadiometer (maximum height recordable: 220 cm; resolution: 1 mm). Body weight was evaluated by a Seca scale (maximum weight recordable: 300 kg; resolution: 100 g; Seca, Hamburg, Germany).

Cervical ROM assessment

Cervical Range of Motion (ROM) was evaluated by Moover® (Sensor Medica®; Guidonia Montecelio, Roma, Italia), a wireless computer-aided accelerometer using freeStep® software (Sensor Medica®; Guidonia Montecelio, Roma, Italia). This non-invasive device allows to measure range of motion, velocity and acceleration values on the X, Y and Z planes.

The cervical ROM evaluation followed a standardized method described elsewhere[15]. The athlete seated in a chair (length: 38 cm; breadth: 40 cm; height: 45 cm) with the accelerometer positioned medially of the frontal bone of the skull and above the bridge of the nose and fastened around the head via a strap. The athlete was required to perform neck movements on the three planes until the maximal ROM was achieved. The standardized position for the cervical measurement provided: back at 90-degree angles, head in a neutral position, sacrum and shoulder blades fixed to the backrest of the chair, hands on his thighs and feet on the floor.

The athlete performed three consecutive movements: the maximal left and right rotation (RT) to evaluate the mobility in the transverse plane, the maximal left and right lateral bending (LB) for the frontal plane and finally the maximal flexion-extension (F-E) movements in the sagittal plane.

All assessments were performed three times but only the maximum value was used for the statistical analysis. No warm-up was allowed before measurements. The same researcher performed all the measurements.

Posturographic assessment

For the posturographic evaluation, the subject performed two different tests: a baropodometric assessment, to measure foot pressure and plantar surface, and a stabilometric evaluation, to assess the coordinates of the center of pressure (CoP). Posturography was measured using the freeMed® baropodometric platform (Sensor Medica®; Guidonia Montecelio, Roma, Italia) and the freeStep® software (Sensor Medica®; Guidonia Montecelio, Roma, Italia). The system samples real time postural sway at 50 Hz. The sensors, coated with 24K gold, guarantee repeatability and reliability of the instrument.

The standardized procedure for baropodometry provided that the subject was positioned for 5 seconds in orthostatic stance on the platform with the head in neutral position facing forward, arms along the trunk and feet placed side-by-side.

Stabilometric assessment was performed in accordance with the Romberg test: the athlete was in a standing position for 51.2 seconds with feet placed side-by-side forming an angle of 30° and both heels were 4 cm apart. Participant repeated the stabilometric test in two different conditions: with eyes open (EO) and then with eyes closed (EC). The parameters considered for both EO and EC tests were: Sway Path Length (SPL) of the CoP; Ellipse Sway Area (ESA).

Training program

The athlete performed a 12-months specific training protocol, from September 2015 to August 2016. The procedure involved a periodization in 12 mesocycles of 20 days each (5 days/week) characterized by a differentiation of working load percentage according to the objectives as reported in Fig. 1.

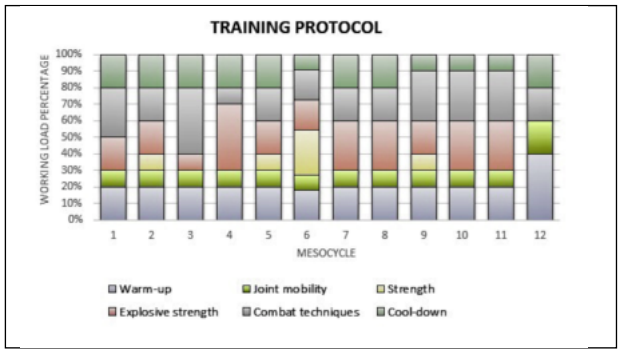

Fig. 1: Working load percentage of the experimental training protocol in the mesocycles.

Each session lasted 2 hours and included 20/30 minutes of warm-up, 15/20 minutes joint mobility, 10 minutes of "ladder" exercises (to train speed and agility), 15 minutes of explosive strength, strength and proprioception exercises (to improve balance and postural control), 30/40 minutes of combat techniques and 10 minutes of cool-down. The different duration of each single-phase respect the objectives of each mesocycle. Table 1 shows a workout example.

Main outcomes

As reported in table 2, stabilometric parameters showed a good balance and postural control both in T_0 (eyes open: SPL, 535.2 mm; ESA, 39.71 mm2 vs. eyes closed: SPL, 587.18 mm; ESA, 233.05 mm^2) and T_2 (eyes open: SPL, 461.31 mm; ESA, 240.24 mm^2 vs. eyes closed: SPL, 380.17 mm; ESA, 278 mm^2).

	Exercise 1	Exercise 2	Exercise 3	Rest period (s)
Warm-up	run: 20'	-	-	-
Joint mobility	10'	-	-	-
Abdominals	crunch: 3 x 20	plank: 3 x 20	V sit: 3 x 15	60
Speed and agility	ladder exercises: 10'	-	-	-
Proprioception	static position: 3 x max	monopodalic position: 3 x max	static and monopodalic position with eyes closed: 3 x max	60
Explosive strength	pistol squat: 3 x 12	leg ext + leg curl (super set): 3 x 12	burpees: 3 x 15	90
Combat techniques	40'			
Cool-down	10'			

Table 1: Example of workout.

right: 46.2° - 48.4° vs. 44.7° - 52.7°), instead, we found an increase of the extension movement from T_0 to T_2 (93.6° - 129.3°), and a decrease in the flexion movement (58.4° - 27.9°) as shown in table 3.

Discussion

With this case study we report changes on posturographic parameters in a taekwondo elite athlete after a specific training protocol. It is known that taekwondo is a sport that all people can practice and it is popular in Korea for promoting health body and mind. However, peculiar characteristics in several aspects of fitness are required for an elite taekwondo athlete to achieve optimal results during competitions[2] as well as an important role is attributed at the dietary behaviour and in particular the quality and the quantity intake and energy expenditure of nutrients[16, 17].

	Baropodometric parameters						*Stabilometric parameters*			
							EO		EC	
	L-F LP (%)	*R-F LP (%)*	*L-FF LP (%)*	*L-RF LP (%)*	*R-FF LP (%)*	*R-RF LP (%)*	*SPL (mm)*	*ESA (mm2)*	*SPL (mm)*	*ESA (mm2)*
T0	54	46	47	53	77	23	535.2	39.71	587.18	233.05
T1	52	48	29	71	80	20	438.41	208.29	445.29	551.54
T2	45	55	46	54	69	31	461.31	240.24	380.17	278

Legend: EO, eyes open EC, eyes closed L-F, left foot R-F, right foot L-FF, left forefoot L-RF, left rearfoot R-FF, right forefoot R-RF, right rearfoot LP, load pressure SPL, Sway Path Length ESA, Ellipse Sway Area.

Table 2: Posturographic parameters.

Baropodometric parameters showed a physiological load pressure distribution between the left and the right foot in T_0 (left foot 54% - right foot 46%) as well as in T_2 (left foot 45% - right foot 55%). The left forefoot-rearfoot ratio pressure showed no differences between T_0 (47% - 53%) and T_2 (46% - 54%), instead, we found an improvement on the right forefoot-rearfoot ratio from T_0 to T_2 (77% - 23% vs. 69% - 31%).

	RT (°)		*LB (°)*		*F-E (°)*	
	L	*R*	*L*	*R*	*F*	*E*
T_0	88.4	85.6	46.2	48.4	58.4	93.6
T_1	91.1	86	40.4	48.7	39	114.5
T_2	85.9	85.3	44.7	52.7	27.9	129.3

Legend: ROM, Range of Motion RT, Rotation LB, Lateral Bending F, Flexion E, Extension L, left R, right

Table 3: Cervical ROM parameters.

Cervical range of motion (ROM) evaluation showed no significant variations from T_0 to T_2 on rotation movements (left - right: 88.4° - 85.6° vs. 85.9° - 85.3°) and lateral bending movements (left -

As in any martial art, the scientific literature reports several studies that show the risk of injury in taekwondo athletes[1, 4]. In particular, the most common types of injuries in taekwondo athletes were contusions and joint sprains[1, 18]. As reported in a number of study, balance training prevents the risk of injuries and improves postural control in athletes and sedentary people[12-14, 19, 20]. Conversely, a poor postural control may increase the risk of injuries[14]. Amongst of physical characteristics, balance plays a central role during the landing phase of kicks in taekwondo athletes to prevent the risk of injuries[21] and taekwondo training contemplates balance exercises to improve this quality. It is demonstrated that martial arts athletes show a better postural control and a significant use of the ankle joint compared to subjects which practice other sports[10, 11].

Many sports, as taekwondo, that are practiced on natural and/or irregular surfaces may be more susceptible to injury[14, 22] than others played on firm surfaces. Since training on unstable surface is

adopted to improve postural control and balance, this condition could increase the ability to respond to unexpected feet movements caused by the uneven floor[14]. Proprioception has a central role in maintaining joint stability[21].

In the present case study, stabilometric parameters have shown a good balance and postural control in the athlete both at T_0 and T_2, in each condition (EO and EC). In particular, the Sway Path Length values at T_0 and T_2 indicated that this fine postural control may be attributed to a good hip strategy of our athlete. In fact, the "hip strategy" is adopted by healthy people, which includes sport subject, in response to low perturbations[9, 23]. We suppose that our results can be explained because the protocol provided proprioception exercises to improve balance and postural control that contemplated, exercises with the use of proprioceptive equipment in which the athlete performed exercises with both feet or in a single leg stance with open and closed eyes.

Baropodometric parameters showed a physiological distribution of the pressure load between the left and the right foot in T_0 as well as in T_2 in accordance with the literature[24]. Plantar pressure distribution between rearfoot and forefoot showed no differences between T_0 and T_2 for the left foot. Instead, for the right foot we found an improvement on the rearfoot-forefoot ratio. However, both feet were unbalanced forwards, even if the right more than the left foot. Our data are in agreement with Alexandrov et al., that have demonstrated that in taekwondo athletes body posture is characterized by a forward attitude in order to have an anticipatory postural adjustment according to the optimal bending model[25].

As seen, from T_0 to T_2 the subject maintains a forward propensity. We hypothesize that the subject maintains this rearfoot-forefoot ratio probably because the athletes of taekwondo during competitions are always on alert. Moreover, we suppose that the athlete showed a better pressure distribution in the left foot compared to the right forefoot-rearfoot ratio probably because during battles he often holds the left leg anchored to the tatami while kicking with the right leg (the dominant leg).

For the right forefoot-rearfoot ratio, we suppose that from T_0 to T_2 the improvement on the load distribution is attributable to the balance exercises provided in the protocol that have rebalanced an asymmetrical adaptation.

Cervical ROM evaluation showed no significant variations from T_0 to T_2 on rotation movements and lateral bending movements. In the sagittal plane movements, we found an improvement on the extension movement from T_0 to T_2, however there is a worsening on the flexion movement.

Furthermore, this experimental training protocol could be very effective in order to obtain relevant results and to prevent the risk of injury. In fact, the athlete has achieved the following results without undergoing any injury: four convocations in the Italian Taekwondo National Team; the participation at the European Championship (Latvia, 23 October 2015) with the Italian Taekwondo National Team; second place at the Interregional Championship (Latina, 7 November 2015) 63 kg-Senior category; second place at the Absolute Italian Championship (Riccione, 12 December 2015) in the 63 kg-category; took part at the Slovenia Open Championship (Slovenia, 27 February 2016) in the 63 kg-category; the convocation in the Italian Taekwondo National Team at the Olympic Preparation Center "Bruno Zauli" (Formia, March 2016); third place at the Interregional Championship (Bagheria, 8 May 2016) in the 68 kg-category; the participation at the Italian Senior Championship (Reggio Calabria, 12 June 2016).

The presented case study showed that the experimental protocol improved the postural parameters and the physical performance of this taekwondo elite athlete. We believe that other athletes may adopt this protocol in order to improve sports performance and to prevent injuries. However, a larger sample size is needed to validate the studied protocol.

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