Postural responses to unexpected external perturbance in judoists of different ability levels

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ABSTRACT

Judo is a sport in which the athlete must have an efficient balance control, as he or she is constantly vulnerable to unexpected movements imposed by the opponents. The aim of this study is to analyze judoist postural responses to an unexpected external perturbation (n = 20) in two levels of ability (brown and green belts) and in those of a non-athlete group (n = 10). An external posterior perturbation (EPP) was applied by means of a horizontal traction to the subject's dorsum, using a fixed pulley system. The EPP was unexpectedly and quickly removed, producing the desired postural response. Displacements of centre of pressure (COP) were obtained by means of a force platform. Postural responses were analyzed in eight intervals of 1 s (t1 to t8), beginning at the moment of EPP removal. The speed and position averages of COP, in anteroposterior plane, were the main parameters used to analyze the postural responses in the balance recovery. A two-factor (group x intervals) repeated measures analysis of variance (ANOVA) followed by Student Newman-Keuls post-hoc ($p < 0.05$) was applied for speed and COP. ANOVA for intervals factor in each group was applied to COP position, in order to verify COP displacement patterns. The group of greater ability presented lower COP speed compared with the control group, and a gradual and continuous COP displacement pattern during balance recovery. Our findings confirmed the hypothesis that the most skilled athletes present better balance control, and show that the proposed sport training and the athlete's level of ability may influence on this control performance.

Keywords: Balance. Martial arts. Sports. Sensory-motor performance.

INTRODUCTION

The performance of complex motor abilities, such as sports gestures, demands a high balance control[1-3]. An adequate balance control is reflected in appropriate muscular synergies, producing effective motor responses, which minimize and restore the displacements of the gravity center[4].

Training and experience make the motor action more efficient and consequently, the postural responses as well[5]. The learning and training of a sport for a period of time seems to improve the postural responses efficiency envolved in the balance control required in sports, especially in sports that require this control somehow, such as marcial arts; dance or acrobatic sports[1-3].

In judo, the athletes need to control their balance efficiently once this sport's techniques are based on constant movements and unexpected external perturbation imposed by their opponents with the aim to unbalance and drop them in combat[1,2]. Judo is an olympic sport with competitors classification by weight, age and sex categories, where the athlete's ability is shown by the color belt graduation that the athlete wears over the judogi (kimono)[6].

Due to the balance demands envolved in the combat and training, it is expected that the judo athlete develops such ability through the training time. Actually, the judoist postural control constitutes the interest of some research groups. However, those authors are basically interested in studying the role of sensory information in the postural control. Compared to athletes of other sports, the judoists present faster muscle responses whenever facing a proprioception perturbation[1]. Compared to ballet dancers, the judoists present better postural control, with smaller oscillation of the gravity center, independently of the lack of the visual information or the proprioception perturbation[2]. Intramodality analysis reveals that the more skilled judoists show bigger vision dependence in the posture control in static test than less skilled judoists[7].

In the previously reported studies, better balance control in judoists is observed, reinforcing that it constitutes an important factor for these athletes' performance. Yet, there are gaps in the literature related to the balance control in this sport, since those previous studies are related to the understanding of the sensory information in the postural control in judoists. Moreover, the previous studies used static tasks or dynamic tasks with perturbations of the base platform The balance control in more challenging tasks, simulating more dynamically the sports' demand, has not been reported yet.

This study has the objective to analyze the postural responses to an enexpected external perturbation in judoists in two ability levels (brown and green belts) and in a non-athletes group, to test the hypothesis that more skilled athletes have better balance control in situations of greater postural demand.

METHODOLOGY

Participants

Twenty male judoists from two levels of ability participated in this study: ten judoists from the brown belt, higher ability level, and ten judoists from the green belt, lower ability level. The purple belt, intermediate ability level between the Brown and green belts[6], did not interest us in this study. Ten male participants who practiced recreational physical activity, without any judo experience, were members of a control group. The composition of the three groups was paired in relation to age, weight and height (table 1). The participants who presented mechanical or functional instability consequent from trauma or ligament, articulatory or muscular lesions, in the three precedent months, were excluded from the study. The training characteristics of each athletes' group are de-

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scribed in table 2. All participants signed the informed consent term, approved by the Institution Ethics Committee, for reasearch envolving humans.

TABLE 1
Age, weight and height of the brown (BG), green (GG) and control (CG) groups

	BG (n = 10)	GG (n = 10)	CG (n = 10)
Age (years)	18,0 ± 2,9	20,0 ± 3,6	21,0 ± 1,0
Weight (kg)	70,2 ± 2,8	69,6 ± 4,6	67,4 ± 3,5
Height (cm)	172 ± 2,8	174 ± 4,9	176 ± 8,8

Values are average and standard deviation (±).

TABLE 2
Practice time and training frequency for the brown (BG) and green (GG) groups

	BG (n = 10)	GG (n = 10)
Years of practice	8,0 ± 2,0	3,7 ± 2,0
Training/week	6,3 ± 2,9	3,2 ± 1,3
Hours/day	2,7 ± 0,9	2,1 ± 0,5

Values are average and standard deviation (±).

Experiment protocol

The displacements of center of pressure (CP) were obtained through a force platform (OR6-WP-2000, AMTI, Watertown, USA), collected in a 100 Hz frequency. The data acquisition and processing were conducted through the Labview 6.0 program.

The CP is the point of application of the result of the ground reaction forces thar act on the platform surface and expresses the neuromuscular response to the displacements of the center of pressure[8]. The PC time related coordinates are parameters commonly used to analyze the balance control[9].

An external posterior perturbance (EPP) applied by means of a horizontal traction through a fixed pulley system and a load, described by Wolfson *et al.*[10], was adapted for this study (figure 1). A load equivalent to 6% of the participant's body weight was applied on the postero-superior half of the dorsum, on the level of the lower corner of the scapula, next to the medium body line[11].

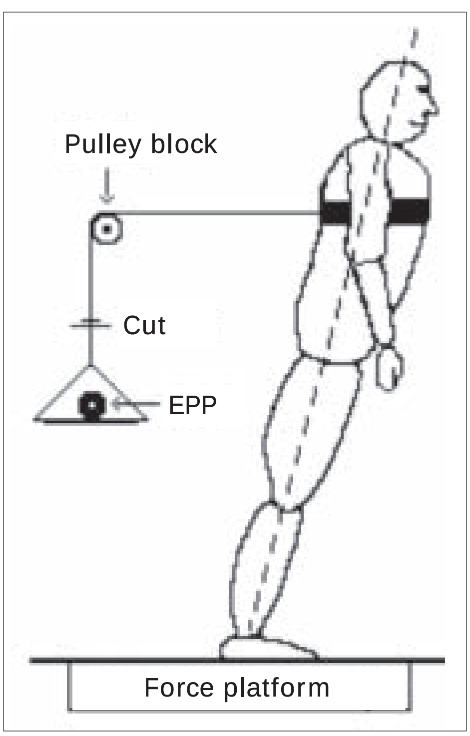

Figure 1 *– Scheme of the external posterior perturbation (EPP) applied by means of a horizontal traction through a fixed pulled system-load*

For the test conduction, the participants were in bipedal standing on the force platform, barefeet and with eyes open during the entire procedure. They were oriented to keep upper limbs along the body, knees straight and feet separated and aligned with the shoulders.

At the beginning of the test, the EPP was slowly applied until the load was totally suspended. When the participant seemed to be adapted to the EPP, the load was unexpectedly removed to the participant, starting the desired perturbation so that the capacity of balance restauration could be evaluated. A previous trial was conducted to ensure the correct understanding of the task. In this protocol, the collection of three trials was established, with the total duration of 30 s for each trial, so that the effects of the fatigue could be avoided and the effects of the antecipatory reactions and the learning could be minimized.

Data analysis

The postural responses to the unexpected external perturbation were analyzed in the antero-posterior direction, in eight intervals of 1 s each (t_1 a t_8), with the t_1 interval starting at the moment of the liberation of the EPP (figure 2).

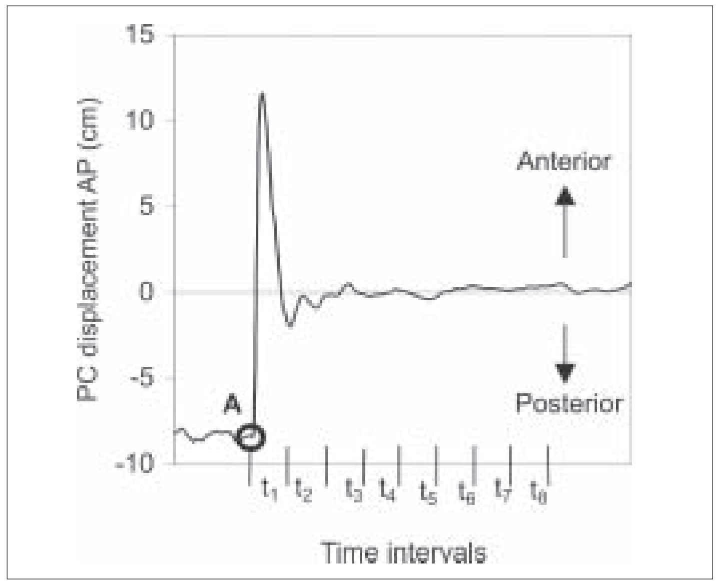

Figure 2 *– Representation of the displacements of the center of pressure (CP), in the Antero-posterior direction, according to time.* ***A:*** *Time of the EPP liberation. Intervals from t_1 to t_8, with 1s each, from the EPP liberation.*

The dependent variables for the comparison between the groups were: (i) PC velocity in the intervals from t_1 to t_8; (ii) PC average position in the intervals from t_1 to t_8; (iii) PC paek in t_1; (iv) PC breadth in t_1 and **(ACHO QUE FALTA ALGO AQUI)**, (v) number of readjustments occurred from t_1 to t_8. The intragroup analysis of the PC average positions was used to verify the postural responses pattern of each group in the intervals from t_1 to t_8.

The PC velocity was obtained adding the scale displacements (accumulated distence) and dividinf them by the chosen time interval[3]. In this study, the PC velocity is equivalent to the accumulated distance of the displacement, since the time interval was pre-established in 1 s. The PC peak and breadth in the t_1 interval correspond to the inertia effects by the liberation of the EPP and to the reflex postural responses. The criterium to verify the number of postural readjustments was the change of direction of the PC displacement, since the postural responses present an oscillatory nature.

Statistical analysis

The average value of the dependant variables was calculated for each time interval through three conducted trials Once the normality of the data distribution was verified, variety analysis (ANOVA) was applied to the averages dependent on the, peak, breadth and number of readjustments, for comparison through the groups. Analysis of variance (ANOVA) with repeated measurements for two factors (group x interval) was applied to the velocity averages and the PC position from the t_1 to t_8 intervals to verify the groups effect for the taken parameters. Analysis of variance (ANOVA) was applied to the PC position averages from the t_1 to t_8 intervals for each group to verify the PC repositioning pattern through the intervals, after the perturbation. The significance level was established in $p < 0,05$ for all measurements of the test and the Student Newman Keuls post hoc was conducted whenever necessary.

RESULTS

The comparative analysis of the peak and the breadth in t_1 showed that the initial, inertial and reflex response, post-liberation of the EPP was similar fro the three groups.

Analysis of variance (ANOVA) with repeated measurements for the group and interval factors, applied to the velocity averages from the t_1 to t_8 intervals revealed effect for group ($F(2,238) = 6,79$, $p = 0.00$), interval ($F(7,238) = 683,25$, $p = 0,00$) and interaction between group and interval. The Student Newman-Keuls post hoc revealed that the difference in the postural adjustments after the liberation of the EPP is significant for the PC velocity in the second immediately after the liberation (t_1) between the brown and control groups. In this interval, the PC velocity in the control group is 27% bigger than in the brown group.

Figure 3 presents the PC velocities averages from the t_1 to t_8 intervals in the brown, green and control groups. In this study, once the velocity equals the accumulated distance of the PC displacement, the brown group presented smaller PC excursion in this interval.

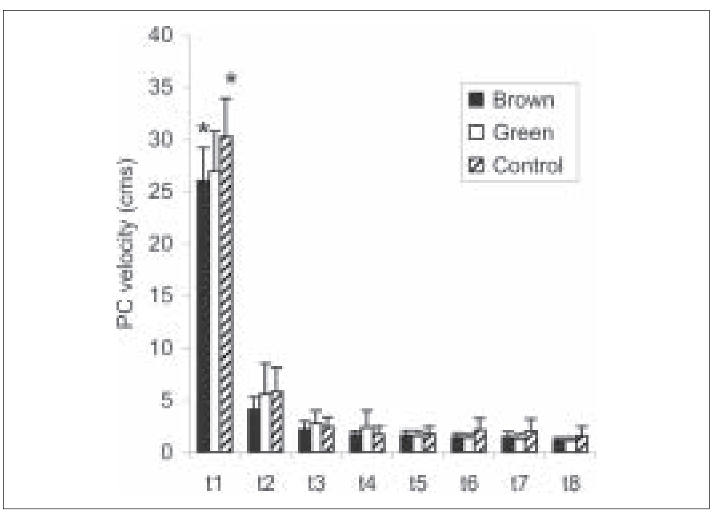

Figure 3 *– PC velocity (average and standard deviation), in the antero-posterior direction, in the time intervals from t_1 to t_8, in the brown, green and control groups*

Analysis of variance (ANOVA) with repeated measurements for the group and interval factors, applied to the PC average position from the t_1 to t_8 intervals showed group effect ($F(2,269) = 7,25$, $p = 0,00$) and interval effect ($F(7,269) = 43,9$, $p = 0,00$). No group x interval interaction was observed.

Analysis of variance (ANOVA) applied from the t_1 to t_8 intervals for the PC average position in each group revealed a different postural recuperation pattern in the groups. In the brown group, after the first second (t_1), the PC gradually reposition so that the difference in the PC position was only revealed from the fifth second ($CPt_2 > CPt_5$), after which, there was a PC stabilization. Such PC repositioning control was observed in an previous interval in the green group ($CPt_2 > CPt_4$), showing less controlled response than in the brown group. In the no-athletes group, such repositioning showed poor postural control, revealing $CPt_2 > CPt_6$, $CPt_2 > CPt_8$.

Figure 4 illustrates the PC average position, in the antero-posterior direction (A/P), from the t_1 to t_8 intervals, in the brown, green and control groups.

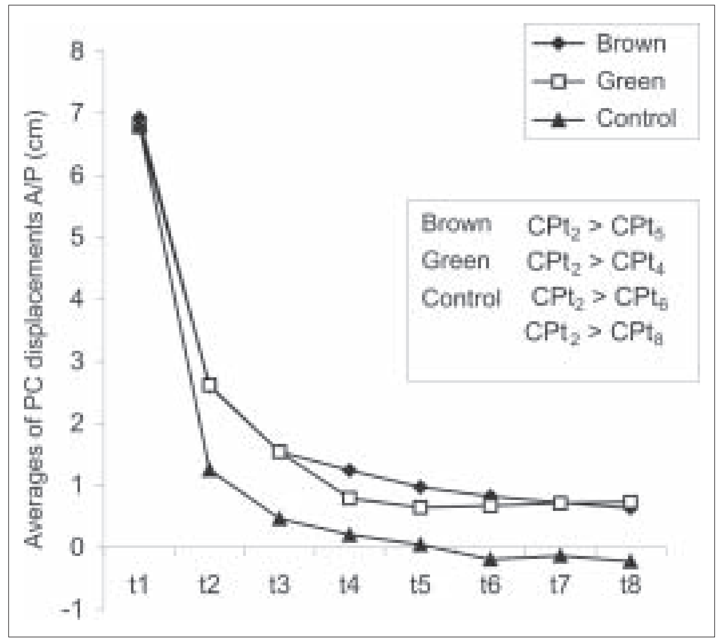

Figure 4 *– Average position of the PC, in the Antero-posterior direction, in the time intervals from t_1 to t_8, in the brown, green and control groups*

The number of postural readjustments was revealed similar among the three groups, although the critical p value between the brown and control groups was found near the significance limits ($p = 0,06$).

DISCUSSION

The protocol used in this study was modified from Wolfson *et al.*[9] and Chandler *et al.*[4]. Our interest concentration was on the postural response to the load removal, which allows us reproduce more closely the demands of the combat in this sport. Furthermore, the choice of this kind of perturbation allows us clearly observe the inertial and reflex reactions before the beginning of the control itself, due to the consistency of its application.

During combat, the athlete is exposed to unexpected pulls and pushes perturbations, imposed by his opponents[1-2]. Previous studies reported in the literature involving judoists, use static or dynamic tasks with perturbations on the base platform. Such tasks were guided to the particular interest of these studies, concerned about the role of sensory information in the balance[1-2,7], differently form our interest that was towards the sport's demand.

The results of this study show that the athletes presented better dynamic postural control in relation to the non-athletes group, revealing that this sport is benefic to this control development[1-2].

The results in relation to the peak and PC breadth in t_1 revealed that the three groups responded with expected inertial and reflex reactions, with anterior PC with big breadth displacement and with high velocities immediately after the EPP liberation. Such responses are not training-dependant, and did not present differences among the groups.

The PC velocity is a parameter widely used to evaluate balance control[8]. Although there are certain controversies about this concept, smaller values of the PC velocity are considered better balance control markers, once they represent less postural activity to maintain it[12]. Nevertheless, in t_1, the moment when the reflex response possibly ends and the postural control adjustments begin, the PC velocity was smaller in brown group compared to the control group. Such results corroborate with previous studies suggestions which report that athletes present better balance performance than non-trained subjects[2,13].

The analysis of the postural response pattern revealed through the PC repositioning in relation to time, considering the athlete's ability in the sport, has not been described in the literature.

Maintenance of balance in the face of an external perturbation is related to the appropriate control of the changes of the PC positions[14]. In the brown and green groups, the balance recuperation pattern shows a gradual and continuing PC posteriorization until a new stabilization, inferring over more adequate postural corrections in the balance recuperation. The control of PC repositioning in the green group occurs with one time interval anticipation, showing less controlled response than the brown group and suggesting an influence of the athlete's ability in the balance control. Compared to athletes of other sports, the judoists activate muscular groups of the lower limbs with smaller latency time and smaller muscular contraction breadth[1]. The findings of these authors in comparison to ours, suggest that judoists activate more rapidly the muscles, but with more control in the correction responses.

The performance in a specific task presented to a subject is influenced by a reference system based on previous experiences[13,15]. The chosen sport may have offered the athlete with better ability a load of previous experiences more adequate, so that the performance in tasks involving dynamic balance is improved. Acknowledging that the exercise of the sensory-motor development is stimulus-dependent, we highlight that while the sport training may improve the balance tasks performance, the specific training of balance tasks may possibly improve sport performance as well.

Finally, our findings point that more skilled athletes present postural responses more adequate in the balance recuperation and suggest that the training and the athlete's ability level may influence in the balance control performance.

Apart from the contribution the present study gives in the understanding of the balance control facing a perturbation in judoists, it presents limitations, though: 1) the applied perturbation occurs only in the posterior direction; 2) the sensory information is not analyzed during the experiment procedure; 3) the age gap analyzed is limited (young adults); 4) this study is limited to a segmented and reduced sample of individuals; 5) the analyzed posture dos not correspond to combat reality and 6) the experiment measurements are conducted in a laboratory environment. Thus, we suggest that the study may be improved using similar protocols, associating the visual and vestibular perturbation, as well as the adoption of postures that better represent the combat reality. The use of more challenging loads for the judoists may be seen in studies involving only athletes and may possibly detect more specifically differences among ability levels.

All the authors declared there is not any potential conflict of interests regarding this article.

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