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Ramadan Fasting Effects on Postural Control in the Elderly: A Comparison Between Fallers and Non-fallers

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Abstract Our purpose was to compare the effects of Ramadan fasting on postural control in elderly fallers and non-fallers. The protocol involved twenty-four healthy old volunteer males divided into two groups: fallers (mean age = 75.43 ± 5.26 years, weight = 67.25 ± 5.30 kg and height = 1.65 ± 0.02 m) and non-fallers (mean age = 72.3 ± 6.42 years, weight = 65.5 ± 6.15 kg and height = 1.64 ± 0.03 m). Participants performed a simple reaction time test (SRT) and a postural control protocol on four different occasions: one week before Ramadan (BR), during the second (SWR) and the fourth week (FWR) of Ramadan and three weeks after Ramadan (AR). Center of pressure (CoP) parameters [the CoP medial–lateral length (CoP_X), and the CoP antero-posterior length (CoP_Y)] were assessed using a force platform under two surface conditions: Firm surface and Foam surface. The results showed that Ramadan fasting influences similarly fallers and non-fallers. In fact, for both groups, the CoP_X and the CoP_Y values increased significantly during the SWR and the FWR compared to BR. These CoP parameters decreased

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significantly in the Firm surface conditions in the FWR. Moreover, the CoP parameters were significantly higher during the FWR and AR in comparison with BR in the Foam surface conditions. However, the amplitude of increase of the $CoP_{[X]}$ % and the $CoP_{[Y]}$ % ($\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ %) between BR and the SWR was significantly higher in the fallers than non-fallers. The SRT of elderly fallers and non-fallers was significantly higher in the SWR and in the FWR compared to BR. In conclusion, Ramadan fasting alters similarly postural control of elderly fallers and non-fallers, but the amplitude ($\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ %) of this alteration seems to be more pronounced in fallers than non-fallers. A probable beginning of adaptation occurs at the FWR. However, three weeks seems to be insufficient to recover postural control alterations due to Ramadan fasting in difficult sensory conditions in elderly fallers and non-fallers.

Introduction

Ramadan fasting is one of the five pillars of Islam observed annually by over one billion people worldwide (Al Wakeel et al. 2013). For a period of one month, healthy Muslims refrain from eating and drinking from dawn to sunset. The changes in meal and activity schedules induce chronobiological and metabolic modifications, also related to behavioral changes (Roky et al. 2003). Especially, a general delay in sleep time, a significant reduction in sleep duration and a partial sleep deprivation have been associated to Ramadan fasting (Laraqui et al. 2001; Taoudi et al. 1999; Roky et al. 2001). Moreover, the cognitive and psychomotor tests such as day time alertness (Roky et al. 2000), memory (Hakkou et al. 1994), reaction time and mood (Roky et al. 2000), as well as functional attention (El Moutawakil et al. 2007), are altered by Ramadan fasting.

Falls are the most common and lethal accidents that occur in the elderly population (Rothschild et al. 2000). Falls are a vicious circle since one-third of fallers developed a fear of falling complex (Vellas et al. 1997) which leads to a restriction of activities and a lower quality of life (Gill et al. 2008). Additionally, fall-related injuries constitute a serious public health problem associated with great financial costs and human suffering (CDC 2000). Although falls are multifactorial (Fuller 2000), postural instability is a main factor contributing to falls (Agmon et al. 2014). In fact, the postural control system deterioration due to aging can lead to balance dysfunction with mobility limitation and sever disability (Tinetti et al. 1988). Compared to non-fallers of the same age, elderly people with a history of falls use wider and faster movements to regulate their posture (Tinetti et al. 1988; Lord et al. 1991). It has been established that elderly adults who regularly fall show greater postural instability when confronted with a change in visual and proprioceptive conditions than elderly subjects who are not falling (Lazaro et al. 2011). Müjdeci et al. (2012) indicated that especially dynamic balance is negatively affected within the elderly individuals who are fallers. Furthermore, fallers have poorer visual acuity, proprioception and quadriceps strength (Lord et al. 1999). It is well known that many cognitive resources are required in postural control (Teasdale and Simoneau 2001). For elderly individuals, previous studies reported an increase in the attentional cost of posture control, even in relatively simple conditions (Lajoie et al. 1993). In this context, fallers showed significantly worse attentional capacities in term of reaction times when compared with non-fallers

(Lajoie et al. 2002). In addition, elderly fallers have been found to display specific executive and attention dysfunctions (Hausdorff et al. 2006).

Changes related to Ramadan fasting (i.e., partial sleep deprivation, slower reaction time, altered attention) could influence postural control. In fact, it has been established that motor control (Frey et al. 2004) and postural control (Liu et al. 2001) were affected by sleep deprivation with more pervasive effect in older than younger adults (Robillard et al. 2011). Based on all considerations mentioned above, the hypothesis of postural impairment in older adults especially fallers due to Ramadan fasting could be raised.

Recently, Souissi and colleagues (2013a, b) investigated the effect of Ramadan fasting on postural control of Judo athletes. Results of these studies proved that postural control was affected during the second week of Ramadan (SWR). Since aging process is widely associated with alterations in sensory, motor and cognitive functions (Parihar et al. 2013), the effect of Ramadan fasting on postural control could be more marked in the elderly. If these effects are observed, are they the same along this month? Are these effects differing between fallers and non-fallers? Based on Souissi and colleagues (2013b) finding, these negative effects of Ramadan observance disappeared 3 weeks after the end of this month. Thus, how much time is needed for elderly fallers and non-fallers to recover from postural control effects due to Ramadan fasting?

Therefore, this study aims to compare the effects of Ramadan fasting on postural control in elderly fallers and non-fallers to provide practical recommendations for safety fasting preventing both of them from fall risks.

Methods

Participants

After receiving a description of the benefits and the possible risks associated with the study, each participant signed a written informed consent prior to participation. Twenty-four older healthy sedentary males aged between 65 and 80 years participated in this study. Twelve (mean age $= 75.43 \pm 5.26$ years, weight $= 67.25 \pm 5.30$ kg and height $= 1.65 \pm 0.02$ m) of the participants have a history of at least two spontaneous and unexpected falls within a year constitute the faller group. The other twelve participants (mean age $= 72.3 \pm 6.42$ years, weight $= 65.5 \pm 6.15$ kg and height $= 1.64 \pm 0.03$ m) constitute the non-faller group. A fall was defined as an event during activities of daily living that resulted in a person coming to rest unintentionally on the ground or other lower level, and not the result of a major intrinsic event or overwhelming hazard (Lord et al. 1999). We excluded falls resulting from unavoidable environmental hazards such as a chair collapsing. Exclusion criteria for both groups were: serious visual impairments, pathology of the central nervous system, orthopedic disorders of the lower limbs and metabolic disorders. Three weeks before Ramadan, each participant (fallers and non-fallers) was required to complete a structured questionnaire with the following data: history of falls (circumstances, clinical outcome and consequences of falls), type of prescribed medication treatment, activities of daily living and fasting recommendation. A self-assessment questionnaire (the three first items) of sleep pattern (quantity and quality) and eating schedules (Zerguini et al. 2007) was completed too. Based on these assessments, a screening process was conducted to include in this study only participants who were healthy; could perform their daily activities by themselves; and have the same sociocultural level, eating schedules

(breakfast at 06:30 ± 1 h, lunch at 12:00 ± 1 h and dinner at 20:00 ± 1 h) and the number of sleep hours per night (sleep between 21:00 ± 1 h and 06:00 ± 1 h).

During and three weeks after Ramadan (AR), each selected participant was asked to continue this self-assessment questionnaire. During Ramadan, for all participants, the break of fasting was at 19:35 h; the night meal was between 22:00 and 24:00 h and the last meal called "Shour" was at 02:30 ± 30 min. None of them participated in any sporting activity. They maintained their normal activities of daily life throughout the study. They were non-smokers and did not consume nutritional supplements, caffeine, drugs or alcoholic beverages.

Experimental Design

The study was carried out before, during and after Ramadan in 2015 when Ramadan started on the 18th of June to the 17th of July. The elapsed time from sunrise to sunset was from 3:06 to 19:35 h at the beginning and from 3:23 to 19:33 h at the end of Ramadan. The length of each daytime fast was approximately 17 h. Participants reported to the laboratory on 5 separate occasions. All the participants were familiarized with the experimental protocol in order to minimize the learning effect one week before the experiment. The other periods took place one week before Ramadan (BR), during the SWR and the fourth week of Ramadan (FWR) and after 3 weeks of Ramadan (AR). In each testing period, participants performed a simple reaction time (SRT) test, then after 1 min of rest, they performed the postural balance protocol. All test sessions were made at 17:00 h.

Simple Reaction Time Measurements

Attentional capacities were evaluated by a SRT test using a "Superlab 4.5" program (Cedrus, San Pedro, USA). It measures the reaction time to visual stimuli. The participant was asked to sit 0.4–0.5 m in front of the computer screen. After 10 familiarization trials, each participant performed randomly and double-blinded 20 SRT tests. The stimulus was a black square, presented for 50 ms at the center of the screen. The interval between the appearances of two consecutive stimuli was randomized (average 1.5 s). After a training trial, participant presses a specific computer key as quickly as possible after the appearance of the black square. The score is established by evaluating the mean reaction time for the correct answers.

Postural Control Assessments

These assessments were performed while participants stood on a static stabilometric platform (PostureWin©, Techno Concept®, Cereste, France; 40 Hz frequency, 12-bits A/D conversion) that recorded center of pressure (CoP) motions. Participants were asked to stand on bipedal posture while barefoot on the force platform with their arms along the body. They were tested under two surface conditions: Firm surface and Foam surface [a Foam block (466 mm length × 467 mm width × 134 mm height above ground) with a density of 21.3 kg/m^3 and an elastic modulus of 20.900 N/m^2]. In each surface condition, participants were tested under two eyes conditions. In the eyes open (EO) condition, participants were instructed to keep their gaze horizontal in a visual target positioned 2 m away. In the eyes closed (EC) condition, they were asked to keep their gaze straight-ahead. For each condition, three trials were performed resulting in a total of 12 trials per

participant. Following French Posturology Association norms, the duration of each trial was 25.6 s followed by 30 s of rest to cancel fatigue effect. During the recording session, the experimenter stayed near the participant for security without adducing additional directions. All experiments were assessed by the same examiner.

In this study, the length X (CoP_X) and the length Y (CoP_Y) corresponding to the sum of the CoP displacement scalars in the medial–lateral (ML) and antero-posterior (AP) directions, respectively, were calculated as CoP parameters to evaluate the participant's postural control. These parameters were averaged for the three trials conditions and per participant in order to obtain a representative measure of the postural balance. The best postural balance is for the lower values of these parameters.

Statistical Analyses

All data are presented as mean ± SD and were analyzed by the Statistica for Windows software (version 6.0; StatSoft, Inc, Tulsa, OK). Data distribution normality was confirmed with the Shapiro–Wilk W test. The CoP data were analyzed using a four-way repeated measures analysis of variance (ANOVA) [2 groups × 4 periods × 2 surfaces × 2 visions].

The change of CoP parameters between the SWR and BR was evaluated in both groups by calculating Delta $CoP_{[X]}$ % and Delta $CoP_{[Y]}$ % as: $\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ % = 100*(SWR − BR)/BR.

A three-way ANOVA with repeated measures (2 groups × 2 surfaces × 2 visions) was used to compare the $\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ % between the two groups.

For the SRT scores, a two-way ANOVA (2 groups × 4 periods) was performed to compare the SRT values.

When appropriate, significant differences between means were tested using the Fisher–Snedecor least significant difference (LSD) post hoc test. The level of significance for all statistical analyses was set at $P < 0.05$.

Results

Simple Reaction Time Scores

The two-way ANOVA showed a significant period ($P < 0.001$) effect on the SRT scores. Post hoc analysis indicated that the SRT values increased significantly for both groups during the SWR ($P < 0.001$) and the FWR ($P < 0.05$) in comparison with those observed

Table 1 Mean values and standard deviation (SD) of the mean simple reaction time (SRT) before Ramadan (BR), during the second (SWR) and the fourth (FWR) week of Ramadan and three weeks after Ramadan (AR) in the fallers and the non-fallers

| | SRT (ms) ± (SD) | | | |
	BR	SWR	FWR	AR
Fallers	468 ± (48)	567 ± (74)	533 ± (89)	445 ± (66)
Non-fallers	434 ± (49)	532 ± (65)	512 ± (54)	422 ± (46)

BR (Table 1). No significant difference was found between the SRT values recorded BR and those recorded AR. Moreover, no significant difference was revealed in the SRT scores between fallers and non-fallers during all periods.

Postural Control Results

The four-way ANOVA (2 groups × 3 periods × 2 surfaces × 2 visions) showed main significant effects of group, periods, surface and vision. Moreover, this ANOVA showed significant period × surface, group × vision, period × vision and surface × vision interactions on the CoP_X and the CoP_Y. However, no significant surface × group and group × period interactions was revealed (Table 2).

For the faller group, concerning the effect of period, post hoc analyses showed significant higher values of CoP parameters during the SWR than BR in all postural conditions (Firm/EO and Firm/EC: $P < 0.01$; Foam/EO and Foam/EC: $P < 0.001$). No significant difference was observed in the CoP parameters in the Firm surface conditions between BR and the FWR. However, these parameters were significantly ($P < 0.001$) higher in the FWR compared to BR in the Foam surface conditions. In addition, CoP parameters were significantly (CoP_X: $P < 0.01$; CoP_Y: $P < 0.001$) higher in the Foam surface conditions AR compared to BR (Figs. 1, 2). Concerning the effect of vision, post hoc analysis showed that the vision suppression increased the CoP parameters significantly in the Firm ($P < 0.01$) and in the Foam ($P < 0.001$) surface conditions in all periods. Regarding the effect of surface, the post hoc test indicated that, irrespective to the period and the vision conditions, standing on a Foam surface ($P < 0.01$) increased the CoP parameters significantly (Figs. 1, 2).

Table 2 A summary of the statistical analyses results

CoP parameters	CoP_X F, P	CoP_Y F, P
Group	309.02, <.001	17.02, <.01
Period	71.07, <.001	23.95, <.001
Surface	846.3, <.001	505.67, <.001
Vision	287. 9, <.001	467. 5, <.001
Group*period	NS	NS
Group*surface	NS	NS
Period*surface	8.67, <.001	12.65, <.001
Group*vision	18.96, <.01	27.54, <.001
Period*vision	3.05, <.05	4.9, <.05
Surface*vision	82.65, <.001	63.04, <.001
Group*period*surface	NS	NS
Group*period*vision	NS	NS
Group*surface*vision	11.5, <.001	NS
Period*surface*vision	NS	NS
ΔCoP %	$ΔCoP_{[X]}$ %	$ΔCoP_{[Y]}$ %
Group	5.22, <0.05	77.27, <0.001
Surface	21.65, <0.001	41.59, <0.001
Vision	NS	NS

F and P values are indicated for significant main effects and interactions of group, period, surface and vision as appropriate and are marked NS where not significant
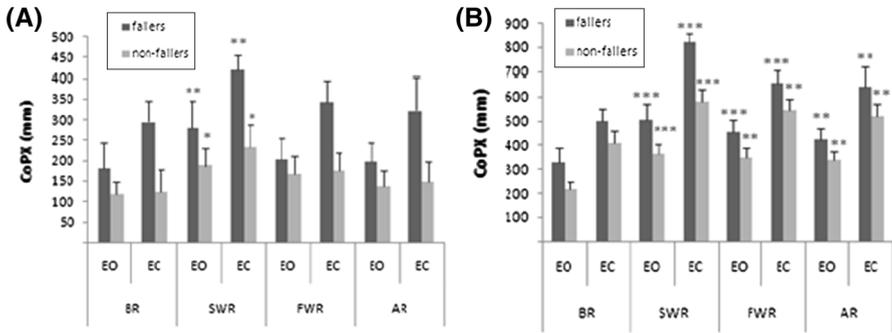
Fig. 1 Mean values and standard deviations of the center of pressure medio-lateral length (CoP_X) in the Firm (**a**) and in the Foam (**b**) surface conditions, in both visual conditions (*EO* eyes open, *EC* eyes closed) and during the four testing phases (*BR* before Ramadan, *SWR* the second week of Ramadan, *FWR* the fourth week of Ramadan, *AR* 3 weeks after Ramadan) in fallers and non-fallers. *Significant difference in comparison between BR/SWR at $P < 0.05$. **Significant difference in comparison between BR/SWR, BR/FWR and BR/AR at $P < 0.01$. ***Significant difference in comparison between BR/SWR and BR/FWR at $P < 0.001$
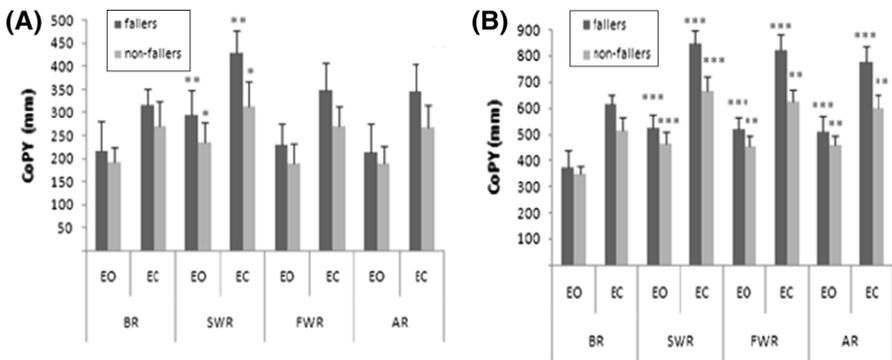

Fig. 2 Mean values and standard deviations of the center of pressure antero-posterior length (CoP_Y) in the Firm (**a**) and in the Foam (**b**) surface conditions, in both visual conditions (*EO* eyes open, *EC* eyes closed) and during the four testing phases (*BR* before Ramadan, *SWR* the second week of Ramadan, *FWR* the fourth week of Ramadan, *AR* 3 weeks after Ramadan) in fallers and non-fallers. *Significant difference in comparison between BR/SWR at $P < 0.05$. **Significant difference in comparison between BR/SWR, BR/FWR and BR/AR at $P < 0.01$. ***Significant difference in comparison between BR/SWR, BR/FWR and BR/AR at $P < 0.001$

For the non-faller group, the CoP parameters increased significantly between BR and during the SWR in the Firm ($P < 0.05$) and in the Foam ($P < 0.001$) surface conditions. In the Foam conditions, the CoP parameters were significantly ($P < 0.01$) higher during the FWR compared to BR. These parameters remain significantly ($P < 0.01$) higher AR in comparison to BR in these conditions (Figs. 1, 2). Regarding the effect of vision, post hoc analyses proved that the vision remove increased significantly ($P < 0.01$) the CoP parameters in the Foam surface conditions in all periods (Figs. 1, 2).

Concerning the effect of group, the post hoc analyses showed that fallers had significantly higher values of CoP parameters BR [CoP_X (Firm surface/EC and Foam surface/EO: $P < 0.001$, Foam surface/EC: $P < 0.01$); CoP_Y (Firm surface/EC and Foam surface/EC:

$P < 0.05$)] during the SWR [CoP_X (Firm surface/EO and Firm surface/EC: $P < 0.01$, Foam surface/EO and Foam surface/EC: $P < 0.001$); CoP_Y (Firm surface/EC and Foam surface/EC: $P < 0.001$)], the FWR [CoP_X (Firm surface/EC and Foam surface/EC: $P < 0.001$, Foam surface/EO: $P < 0.05$); CoP_Y (Firm surface/EC: $P < 0.05$, Foam surface/EC: $P < 0.001$)] and AR [CoP_X (Foam surface/EO: $P < 0.05$, Firm surface/EC and Foam surface/EC: $P < 0.001$); CoP_Y (Firm surface/EC: $P < 0.05$, Foam surface/EC: $P < 0.001$)] compared with non-fallers.

Delta $CoP_{[X]}$ % and $CoP_{[Y]}$ % Results

The two-way ANOVA results showed main significant effects of group and surface on the $\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ % (Table 2). The post hoc test indicated that $\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ % were significantly higher for the faller group than the non-faller one. Moreover, for both fallers and non-fallers, $\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ % were significantly higher in the Foam surfaces than in the Firm surfaces (Table 3).

Discussion

Falls are a leading cause of injury and death among older adults and a significant public health issue (Tinetti 2003). The ability to identify the risk of future falls is needed in order to target high-risk individuals for preventive strategies (Melzer et al. 2004). The aim of the present study was to compare the effect of Ramadan fasting on postural control in elderly fallers and non-fallers.

The main result of this study showed that postural control was altered by Ramadan observance in both groups. Similarly, Souissi and colleagues (2013a, b) proved that Ramadan fasting impaired the static and the dynamic postural control of Judo athletes. Postural control impairments may be due to the lifestyle disturbances that characterize this

Table 3 Mean values and standard deviations (SD) of the amplitude of the center of pressure medial–lateral and antero-posterior length increases ($\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ %) between the second week of Ramadan (SWR) and before Ramadan (BR) in the fallers and the non-fallers

| | | Group (m ± SD) | | Post hoc statistical analyses | | |
| | | Fallers | Non-fallers | Group factor (fallers/non-fallers) | Surface factor (Firm/Foam) | |
					Fallers	Non-fallers
$\Delta CoP_{[X]}$ %	EO Firm	43.2 % ± 8.6	33 % ± 4.5	$P < 0.05$	$P < 0.01$	$P < 0.01$
	EO Foam	55.9 % ± 9.3	51.55 % ± 12	NS		
	EC Firm	45.4 % ± 7.5	38.48 % ± 6.8	NS	$P < 0.001$	$P < 0.05$
	EC Foam	61.44 % ± 11.4	47.7 % ± 9.2	$P < 0.01$		
$\Delta CoP_{[Y]}$ %	EO Firm	34.1 % ± 7.2	20.8 % ± 3.9	$P < 0.01$	NS	$P < 0.01$
	EO Foam	42 % ± 8.9	33.69 % ± 4.6	NS		
	EC Firm	37.3 % ± 4.4	18.5 % ± 3	$P < 0.01$	$P < 0.05$	$P < 0.01$
	EC Foam	46.95 % ± 9.1	35 % ± 6.2	$P < 0.05$		

CoP center of pressure, *CoPx* medial–lateral length, *CoPy* antero-posterior length, *NS* nonsignificant

month. In fact, Ramadan fasting displacement in energy intake and hydration to the hours of darkness reverses the normal circadian pattern of eating and drinking (Waterhouse 2010). These eating patterns plus more activities at night impacts core body temperature and sleep (Herrera Christopher et al. 2015). In fact, a general delay in sleep time, a substantial reduction in sleep duration and a partial sleep deprivation have been reported during this month (Laraqui et al. 2001, Taoudi et al. 1999). Based on the self-assessment questionnaire, the sleep duration of our participants was reduced (the average sleep loss between BR and the four weeks of Ramadan was $02:00 \pm 00:15$ h) because they were consuming food later at night and their sleep quality was poorer than BR because the sleep cycle is disrupted to accommodate food intake (Zerguini et al. 2007). In fact, to prepare for the period of fasting during Ramadan, our participants woke up earlier and ate a meal before sunrise. As a result, they could have been suffering from the effects of partial sleep deprivation (Waterhouse et al. 2009).

On the other hand, several studies demonstrated that sleep deprivation has many effects on the human body, such as increased lapses in concentration, cognitive slowing, decreased vigilance and attention and memory impairment (Patel et al. 2008; Shu et al. 1997). Importantly, sleep deprivation impairs postural control and these impairments are more pronounced in the elderly (Robillard et al. 2011).

In this study the SRT of both groups were altered during the SWR and the FWR. Various factors may affect cognitive performance including lifestyle changes, sleep disturbance, temperature, and composition and schedule of meals (Leigh Gibson and Green 2002; Lieberman et al. 2005; Bahammam et al. 2013). Participants of our study practiced the fast during the summer with relatively high environmental (30°–31°) temperature and long hours spent on fasting (17 h) which could lead to dehydration associated with poorer attention and memory in older adults (Suhr et al. 2004). It has been also established that cognitive performance of young adults was impaired by fasting during Ramadan. In fact, subjective alertness, memory, reaction time and functional attention are adversely altered during Ramadan (Roky et al. 2000; Hakkou et al. 1994; El Moutawakil et al. 2007). These Ramadan fasting changes may explain our findings since postural control needs significant attentional demands in the elderly (Lajoie et al. 1993).

Even though Ramadan fasting affects similarly postural control of fallers and non-fallers (no significant interaction period × group), this effect was more marked in fallers compared to non-fallers as indicated by the greater positive $\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ % between the SWR and BR in the faller group. This higher CoP parameters increase in fallers could be due to the fact that these individuals suffer from increased postural balance impairments at baseline (BR) (Lajoie et al. 2002). It seems that this preexisting difference in the postural control impairment observed in fallers was excessively accentuated by Ramadan observance.

Importantly, for both groups, postural instability decreased significantly in the Firm surface conditions during the FWR compared to BR. This finding suggests a probable beginning of body physiological adaptation at the FWR of Ramadan. In young adults, a subjective alertness decrease has been found only at the beginning of Ramadan suggesting an adaptation mechanism to Ramadan fasting (Lagarde et al. 1996). Nevertheless, our data showed that in the Foam surface conditions, the CoP parameters remain higher during the FWR in comparison with BR for both groups. In these conditions, CoP parameters decreased slightly AR but did not return to their baseline values. This may be due to the greater postural impairment ($\Delta CoP_{[X]}$ % and $\Delta CoP_{[Y]}$ %) between BR and the SWR in the Foam surface conditions. Attentional capacities impairment found in our study in the FWR could explain the fact that CoP parameters did not recover their baseline values in the

FWR. In fact, postural control needs significant attentional demands that vary depending on the postural task, the age of the individuals and their balance abilities (Woollacott and Shumway-Cook 2002). It is known that as the sensory information decreased, the postural task became increasingly difficult for the elderly and required more of their attentional capacity (Woollacott and Shumway-Cook 2002). However, even thought SRT did recover their baseline values 3 weeks after Ramadan, CoP parameters did not. Probably, there are other cognitive capacities (i. e, memory, executive function) required for postural control (Borel and Alescio-Lautier 2014) that did not recover. Racinais and colleagues (2012) demonstrated that Ramadan may have residual effects on the way that people organize their daily activities during the month following Ramadan. In a previous study, it has been indicated that dynamic postural control of Judo athletes returns to the same pattern 3 weeks after Ramadan (Souissi et al. 2013b). Elderly people seem to be less flexible and adaptive than younger people (Canavan et al. 1993) and do not adapt optimally to changing internal and external conditions (Mulder et al. 2002). Therefore, more than three weeks seems to be needed for elderly fallers and non-fallers to recover postural control alterations due to Ramadan fasting in difficult sensory conditions.

Since postural control system can be influenced by multiple factors (Robillard et al. 2011), identifying the conditions that modulate the effect of Ramadan fasting on postural control could provide empirical evidence for prevention strategies. Significant interactions period × vision and period × surface were revealed in this study. Thus, altering visual and/or proprioceptive inputs amplifies the postural instability induced by Ramadan fasting in both groups. Therefore, in the elderly, the risk of falls may be greater during Ramadan when the visual and/or proprioceptive environment is complex (i.e., Foam surface, dark or when visual aids, such as glasses, are not worn).

Concerning the effect of group, the current data indicated that elderly adults who regularly fall show greater postural sways in all testing periods than elderly subjects who are not so prone to falling. Several hypotheses could explain this difference considering that posture regulation is multifaceted (Lajoie et al. 2002). These differences could be attributable to problems adapting to environmental aspects in fallers (Tinetti and Speechley 1989). Menz and Lord (2001) found that subjects with a history of multiple falls had a significantly greater foot problem than did non-fallers. Fallers also had poorer visual acuity, proprioception and quadriceps strength (Lord et al. 1999).

Significant vision × group interaction was observed in the present study. In fact, suppression of vision increased significantly the CoP parameters even in the Firm surface for fallers. This result suggests that elderly fallers may be less able to compensate for the loss of visual input through reweighing vestibular and somatosensory information (Melzer et al. 2010). Lord and Webster (1990) claimed that the greater dependence on visual information shown by fallers might be the result of reduced proprioceptive and vestibular function resulting from increased age and chronic health problems.

Practical Recommendations

Fasting during Ramadan is one of the five pillars of Islam and mandatory for all healthy Muslim older adults. It is well known that Ramadan fasting is a healthy non-pharmacological means for improving the overall health of the individuals (Meo and Hassan 2015). However, elderly people especially fallers may be at great risk of falls during Ramadan. Therefore, the education concerning fasting during the holy month of Ramadan is essential, and physicians and health educators must play a key role of a mentor (Meo and Hassan 2015). Since postural sways decreased in the FWR, a pre-Ramadan fasting exercise

consisting of changes in meals and sleep habits is recommended. Such training is essential in order to promote adaptation and probably minimize the effect of fasting on postural control. Moreover, older adults are encouraged to maintain a healthy lifestyle practice during this month in term of sleep quality and quantity which could approximate Ramadan condition. Elderly people should be careful and avoid complex and inadequate environment (Foam surfaces, dark) during this month and even three weeks after. In order to investigate Ramadan fasting effect on postural control, sensory input manipulation should be considered.

Limitations

This study has some limitations that need to be considered. First, we didn't use a control group who did not fast because non-fasting Muslims people do no avow themselves as non-fasting. Furthermore, it would be better to assess the quantity and quality of food ingested BR and after the sunset during Ramadan in the attempt to find other possible explanations to our findings. Finally, postural control evaluation one month after Ramadan seems to be required to determine how much time is needed for fallers and for non-fallers to recover postural control impairment due to Ramadan fasting in difficult sensory conditions.

Conclusion

In conclusion, this study demonstrated that Ramadan fasting alters similarly postural control of elderly fallers and non-fallers, but the amplitude ($\Delta CoP_{[X]}$ %, $\Delta CoP_{[X]}$ %) of this alteration seems to be more pronounced in fallers than non-fallers especially between the SWR and BR. Although these alterations decreased in the FWR, more than three weeks are needed to recover postural control alterations due to Ramadan fasting in elderly fallers and non-fallers in difficult sensory conditions.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and Animal Rights Statement This study involved human participants.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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