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Rita Canaipa , Diogo Mendonça , Mariana Agostinho ,
Vanda Nascimento , Liat Honigman , Roi Treister

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A short running title: Variability of pain reports in dancers vs. controls

En pointe: dancers report their pain less variably than do controls

Rita Canaipa*^a, Diogo Mendonça*^b, Mariana Agostinho^b, Vanda Nascimento^c, Liat Honigman^d,
Roi Treister^d

^a CIIS, Centre for Interdisciplinary Health Research, Institute of Health Sciences, Catholic University of, Palma de Cima, 1649-023 Lisbon, Portugal;

^b Institute of Health Sciences, Catholic University of Portugal, Palma de Cima, 1649-023 Lisbon, Portugal;

^c Higher School of Dance, Lisbon Polytechnic, Campus do ISEL, Rua Conselheiro Emídio Navarro, 1, 1959-007 Lisbon, Portugal;

^d The Clinical Pain Innovation Lab, The Cheryl Spencer Department of Nursing, Faculty of Social Welfare and Health Sciences, University of Haifa, 199 Aba Khoushy Ave., Mount Carmel, Haifa, Israel

*Equal contribution

Corresponding author: Roi Treister, PhD.

University of Haifa, 199 Aba Khoushy Ave. Mount Carmel, Haifa, Israel.

Tel: 972-533-839935; Fax: 972-4-9529926; E-mail: tresiter.roi@gmail.com

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Highlights

- Dancers demonstrate improved interoception as compared with the general population.
- We compared variability of pain and taste reports in dancers and controls.
- Dancers demonstrated less variability of pain, but not of taste, intensity reports.
- The longer a dancer was trained, the less pain variability was observed.
- Training could reduce pain variability, and potentially improve its assessment.

Abstract

The subjective nature of pain and the lack of a gold standard for objective measurement hinders effective assessment, diagnosis, and treatment. Some individuals, such as professional dancers, are better in assessing and reporting bodily sensations. This observational study aimed to assess whether dancers report their pain less variably, than other people do.

After consenting, subjects completed the Focused Analgesia Selection Task (FAST), which assesses subjects' variability of pain reports. FAST outcomes, ICC and R^2 reflect the magnitude of variability of pain reports observed. In addition, subjects underwent a taste task, which similarly assesses variability of tastes (salty and sweet) intensity reports and completed the Multidimensional Assessment of Interoceptive Awareness (MAIA) questionnaire.

Thirty-three professional dancers and thirty-three healthy aged-matched controls were recruited. The dancers exhibited less variability of pain reports than controls ($P=0.013$), but not in case of tastes-reports. Years of practice was positively correlated with pain reporting variability ($r=0.447$, $P=0.009$, and $r=0.380$, $P=0.029$; for FAST ICC and R^2 , respectively). MAIA sub-scores correlated with pain reporting variability: R^2 and ICC with emotional awareness ($r=0.260$, $P=0.040$, and $r=0.274$, $P=0.030$, respectively), and R^2 with trusting [$r=0.254$, $P=0.044$].

Perspective

The difference between dancers and controls in the magnitude of variability of pain reports is probably due to the dancers' extensive training, which focuses on attention to body signals. Our results suggest that training can improve subjective pain reports, which are essential for quality clinical care.

Key words – Pain intensity, pain assessment, pain variability, interoception, athletes,

Introduction

The perception of pain derives from complex processes modulated at both spinal and super-spinal levels of the central nervous system. Its subjective nature and lack of a gold standard for objective markers impede accurate assessment and diagnosis, communication between patients and healthcare providers, and clinical care. Identifying factors affecting the variability of pain, and how the latter could be modulated, is of importance.

We recently developed the Focused Analgesia Selection Test (FAST) to assess how variable patients are in reporting their pain. The FAST is based on subjects' pain responses to noxious stimuli of various intensities, each stimulus intensity is repeated multiple times, in random and blinded manner. This paradigm allows to assess the variability of patients' responses of both one intensity (within-stimulus) and different intensities (between stimuli). Results from several studies showed that subjects' ability to perform in the FAST varies among people (i.e. some show large variability, while others show small variability) and that this characteristic is clinically relevant. After exercise involving their affected joints, patients with osteoarthritis of the knee who perform well in the FAST reported worse knee pain, as expected; those who perform poorly in the FAST reported no change or even improvement in their knee pain⁴¹. In another study, patients' pain-reporting variability correlated with their day-to-day fluctuations in clinical pain⁴². Although subjects' tendency to demonstrate low variability in the FAST is clinically relevant, our understanding of the mechanisms underlying this ability is limited.

Unlike pain assessment, interoception has been intensively investigated. Interoception is currently defined as "the sense of the physiological condition of the entire body"^{8,10}. It can be assessed with several methods, including the Multidimensional Assessment of Interoceptive Awareness (MAIA) questionnaire. Garfinkel (2015) proposed a three-domain terminology for interoception: (1) *interoceptive accuracy*, the ability to perceive internal (bodily) signals using

objective measures; (2) *interoceptive sensibility*, the subjective, self-reported measure of interoception, assessed via questionnaires such as MAIA; and (3) *interoceptive awareness*, the metacognitive awareness of interoceptive accuracy²¹. In a recent study, we evaluated whether pain-reporting variability is related to interoceptive accuracy, as assessed by the heartbeat detection task³⁶ and to the variability of tastes intensity reports. Our results suggest that variability in reporting sensations cannot be generalized across modalities¹. For the latter study, we developed and used a taste paradigm based on the FAST and designed to assess subjects' variability in reporting intensities of salty and sweet tastes.

To shed more light on this topic, we decided to compare pain-reporting variability in groups that were suggested to be more interoceptive than the general population. As recently shown by Christensen, Gaigg and Calvo-Merino (2018)⁹, professional dancers are more interoceptive, as assessed by the heartbeat detection task, than is the general population. Furthermore, the more experienced the dancer, the better his/her interoception. Like other professional athletes, dancers are also known to be less pain sensitive, as demonstrated by higher pain thresholds and longer tolerance to experimental pain^{38,40}.

The current study aimed to compare interoceptive sensibility, and pain and tastes reporting variability in dancers and non-dancer controls. We expected dancers to show better interoceptive awareness and lower sensitivity to pain. Our hypothesis was that dancers would report pain less variably than would controls and that dancers and controls would show no differences in their taste intensity reporting variability.

Methods

Subjects

The study sample included undergraduate and graduate dance students who were recruited from the Higher School of Dance of Lisbon (Escola Superior de Dança do Instituto Superior Politécnico de

Lisboa). To compare the pain-reporting accuracy and interoceptive awareness parameters between dancers and non-dancers, we used data of age- and gender-matched control subjects that was collected as part of a recently completed research project conducted by us in the same lab using the same tools and protocols¹. The ethical committee of the Institute of Health Sciences, Catholic University of Portugal, approved the study protocol in accordance with the Helsinki Declaration. Participants who agreed to participate and met eligibility criteria provided written informed consent. Participants enrolled in the study after meeting the following criteria: (1) age above 18; (2) absence of acute or chronic pain condition at the time of evaluation; (3) absence of psychiatry, cognitive, and/or neurological disorders; and (4) no chronic use of medications except for oral contraceptives.

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Power calculation was performed using G*Power (version 3.1.9.4). Based on an alpha of 0.05, power of 0.8, effect size of 0.65 and allocation ration of 1, 60 subjects (30 in each group) are needed to detect significant differences between groups.

Instruments and procedures

The Focused Analgesia Selection Test (FAST)

FAST is an instrument designed to assess pain-reporting skills in response to thermal noxious stimuli of varying intensities applied to the ventral surface of the subject's non-dominant forearm⁴¹. The procedure utilizes the Medoc® Thermal Sensory Analyzer II with a Peltier element-based thermode (30 x 30 mm²). The subject rates the pain intensity of each stimulus on a 0-100 numerical rating scale (NRS), in which 0 indicates "no pain" and 100 "the worst pain imaginable." Baseline temperature was 32°C, from which the stimulus increase to a 3-second peak, at 1 out of 7 predetermined temperatures (44, 45, 46, 47, 48, 49, or 50°C), and thereafter returning back to baseline, with a total stimulus duration of 8 seconds and inter-stimulus intervals (ISI) of 15 seconds. Each temperature was repeated 7 times in a random block-ordered design (total of 49 stimuli). The

location of the thermode was adjusted every 10 stimuli to minimize sensitization and/or habituation effects. Total FAST procedure length was approximately 20 minutes.

The two FAST outcome measures, the R^2 and the Interclass correlation coefficient (ICC), allow to quantify variability of pain reports. The R^2 is calculated by means of power model regression. It measures agreement (or correspondence) between actual and predicted scores. Higher R^2 scores mean less variability and vice versa. The Interclass correlation coefficient (ICC) is calculated using a 2-way mixed model for the 7 presentations of each of the 7 stimuli intensities, thus measuring the agreement or consistency in responses to the same stimulus over several presentations independent of their order. Higher ICC values denote lower variability.

Taste Perception Task

The taste perception task in this study is a modified version of Hendi and Leshem²⁴ procedure, which originally was developed to assess the sensitivity to salty and sweet tastes. Unlike the original version, our version was modified to replicate the FAST, so the within-subjects' variability of tastes intensity reports could be assessed. Participants were instructed to avoid eating, drinking (except water), and smoking 2 hours before the test. During the task, the experimenter sprayed each solution into the participant's mouth and asked him/her to grade the intensity of each of 5 different solution concentrations. The volume of each spray was 0.29cc²⁷, and subjects washed their mouth with fresh mineral water in between each application of the spray. There were 5 repetitions for each concentration (a total of 25 repeats for each taste), administered in a randomized order (excluding sequential concentrations); and subjects were randomly assigned to start with either salty or sweet taste series, followed by the other taste. For each of the taste concentrations, participants were asked to indicate how strong the taste was, on an NRS ranging from 0, "not feeling," to 100, "most strong." The taste outcome measures, calculated in the same manner as the FAST, were R^2 , and ICC, reflecting the magnitude of within-subjects variability of taste reports. Concentrations of the sweet solutions (ranging from low to high) were 0.03 M, 0.09 M, 0.26 M, 0.39 M, and 0.79 M. The salt

solution concentrations were 0.09 M, 0.28 M, 0.85 M, 1.71 M, and 2.56 M. These concentrations were identical to those used by Agostinho et al. (2019) ¹.

Psychological Questionnaires

Multidimensional Assessment of Interoceptive Sensibility

Interoceptive sensibility was assessed via the Portuguese version ²⁸ of the Multidimensional Assessment of Interoceptive Awareness (MAIA) ³⁰. The questionnaire aims to distinguish beneficial from maladaptive interoception attention. The Portuguese version of the MAIA questionnaire includes 33 items, 1 more item than the original MAIA, and is divided into 7 subscales: (1) *noticing*, awareness of one's body sensations (3 items); (2) *not-distracting*, the tendency not to ignore or distract oneself from sensations of pain or discomfort (4 items); (3) *not-worrying*, the tendency not to experience emotional distress or worry with sensations of pain or discomfort (4 items); (4) *attention regulation*, the ability to sustain and control attention to body sensations (7 items); (5) *emotional awareness*, awareness of the connection between body sensations and emotional states (5 items); (6) *self-regulation*, the ability to regulate psychological distress by attention to body sensations (7 items); and (7) *trusting*, the experience of one's body as safe and trustworthy (3 items). All 33 items are answered on a 6-point Likert scale, ranging from 0 ("never") to 5 ("always"). Higher subscale scores indicate higher levels of positive awareness.

Experimental protocol

Experiments were conducted in the same setting at the school of dance (for dancers) and at university, and the Neuroser clinic for non-dancers, between November 2018 to January 2019. The study began with a short training in which subjects were familiarized with the devices, sensations, and rating scales. After the familiarization stage, we conducted the FAST procedure. Thereafter, we familiarized the subjects with the taste perception task and conducted this procedure. Participants

filled in the MAIA in the break between the applications of two tastes. Altogether, the procedures took approximately 1.5 hours for each participant.

Statistical Analyses

Data were processed by Excel (Microsoft Corp, Redmond, WA, USA), and analyzed by SPSS software version 23 (SPSS, Inc., Chicago, IL, USA). Descriptive statistics were used to present demographic and baseline characteristics. FAST outcome measures and questionnaires were assessed for normality using the Shapiro-Wilk test. The nonparametric Mann-Whitney test compared the FAST, taste and MAIA questionnaire outcomes between the two groups of dancers and controls. Spearman correlation analyses were employed to explore possible associations between the FAST outcomes, taste outcomes, questionnaire results and specific features of the dancer group for the whole sample as well as for the specific 2 groups. Friedman test was used to investigate habituation effects. The process macro function (of the SPSS) was used to assess the potential of pain sensitivity as a moderator or a mediator of the relations between pain reporting variability and groups. Data were expressed as means \pm SD or as percentages. Statistical significance was defined as $P \leq 0.05$.

Results

Participants' Characteristics

The study sample included 33 dancers (26 women and 7 men) and 33 aged-matched controls (healthy volunteers, 26 women and 7 men) ranging in age from 18 to 25 (mean \pm SD = 19.89; SD=1.91). Demographic data is presented in Table 1. The only significant difference between groups was found in education; dancers were more educated than controls ($P=0.027$, Mann-Whitney). Subjects in the dancers group practiced dancing 11.1 ± 3.83 years on average, ranging from 3 to 18 years.

Results of the FAST procedure

Mean pain intensities for the entire study population reported in response to each of the 7 stimuli intensities are presented in Figure 1. Mean \pm SD responses ranged from 14.97 ± 16.6 for the lowest stimulus intensity (44°C) to 62.06 ± 25.0 for the highest stimulus intensity (50°C). Mean pain scores significantly differed from each other (Friedman's test, chi-square 330.16; $P < 0.001$). Post hoc Wilcoxon test revealed significant differences between all stimuli intensities ($P < 0.003$). When comparing dancers and healthy controls, significant differences were observed in mean pain scores in stimuli intensities of 44, 45, 46, 47, 48°C (7.04 ± 5.8 vs. 23.40 ± 19.9 , 10.85 ± 8.5 vs. 23.78 ± 20.9 , 14.13 ± 9.3 vs. 32.28 ± 23.6 , 19.56 ± 13.0 vs. 35.51 ± 23.9 , and 27.63 ± 16.4 vs. 41.47 ± 23.5 , Mann-Whitney $P = 0.00$, $P = 0.006$, $P = 0.001$, $P = 0.006$, $P = 0.015$, respectively). There was no significant difference between dancers and healthy controls at the highest stimuli intensities (49°C and 50°C , $P > 0.05$). These results imply that dancers are less sensitive to noxious stimuli than healthy subjects. The mean pain intensity for all stimuli together (44°C – 50°C) for the entire study population was 32.45 ± 18.5 . A significant difference was observed between dancers and healthy controls in the mean pain intensity score for all stimuli together (25.91 ± 12.6 vs. 39.41 ± 21.3 ; Mann-Whitney $P = 0.009$), results which further support that dancers are less sensitive than healthy subjects. To further investigate sensitivity to pain in response to each stimulus intensity, and to assess possible carry-over effects, additional analyses were performed (see Supplementary figures S1 & S2). The results showed that in the entire group, habituation (i.e. reduced sensitivity in response to repeated administration of the same stimulus intensity) was seen in the lower and mid-range intensities (44 – 48°C), but not in the higher intensities. When assessing it separately for each group, it was found that habituation was seen in the dancers, but not in the controls (excluding one temperature, 48°C), which could explain, at least partly, their lower overall pain sensitivity.

The R^2 and ICC values were widely distributed, suggesting that subjects varied in the magnitude of variability of pain scores. R^2 for the whole group had a mean of 0.56 (range 0.01–0.81), and ICC

with mean of 0.64 (range 0.08–0.87). A significant difference was found between dancers and controls in the FAST ICC outcome measure (0.69 ± 0.1 vs. 0.60 ± 0.18 , $P=0.013$), and a trend in the FAST R^2 outcome measure (0.59 ± 0.11 vs. 0.53 ± 0.17 , $P=0.095$) (Fig. 2). Such differences reflects that dancers demonstrated less pain reports variability than controls. There were no correlations between sensitivity to pain, as assessed by the mean of all stimuli, and the FAST outcomes (ICC and R^2) in either groups ($P>0.05$ for all), suggesting that the differences in FAST outcomes between the groups are not due to differences in sensitivity to pain. In addition, sensitivity to pain was not a mediator or moderator (using process macro function of the SPSS) of the relations between group and pain variability ($P>0.1$ for both tests, one for each FAST outcome). Similarly, education was not correlated, nor served as a mediator or moderator of the relations between group and pain variability.

In dancers, significant positive correlations were found between years of practice and both FAST outcome measures ICC and R^2 ($r=0.447$, $P=0.009$, and $r=0.380$, $P=0.029$, respectively) (Fig. 3A and 3B), suggesting that the more the dancer is trained, the less variability he/she exhibit. No correlations were found between age and both FAST outcome measures ICC and R^2 ($r=0.180$, $P=0.316$, and $r=0.210$, $P=0.241$, respectively), which support that the duration of training, but not the age of the dancer, contributes to the difference in pain-reporting variability. Furthermore, there was no correlation between sensitivity to pain, as assessed by the mean of all stimuli, and the years of practice ($r=-0.064$, $P=0.723$), suggesting that the relations between duration of practice and the magnitude of variability are not mediated by pain sensitivity.

Taste task outcome measures

Mean taste intensity ratings reported in response to each of the 5 concentrations for both sweet and salty tastes are presented in Figure 4. Group mean \pm SD responses ranged from 1.59 ± 3.14 and 1.80 ± 3.42 for the lowest stimuli intensity (salty and sweet, respectively) up to 60.21 ± 25.14 and 35.59 ± 24.35 for the highest stimuli intensity, respectively. Mean taste intensity scores of salt

(Friedman's test, chi-square 256.06, $P<0.001$) and sugar tastes (Friedman's test, chi-square 243.28, $P<0.001$) significantly differed from each other. Post hoc Wilcoxon test revealed significant difference between each concentration of both sugar and salt ($P<0.001$). Dancers and controls showed no significant differences in mean intensity scores for either salt or sugar taste at any of the concentrations ($P>0.05$ for all, Fig. 5).

The R^2 and ICC of tastes intensity reports were widely distributed, implying that subjects differed in the magnitude of variabilities of taste intensity reports. No significant differences were found between the dancers and the healthy controls in the magnitude of variability of salt or sweet intensity reports ($P>0.05$ for all).

Interoception as assessed by the MAIA questionnaire

Table 2 depicts the results of the MAIA questionnaire for all subjects and subgroups. Significant differences were found in the "noticing," "emotional awareness," and "self-regulation" subscales between the dancers and healthy control (Mann-Whitney, $P=0.003$, $P=0.048$, and $P=0.001$, respectively), suggesting that at least in some aspects of interoception, dancers are more self-aware than controls.

Relationship between MAIA and magnitude of variability of pain and taste reports

Significant positive correlations were seen between the emotional awareness subscale and both FAST outcome measures R^2 and ICC ($r=0.260$, $P=0.040$, and $r=0.274$, $P=0.030$; respectively). These results imply that the more aware the person is, the less his/her pain reports vary. Mediation analyses revealed that among these 3 MAIA subscales (noticing, emotional awareness, and self-regulation), only emotional awareness significantly ($p=0.037$, 95% CI -0.061,-0.001) mediated the effect of group on the ICC measure, meaning that dancers with higher ICC demonstrate higher emotional awareness. In the case of R^2 , the mediation model was non-significant ($p>0.1$). In addition, a positive correlation between the trusting subscale and FAST R^2 ($r=0.254$, $P=0.044$) was seen. No

significant correlations were found between any of the MAIA subscales and the magnitude of taste intensity reports.

When testing these correlations separately in each group, the dancers showed significant positive correlations between the “not distracting” subscale and FAST R^2 ($r=0.390$, $P=0.025$). That is, the less distracted the dancer, the less variability he/she express. . The same correlations were seen with the taste task for R^2 sugar, ICC salt, and ICC sugar ($r=0.411$, $P=0.019$, $r=0.419$, $P=0.015$, and $r=0.350$, $P=0.046$, respectively), suggesting that the less distracted the person is, the less variability he/she express (for both sweet and salt). No other correlations were found between any of the other MAIA subscales and FAST or taste outcome measures in the dancers group. In the control group, positive correlations were found between the “trusting” subscale and both FAST R^2 and ICC measures ($r=0.434$, $P=0.017$, and $r=0.475$, $P=0.008$, respectively). No other relationships were observed.

Discussion

The main aim of the current study was to investigate if dancers, known for their interoceptive accuracy, will demonstrate lower variability of pain intensity reports than controls in reporting their pain. Our hypotheses were confirmed: Dancers exhibited less variability than non-dancers did, but showed no difference in variability of taste intensity reports.

Not only that dancers’ demonstrated lower pain-reporting variability, the more years of practice the dancer had, the lower the variability of pain reports was. Subjects’ variability of pain reports is probably affected by multiple factors. One possible contributor relates to how often the subject experiences the subjective construct (feeling/sensation) being evaluated. Not unexpectedly, professional dancers, who experience pain regularly during their extensive training, will report their pain less variably than controls. Studies have found that athletes are more accurate in the perception of ventilation than are sedentary individuals ¹⁵ and that the improved accuracy of this interoception

modality (breathing) is related to an increased activation of preparatory and anticipation brain networks¹⁴. These findings have been interpreted according to the Bayesian model, and some authors suggest that training can improve accuracy by decreasing the error predictions³² or by improving expectations related to body signals¹⁶.

The same explanation applies to the improved interoception as assessed by the MAIA in dancers. Professional dancers are given extensive training in detecting and modulating their body states²⁷. This training requires physical fitness and integration between emotional, motor, and auditory systems²². Studies have reported that long-term dance training is related to changes in several physical parameters (e.g. fitness, flexibility, range of motion, and balance^{2,13}), in neurocognitive motor control (e.g., movement timing, visual and motor imagery⁵), in pain mechanisms (e.g. greater activity of the descending inhibitory system¹⁸), and in brain function and structure^{7,22}.

The effects of training/learning on various aspects of perception and communication of subjective body states was demonstrated in other interoception modalities¹⁶, in the MAIA self-regulation subscale^{6,25}, and in several diseases^{3,8}. Our previous study demonstrated that the variability of pain reports was reduced with training and that the placebo response was lower in the trained subjects than in controls⁴³.

As demonstrated by Christensen et al. (2018), dancers more accurately report heartbeat than controls do, and senior dancers are better than junior dancers in this task⁹. Unlike the heartbeat task, which assesses interoceptive awareness, the MAIA assesses another interoceptive domain: interoceptive sensibility²¹. Our results expand on the findings of Christensen et al., showing that in some aspects, dancers have better interoception sensibility than non-dancers have. In the current study, the two groups differed on the “noticing,” “emotional awareness,” and “self-regulation” subscales of the MAIA. This confirms that dancers are more aware of body signals and better

understand the relationship between emotions and body states. Emotional awareness was found to mediate the effect of group on pain variability, such that dancers demonstrated lower pain variability due to, at least partly, improved emotional awareness. The improved self-regulation skills suggest that dancers are also better able to regulate these states. Results from studies of patients with anxiety and medically unexplained diseases suggest that increased attention to body signals may have negative consequences in some individuals, resulting in negative effects^{29,33}. Other individuals, however, particularly those with higher self-regulation scores in the MAIA subscale (e.g., dancers), may see benefits²⁹.

The MAIA subscales that were found to correlate with pain-reporting variability deserve consideration. In dancers, but not in controls, the better the ability to focus on body signals and to avoid being distracted from pain or other negative sensations, the lower the variability of pain and taste (sugar). These results indicate that dance training may help individuals to be less affected by contextual and external clues and be more focused on internal body signals.

Worth noticing is that the relations between the different interoception domains (interoceptive accuracy, sensibility and awareness²¹ are yet to be determined, hence it is unclear if our findings could be generalized to other domains of interoception.

There is a general conception that interoception and pain sensitivity are positively correlated, and our results are seemingly in an opposite direction. Indeed, there are studies in which interoception was associated with pain sensitivity^{12,34,37}. This could be due to methodological differences. There are different domains of interoception²¹ and different aspects of pain sensitivity (as assessed by quantitative sensory testing, with parameters such as threshold and tolerance vs. pain intensity reports). In addition, it was proposed that individual differences can play a role: Wiech and Tracey (2009) suggested that higher interoception is related to higher pain only when negative emotions

(which are more relevant to clinical pain patients and less relevant in the case of healthy dancers) are involved⁴⁶.

The low variability in dancers' pain reports but not in their taste-intensity reports is not unexpected. As we¹ and others^{17,20,23,44,45} have shown, interoception does not apply to all sensory modalities. Accordingly, Ferentzi et al. (2018) used a multichannel approach and assessed six sensory channels: heartbeat, gastric, pain, and bitter perception; proprioception; and balance. After conducting correlations and factor analyses, the researchers found no correlations or common factors between different modalities¹⁷. We assessed different interoception modalities and had similar results¹. Interoception (measured by heartbeat task and MAIA) is not related to variability report pain (measured via the FAST), or to variability of tastes reports.

As previous work has shown, dancers are less sensitive to pain than controls are. The differences were more pronounced at the lower stimuli intensities, suggesting that mild to moderate pain stimuli intensities promote a less intense pain experience in dancers than they do in non-dancers. Several lines of research suggest that dancers³⁸ and athletes in general have lowered pain sensitivity^{4,26,31,35} and improved pain modulation^{19,39} compared with healthy, physically active individuals. These differences are usually explained by the need to endure pain, more efficient pain modulation and coping mechanisms, and greater motivation to overcome pain to reach the expected performance⁴⁰. The lack of a relationship between pain-reporting variability and sensitivity to pain suggests that the reduced pain-reporting variability in the dancers is not due to reduced sensitivity.

Few limitations deserve discussion: First, the sequence of stimuli was fully randomized with unique sequence for each subject. Given possible carry-over effects, we cannot rule out that it biased the results. However, assuming that randomization is proper and the cohort is big enough, this potential source of bias should not pose a threat.. Second, data included in this analysis were collected in two study projects, which might contribute to the differences between groups. However,

both projects were done by the same research group (in Lisbon), at the same time, by using the same tools, designs and protocols, and the fact that the differences were seen in the expected measures, but not in others, reduced our concerns. Third, only interoceptive sensibility was assessed in this study. The inclusion of other interoception domains, such as interoception accuracy (using the heartbeat detection task) and interoception awareness (using interoception error prediction) might have provided additional insights. Lastly, the small age range of the cohort does not allow to assess the possible contribution of age to our findings.

To summarize, dancers demonstrated better interoception sensibility and less pain variability than did non-dancers, and senior dancers had lower variability than juniors. Based on the current results and on our previous findings^{41–43}, we can hypothesize that dancers, and perhaps other professional athletes, will demonstrate lower placebo response and reduced day-to-day fluctuations in clinical pain (in case they exhibit chronic pain). Future studies should examine these hypotheses.

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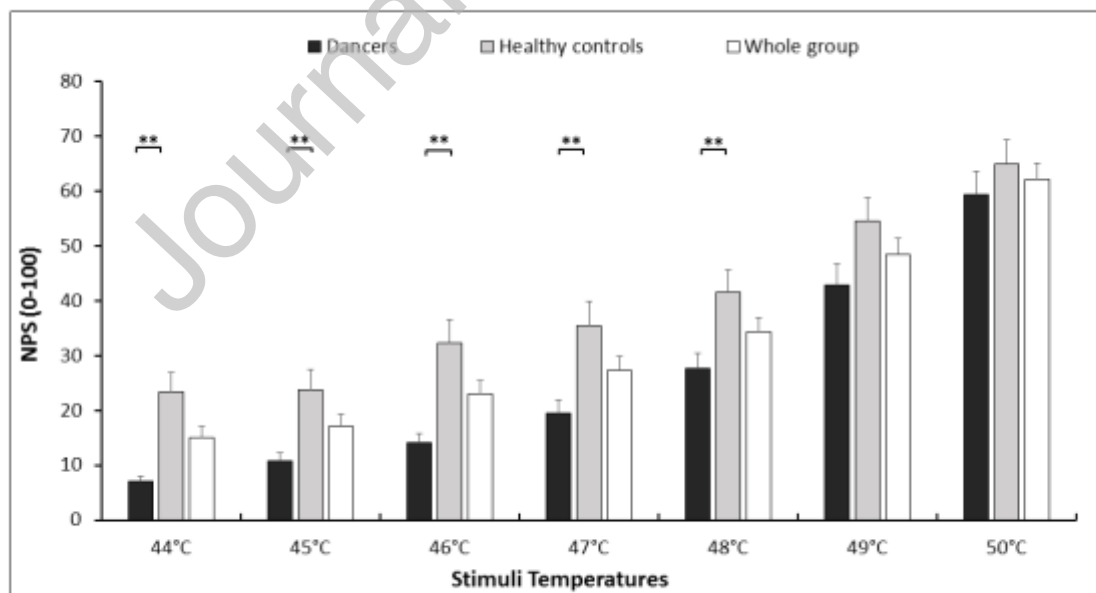


Figure 1. Mean pain scores in response to the 7 stimuli intensities of the FAST procedure.

All bars represent the average pain scores in response to the 7 stimuli intensities. The black bars represent dancers' pain ratings, grey bars represent pain ratings of controls, and the white bars represent pain ratings of the whole sample. Error bars represent the standard error of the mean.

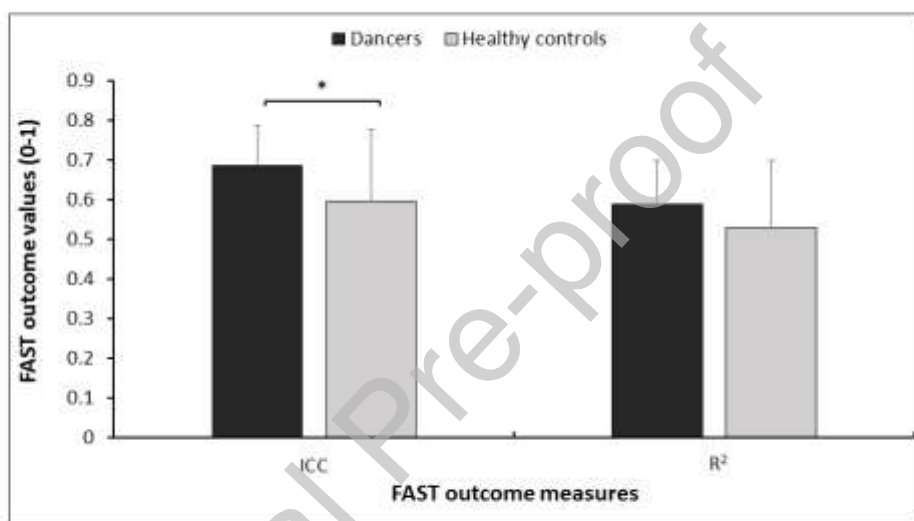


Figure 2. Dancers report their pain less variably than healthy controls

FAST, Focused Analgesia Selection Test; ICC, intraclass correlation coefficient. FAST outcome values represent subjects' pain reporting variability. The closer the value is to one, the less variable the pain reports are. * denote $P < 0.05$.

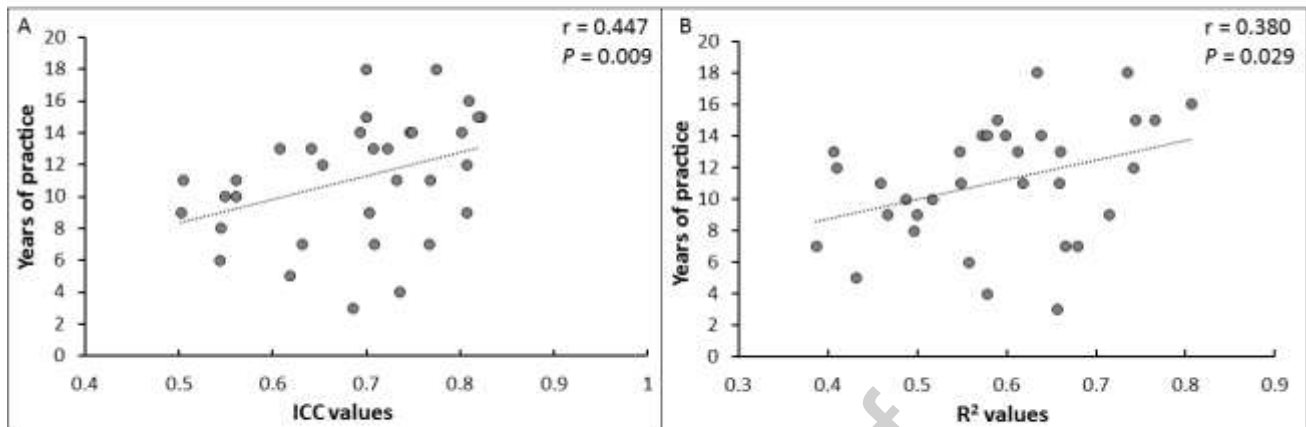


Figure 3. Associations between dancers' years of practice and variability of pain reports.

Significant positive correlations were found between the number of years the dancers practiced and pain reporting variability as assessed by the ICC and R^2 measures of the FAST procedure.

Spearman's $r = 0.447$, $P = 0.009$, and $r = 0.380$, $P = 0.029$; respectively.

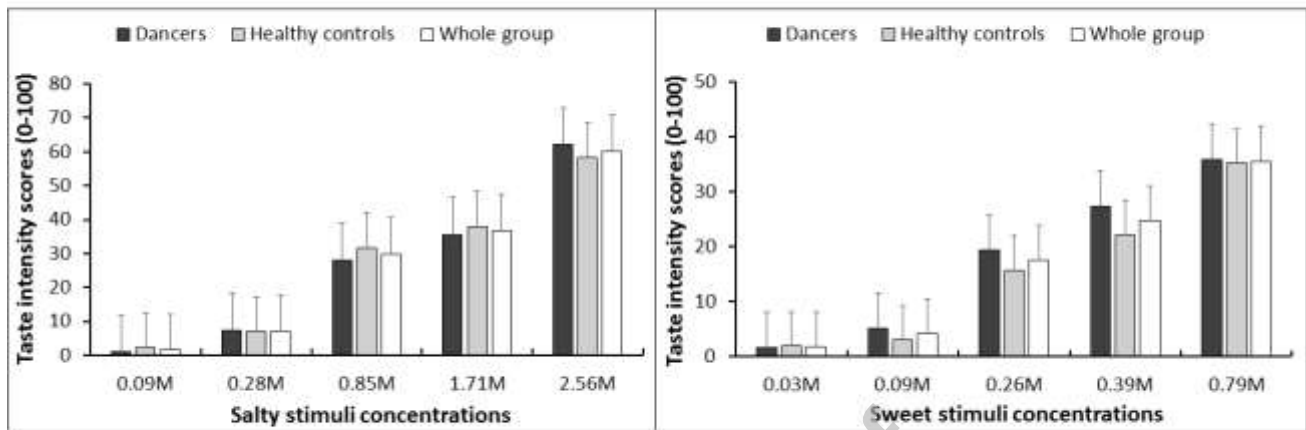


Figure 4. Mean intensity taste scores.

Each bar represents the average taste scores in response to the different salty/sweet concentrations. The black bars represent the dancers' pain ratings, the grey bars represent the controls pain ratings, and the white bars represent the pain ratings of the whole sample. Error bars represent standard errors. Taste concentrations are labeled by concentration (molarity), from lowest to highest concentration.

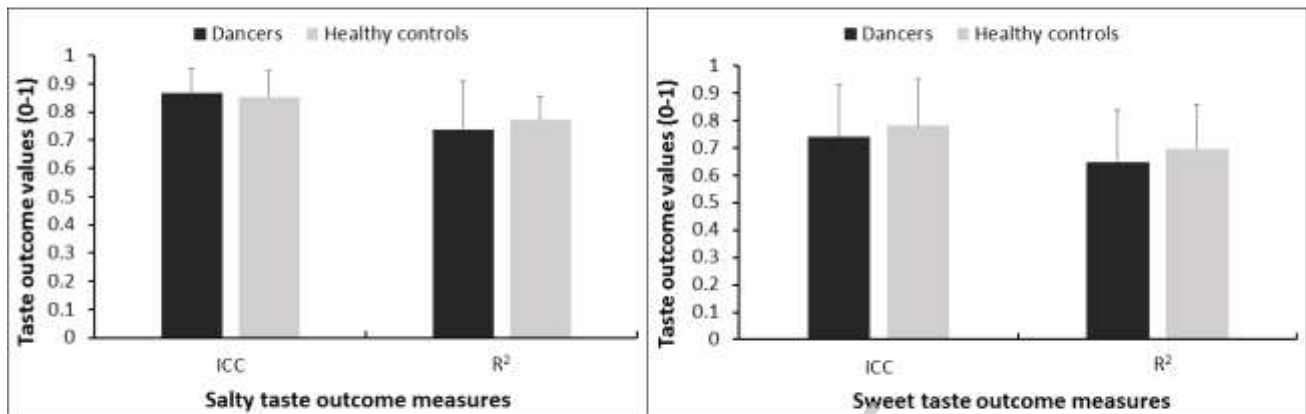


Figure 5. No differences between dancers and healthy controls in reporting sweet and salty tastes.

ICC, intraclass correlation coefficient. Taste outcomes represent the subjects' variability in reporting sweet and salty tastes. The closer the value is to one, the less variable the taste reports are.

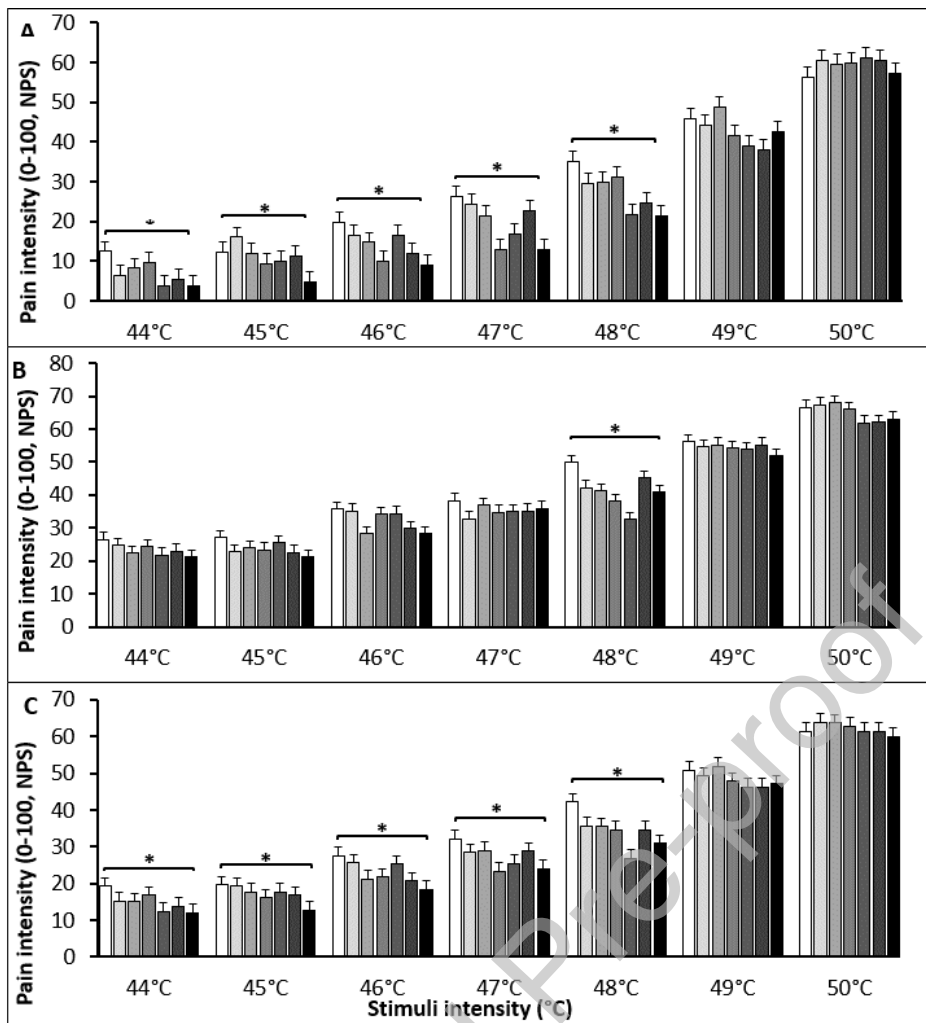


Figure S1: Mean pain scores in response to the 49 stimuli by stimulus order in the dancers (S1A), controls (S1B) and in the entire group (S1C)

For each stimulus intensity, the 7 bars represent the 7 repetitions of stimuli for each intensity, organized by order. The white bar on the left represents the first stimulus and the black bar on the right the 7th stimulus. Error bars represent the standard error of the mean. Note that in the low and mid-range temperatures, significant habituation (i.e reduction of pain in response to repeated administration of the same stimulus) effect was seen in the dancers (S1A), but not in the controls (S1B), excluding the 48°C temperature, in which habituation was seen in the controls. * $P < 0.05$, Friedman test, separately for each temperature.

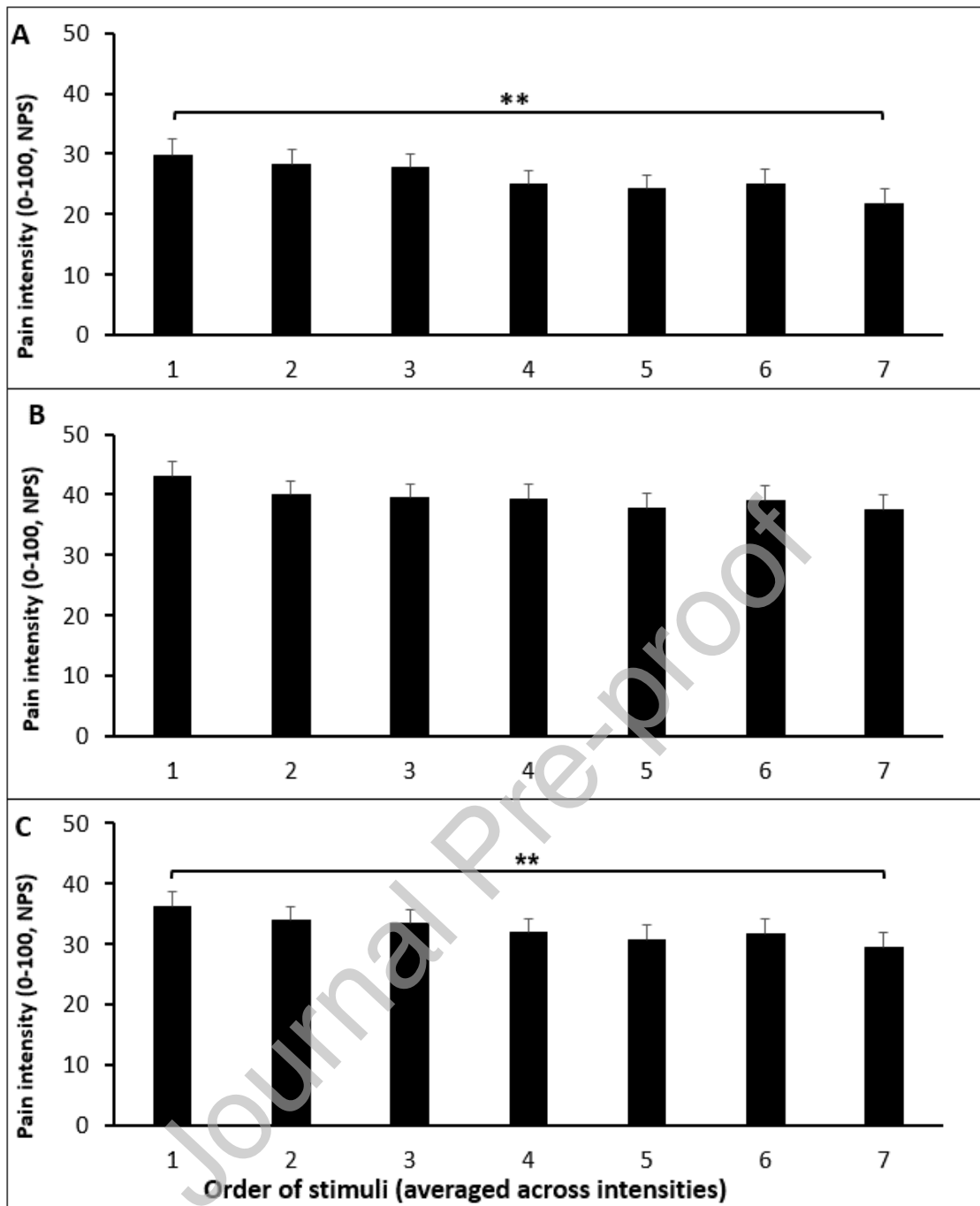


Figure S2: Mean pain scores in response to the 7 stimuli intensities by stimulus presentation order in the dancers (S1A), controls (S1B) and in the entire group (S1C)

Black bars represent the average pain scores in response to each stimulus order, across stimulus intensities (i.e. 1 denotes the mean of pain intensity in response to the first presentation of each of the 7 stimuli intensities). Error bars represent the standard error of the mean. ** $P < 0.01$, Friedman test.

Table 1: Demographic characteristics of the study population

Characteristics	Dancers n = 33	Healthy controls n = 33	P-value
Age (years)			
Mean \pm SD	19.7 \pm 2.03	20.1 \pm 1.80	0.339
Range	18–24	18–25	
Sex, n (%)			
Male	7 (21.2%)	7 (21.2%)	
Female	26 (78.8%)	26 (78.8%)	
Education (years)			
Mean \pm SD	5.2 \pm 0.44	5.0 \pm 0.30	0.027 *
Range	5–6	4–6	
BMI (Kg/m ²)			
Mean \pm SD	20.8 \pm 1.78	20.9 \pm 2.75	0.910
Range	17.48–25.18	14.07–27.85	

Abbreviations: SD, standard deviation. Data are n (%) or mean (SD); (n=66). * denotes significant difference $P < 0.05$

Table 2. A summary of the values distribution of the MAIA questionnaire

MAIA sub-scales	Dancers		Controls	Whole group
Noticing	3.99 ± 0.7	*	3.47 ± 0.7	3.73 ± 0.8
Not Distracting	1.27 ± 1.1		1.66 ± 1.0	1.46 ± 1.1
Not worrying	2.98 ± 0.9		2.59 ± 1.3	2.78 ± 1.1
Attention Regulation	3.44 ± 0.8		3.13 ± 0.8	3.29 ± 0.8
Emotional Awareness	4.06 ± 0.7	*	3.63 ± 0.9	3.63 ± 0.9
Self-Regulation	3.04 ± 1.0	*	2.13 ± 1.1	2.59 ± 1.1
Trusting	3.78 ± 0.7		3.89 ± 0.8	3.83 ± 0.7

MAIA, Multidimensional Assessment of Interoceptive Awareness; * denotes significant difference $P < 0.05$