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ORIGINAL PAPER

The Effect of Praying on Endogenous Pain Modulation and Pain Intensity in Healthy Religious Individuals in Lebanon: A Randomized Controlled Trial

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Abstract

Prayer is considered to be the most common therapy used in alternative medicine. This study aimed to explore the effect of prayers on endogenous pain modulation, pain intensity, and sensitivity in healthy religious participants. A total of 208 healthy religious participants were enrolled in this study and randomly distributed into two groups, a prayer group ($n=156$) and a poem reading or control group ($n=52$). Participants from the prayer group were then selectively allocated using the prayer function scale to either an active prayer group ($n=94$) receiving an active type of praying or to a passive prayer group ($n=62$) receiving a passive type of praying. Pain assessments were performed before and following the interventions and included pressure pain threshold assessment (PPT), conditioned pain modulation (CPM), and a numerical pain rating scale. A significant group-by-time interaction for PPT ($p=0.014$) indicated post-intervention increases in PPT in the prayer group but not in the poem reading control group. Participants experienced a decrease in CPM efficacy ($p=0.030$) and a reduction in their NPRS ($p<0.001$) following the interventions, independent of their group allocation. The results showed that prayer, irrespective of the type, can positively affect pain sensitivity and intensity, but does not influence endogenous pain inhibition during hot water immersion. Future research should focus on understanding the mechanism behind "prayer-induced analgesia."

Keywords Pressure pain threshold · Conditioned pain modulation · Prayer · Religion · Pain

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Introduction

Religion can be defined as a "Sentiment of learned behaviors and social expressions that reflect cultural values"(White et al., 2011). Prayers, religious activities, and seeking spiritual guidance all refer to religion (Tzeng & Yin, 2008; Wachholtz et al., 2007). Religion is also defined as a belief system, a connection with the divine being, a relationship with the supernatural, and a philosophy (Narayanasamy, 2004). Religiosity can be divided into three major dimensions (Levin et al., 1995). The first dimension comprises organizational religious activity (ORA), which reflects the social dimension of religiousness and includes attending church, synagogue, and taking part in prayer or Bible study groups. The second dimension of religiosity is the non-organizational religious activity (NORA), and it comprises more private and personal religious behaviors such as prayer, meditation, reading the Bible, or other religious literature. The final and third dimension is subjective or intrinsic religiosity (IR), and it reflects the extent to which religion is the primary motivating factor in people's lives and how it influences decision-making and behavior (Koenig et al., 2004).

Prayer is considered the most common alternative medicine therapy (South & McDowell, 2018; Tippens et al., 2009). In pain management, traditional strategies do not always ease pain or improve quality of life, leading to alternative pain relief approaches (Breivik et al., 2006). Previous studies showed that prayer for self (43%) and prayer for others (24.4%) as being two of the most used alternative medicine practices in the USA (Barnes et al., 2004) and that the inclusion of prayer in the definition of alternative and complementary medicine resulted in a significant increase in its usage (Robles et al., 2017). Recently, researchers showed interest in understanding the role of spirituality on pain experience (Ferreira-Valente et al., 2019; Illueca & Doolittle, 2020; O'Beirne et al., 2020) based on the need for a model that incorporates spirituality in the biopsychosocial frame of pain (Wachholtz A.B. et al., 2007). However, many of these studies identify prayer as a coping mechanism and do not focus on the therapeutic effect of prayer in pain management. In addition, one can also distinguish different forms of prayer (Laird et al., 2004): adoration, confession, thanksgiving, reception, and supplication defined also as petitionary prayer (Poloma & Pendleton, 1991).

The current study focuses on supplication or petitionary prayer, which is a specific request for (a) oneself or (b) others (Jors et al., 2015). The praying ritual is structured as follows: a motive to pray (a problem), an action to perform (ask something), and an effect to be sought (the solution to the problem). Depending on the individual's relationship with God, we can distinguish 3 methods of problem-solving or 3 methods of praying to address a problem (K. Pargament & Mahoney, 2005; Pargament et al., 1988). In the first type, known as "self-directing," the individual is very active, and God is passive, giving people the freedom and resources to direct their own life. The second type describes a style in which the individual takes no active steps and passively waits for God to solve the problem known as "deferring." The third type describes a pattern of coping in which the individual and God both take active roles, in partnership with each other, to

solve a problem known as "collaborative" (Pargament et al., 1988). While the deferring type represents a passive type of prayer and coping, the collaborative and self-directing types represent a more active type of prayer and coping.

Biologically, there are multiple potential pathways through which prayer may affect pain modulation (Seybold, 2007). Spiritual/religious activities are associated with an increase in serotonin levels (Mohandas, 2008). This raises the possibility that the serotonin system, which plays an important role in endogenous pain modulation through the facilitatory and inhibitory pathways, serves as a biological basis for spiritual experiences (Borg et al., 2003). Besides, prayer and other religious practices such as meditation activate various brain regions, including the medial prefrontal cortex (mPFC) and posterior cingulate (Neubauer, 2014). The mPFC is important for pain processing and its involvement in the modulation of pain catastrophizing (Seminowicz & Davis, 2006), reduction of pain-induced sympathetic activity (Perlaki et al., 2015), and decrease in facial expressions of pain (Karmann et al., 2016). Previous studies (Jegindø et al., 2013; Wiech et al., 2008) have demonstrated that religious participants perceived painful stimulation as less intense after prayer or after meditating over religious images. In addition, an active style of prayer and in contrast to passive prayer is associated with greater pain tolerance for participants with religious beliefs undergoing an experimental painful procedure (Meints et al., 2018). However, none of these studies investigated the effect of prayer on endogenous analgesia.

More research should reveal if prayers affect endogenous pain modulation. Conditioned pain modulation (CPM) has recently been coined for the psychophysical protocols that assess the functioning of descending pain inhibitory pathways in humans and could thus assess the effect of prayer on endogenous pain modulation. Besides, pressure pain threshold (PPT) assessments are a way of quantifying the sensitivity of deep structures to mechanical pain (Balaguier et al., 2016b). PPT provides a quantitative value related to deep structures sensitivity, allowing researchers to make comparisons over time (Balaguier et al., 2016a), and could be used to evaluate the effect of prayer on pain sensitivity.

The primary purpose of this study was to explore the effect of petitionary praying on endogenous pain modulation. It was hypothesized that prayer would increase PPTs, CPM efficacy, and reduce pain intensity during painful hot water immersion compared to a no-prayer control group in a healthy religious population. The secondary purpose of this study was to investigate the effect of different types of praying on pain outcomes since the style of praying has been shown to affect health outcomes in different ways. For instance, active prayers are associated with better mental health outcomes than passive prayers (Bade & Cook, 2008; Tait et al., 2016). Therefore, it was hypothesized that participants engaging in active prayer would show greater improvements in pain outcomes compared to those engaging in passive prayer.

Methods

Design Overview and Setting

The experiment trial took place from October 2020 to February 2021 in Rehabzone clinic, a rehabilitation clinic affiliated with the physical therapy department of Antonine University in Lebanon. The local ethics committees from Antonine University approved the trial. All participants signed informed consent. The full study protocol is registered at ClinicalTrials.gov (NCT04614272.). In the present paper, the effects of two types of prayer (active and passive) versus a control condition (poem reading), on CPM, PPT, and pain intensity rated on a numeric pain rating scale (NPRS) in healthy religious university students are reported. Outcome measures were assessed at baseline and directly after the intervention. The trial is reported following the CONSORT guidelines (http://www.consortstatement.org). Since the study was performed during the Covid-19 outbreak, a hygiene policy was adopted to ensure the safety of the participants and the assessors.

Study Design

The present study is a double-blind randomized controlled experiment. The study participants were blinded to the study hypothesis, and the therapist collecting the data was also blinded to the randomization sequence.

Study Population and Sample Size

Healthy Christian and Muslim male and female participants were recruited through different sources: Flyers distributed at the Antonine University and Rehabzone clinic, emails sent to the Antonine University students, and adverts on social media. People interested to take part in the study were asked to fill out an online questionnaire that screened for inclusion and exclusion criteria. The inclusion criteria were Lebanese English-speaking students aged between 18 and 25 and with a minimum score of at least two over six on the second question from the Duke University Religion Index (DUREL): "*How often do you spend time in private religious activities, such as prayer, meditation, or Bible study?"* the scores were from one (rarely or never) to six with (more than once a day) (Koenig & Büssing, 2010). This question was chosen from the DURELL since it reflects the NORA and it helped to define the religious activities performed by the participants in private, such as prayer. Subjects who scored low in religiosity (< two/six) were excluded from the study. Subjects were also excluded in case of regular use of medication, pregnancy, severe allergic reactions, systemic, neurological, metabolic, cardiovascular pathologies, chronic pain, psychiatric disease (being under pharmacological or psychiatric treatment), or suffering from hypertension (> 140/90 mm Hg) (Chalaye et al., 2013). People meeting the criteria were called to set up an appointment.

To minimize the risk of bias, confounding variables affecting both the autonomic and the central nervous systems were controlled. While scheduling appointments, participants were asked to consume a light meal must no later than two hours (heavy meals no later than four hours) before the initiation of the experiments (Anjana & Reetu, 2014; Zmarzty et al., 1997) and requested to refrain from physical exertion 24 h before the experiments (Flood et al., 2017; Lemley et al., 2015; Lima et al., 2017; Stolzman & Bement, 2016), to abstain from analgesic medications 48 h before the experiments (Niesters et al., 2013), and to refrain from smoking (Ditre et al., 2016; Perkins et al., 1994), alcohol (Horn-Hofmann et al., 2019), and caffeine (Sawynok, 2011) in the two hours before the experiments. On the day of the experiments, participants were questioned regarding their adherence to these requests.

Sample Size and randomization

The sample size needed for this study was calculated using the software program G*Power 3.1. To detect an average effect size (f = 0.25) based on Cohen's conventional standards for the interpretation of effect sizes (Cohen, 2013) with a power of $P = 0.8$ and a significance threshold of $\alpha = 0.05$ using a one-way between-subject ANOVA, a total sample size of 159 individuals was warranted, with 53 individuals per group (active prayer group, passive prayer group, poem control group) (Faul et al., 2007).

Randomization

Randomization of the 208 participants was performed using a permuted block allocation (block size of four) with 52 blocks and a ratio of 3:1, with three being the prayer group and one representing the control (poem) group. Unequal randomization was used to allocate the participants to an intervention (prayer) or control group (poem). Selective allocation was later used to allocate the participants into an active or passive prayer group based on the style of praying. However, unequal randomization has consequences for statistical power and a 3:1 randomization scheme requires 33% more patients (Hey & Kimmelman, 2014). Therefore, a total sample size of 208 participants was required to provide adequate power for the analyses.

Style of Praying

All participants filled out a self-reported questionnaire called "the prayer function scale" (PFS) which describes ways that people use prayer to deal with personal difficulties (Bade & Cook, 2008). The PFS helped to identify the style of praying (Bade & Cook, 2008). It is a self-report instrument that assesses the motivation or purpose behind an individual's prayer, while she or he is coping with difficult circumstances. This scale comprises 58 items that are scored on a five-point Likert-type scale ranging from one (almost never) to five (a great deal), and it is divided into four scales: provides acceptance (17 items), provides calm, and focus (11 items), deferring/

avoiding (16 items), and provides assistance (14 items). While the deferring/avoiding scale represents a passive type of prayer and coping, the assistance scale represents an active type of prayer and coping. The PFS deferring/avoiding scale and the assistance scale were used to allocate participants from the prayer group into, respectively, a passive or an active prayer group.

Intervention

While the "deferring/avoiding" group was given a script for a passive type of praying, the "ask for assistance group" was given a script for an active type of praying. The two types of prayers were inspired by the PFS (Bade & Cook, 2008). The passive prayer script (i.e., "Please God, take the pain away") was inspired by the questions in the PFS related to the deferring/avoiding style, and the script for the active prayer (i.e., "Please God, help me endure this pain") was inspired from the PFS questions related to the ask for assistance style of praying. The control group received the script of a poem and was asked to read this (i.e., "The earth is our home, so blue and so green, let's do our part to keep the earth clean''). The poem was chosen to be emotionless, to avoid the psychophysiological responses related to a poetry reading (Wassiliwizky et al., 2017). All three groups received the instructions and scripts on a piece of paper and were asked to repeat the prayer or the poem for a duration of three minutes. The instructions read: "In the next three minutes you are asked to repeat the following sentence, during which you can choose your preferred posture (sitting, standing, or kneeling)."

Outcome Measures

Outcome measures were PPT, CPM, and NPRS assessed before and directly following the intervention. Sociodemographic data such as religious affiliation, age, gender, body mass index (BMI), hand dominance, smoking, alcohol intake, caffeine intake, and physical activity level were also collected at baseline using a self-reported questionnaire. In addition, the DUREL, which is a five-item self-report measure of religious involvement, was used to assess the religiosity level. It assesses the three major dimensions of religiosity: ORA, NORA, and IR (Koenig & Büssing, 2010).

PPT

PPT assessment is considered a reliable method for measuring mechanical pain thresholds (Cathcart & Pritchard, 2006). PPTs were assessed in a sitting position using a digital algometer (FPX 50, Wagner Instruments, Greenwich, USA) unilaterally (at the side of the dominant hand) at two different body sites. The investigator applied the pressure in a perpendicular direction relative to the muscle while increasing the force at a rate of one kg/s until the participant said to stop when the sensation became intolerable. The pressure marked at that moment was determined as the PPT, measured in kg/cm^2. The first location was the trapezius belly, with

PPTs being assessed at mid-distance between the acromion and the spinous process of the seven cervical vertebrae (Salavati et al., 2017). The trapezius muscle is a reliable test location for measuring the PPT (Persson et al., 2004). The second location was on the calf belly, with PPTs being measured at the proximal one-third of the calf (Giesbrecht & Battié, 2005; Meeus et al., 2010). The PPT was taken at each of the two anatomical sites with an interval of 30 s until the circuit was repeated a total of two times, starting with the trapezius as the first measurement and then proceeding with the measurement of the calf (Bisset et al., 2015). The time between two PPT measures of the same body location was enough to prevent the pain wind-up effect that might be induced by temporal summation (Cathcart et al., 2009). Four PPT measurements were taken, from which a mean PPT was calculated using the following formula: (PPT calf 1 + PPT calf 2 + PPT trapezius 1 + PPT trapezius 2) / 4.

CPM

Conditioning stimulus (CS). The CS consisted of thermal, hot water stimulation of the non-dominant hand. Participants were comfortably seated next to a water bath and instructed to immerse the non-dominant in hot water for one minute. The temperature water of 45,5 °C, was achieved using an immersion circulator (Immersion Circulator LX, Polyscience, Illinois, USA). The temperature of 45,5 °C has been shown to elicit a robust CPM effect, without potential ceiling or floor effects (Nir et al., 2011, 2012). A line was drawn 10 cm proximally of the wrist crease marking until where the hand needs to be immersed, to ensure whole-hand immersion. Participants were instructed to keep their hands still and unclenched and motivated to complete one full minute of hand immersion. Participants could see a countdown timer of the immersed time. If the participant could not complete the entire one minute, the duration of immersion was recorded. Previous research has shown fair to excellent reliability for the use of a hot noxious water bath as a CS (Kennedy et al., 2016).

Test stimulus (TS). The TS existed of mechanical pain stimulation applied using algometry and assessed by determining the PPT. Therefore, PPTs were taken prior to and following the application of the CS as described in the section PPT. The use of PPT has been validated as a proper TS for measuring CPM (Klyne et al., 2015). It has been shown that CPM is still active five minutes after the removal of the CS in studies using experimental pain (France & Suchowiecki, 1999; Motohashi & Umino, 2001) and argued that the purest CPM effect is obtained by measuring immediately following the CS (i.e., sequential) and not during (i.e., parallel) (Yarnitsky et al., 2015). In line with this recommendation, a sequential CPM paradigm protocol was used.

The CPM outcome score was calculated using the following formula: average of the two consecutive PPTs per location following CS—the average of the two consecutive PPTs per location before the CS (i.e., (T1 (PPT1 trapezius + PPT2 trapezius + PPT1 calf + PPT2 calf)/4)-(T0 (PPT1 trapezius + PPT2 trapezius + PPT1 calf + PPT2 calf)/4)). Hence, higher CPM values reflect better functioning of endogenous pain inhibition. The CPM protocol was repeated before and following the

intervention (prayer or poem reading). The post-intervention CPM protocol took place at least 10 min after the pre-intervention or baseline CPM protocol to ensure wash-out of the CPM effect (France & Suchowiecki, 1999; Motohashi & Umino, 2001). The intervention was delivered during the 10-min break, each participant moved to another room to practice either three minutes of active praying, passive praying, or three minutes of poetry reading.

NPRS

Pain intensity for thermal hot water stimulation was evaluated using a NPRS from 0 to 100, with 0 referring to "no pain" and 100 to "maximal pain" felt. It was assessed after the first 30 s of immersion and once more immediately after removing the CS.

Statistical Analysis

All analyses were conducted using SPSS version 2.6 (IBM, New York, USA). The normality of the data was assessed using the Shapiro–Wilk test. Descriptive analyses were used to present the sociodemographic and clinical group characteristics, which were described for the control and prayer group as a whole, and separate for the active prayer group and the passive prayer group. Mean, median, standard deviation, interquartile, and confidence intervals were calculated for the description of continuous variables, whereas frequencies and percentages were calculated for the categorical variables. To evaluate differences in sociodemographic features between all groups, the Chi-square was used for categorical variables, the Kruskal–Wallis was used for the continuous variables with non-normal data distribution, and the Mann–Whitney was used for the continuous variables with normal data distribution. The presence of CPM effects before the intervention was examined using the Wilcoxon signed-rank test to compare the PPT post-conditioning vs. pre-conditioning.

To answer the first research question which evaluated the effect of prayer on PPT, CPM, and NPRS compared to the poetry reading in religious individuals, linear mixed models (LMM) were constructed to test for mean differences between groups (prayer vs control) with the factors "time" (pre, post) and "group" (prayer, control). To answer the second research question which evaluated the effect of two types of prayer (active, passive) on PPT, CPM, and NPRS compared to a poetry reading in religious individuals, LMMs were constructed to test for mean differences between three groups (active, passive, control), with the factors "time" (pre, post) and "group" (active, passive, control). The residuals of the LMMs were checked for normal distribution. When required, post hoc pairwise comparisons were taken using a Bonferroni correction. An intervention-by-time interaction for fixed effects and a main effect for the factor time were analyzed, and random intercept for subject was included to account for within-subject variability. Statistical significance was accepted at a p level of 0.050. Imbalances in demographic data were considered covariates and were included in the analysis.

Results

Participant Characteristics

The participant flow diagram reflected in Fig. 1 shows the number of total responders and participants who were assessed for eligibility, and those who were randomized and underwent allocated intervention and measurements for each group. A total of 208 religious individuals (age range, 17–25 years) took part in the study. While 156 participants were allocated to the prayer group, 52 were allocated to the control group. Within the prayer group, 94 subjects (62%) were allocated to the active prayer group, whereas 62 individuals (38%) were allocated to the passive prayer group in line with the results of the PFS. All participants reported having performed the prayer or read the poem in a sitting position.

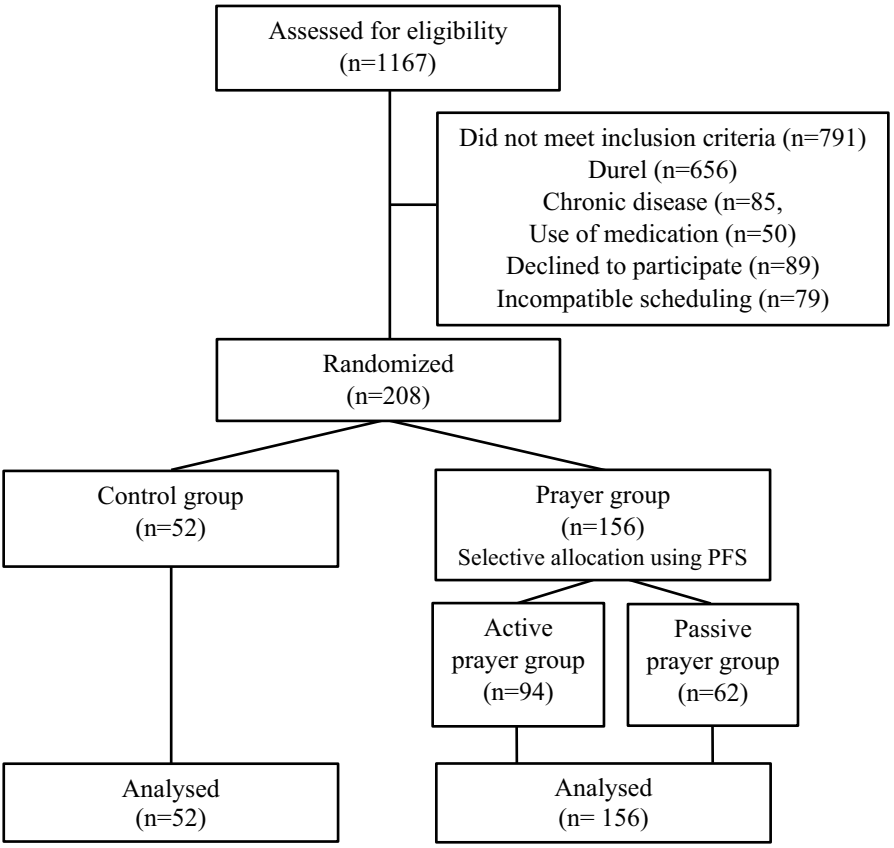

Fig. 1 CONSORT flow diagram that shows the number of total responders and participants who were assessed for eligibility, and those who were randomized and underwent allocated intervention and measurements for each group

Group Differences over Sociodemographic Variables

There was a significant difference in alcohol consumption ($p = 0.010$) between the two groups (prayer and control), whereas significant imbalances between the three groups (active prayer, passive prayer, and control) were observed for age ($p = 0.027$), religion ($p = 0.025$), and alcohol consumption ($p = 0.022$). These imbalances were included as covariates in the LMM analyses. The three groups showed no differences in the NORA ($p = 0.434$). Demographic features of the prayer and control group are summarized in Table 1, whereas features of the active prayer, passive prayer, and control are represented in Table 2.

CPM effect

The results of the Wilcoxon signed-rank assessing the occurrence of the CPM effect before the intervention showed that the CS elicits a significant change in the average PPT before the intervention ($Z = -4.29$, $p < 0.001$) which indicates the overall presence of a CPM effect. Looking at individual responses, 128 participants out of 208 participants (61.5%) showed an increase in the PPT following CS indicating that they were CPM responders, while 80 participants (38.5%) were considered to be non-responders.

Results to Answer the First Research Question.

Effects of prayer versus control on PPT, CPP, and NPRS

Descriptive statistics of PPT, CPM, and NPRS for the data related to the first research question are shown in Table 3.

PPT The LMM analysis showed a significant group-by-time interaction for PPT ($p = 0.014$). Post hoc pairwise comparisons showed a significant increase in the PPT after the intervention in the prayer group ($p < 0.001$) (mean difference (MD): 1.806; 95% CI, 1.357 to 2.25) which was not the case for the control or poem group ($p = 0.085$) (MD: 0.682; 95% CI, − 0.95 to 1.460).

CPM No significant group-by-time interaction effects were found for CPM ($p > 0.050$). However, a significant main effect for time was observed ($p = 0.030$). Participants presented a drop in their CPM scores following the intervention ((EM mean post-intervention 1.058; 95% CI, 0.198 to 1.919; EM mean pre-intervention 1.440; 95% CI, 0.579 to 2.301) regardless of being in the prayer or the control group.

NPRS No significant group-by-time interaction effects were found for NPRS ($p > 0.050$). However, a significant main effect for time was shown ($p < 0.001$). Participants experienced a drop in their NPRS scores following the intervention (EM mean post-intervention 28.96; 95% CI, 14.416 to 43.49; EM mean pre-intervention 38.049; 95% CI, 52.59 to 23.51) independent of the group which they were in.

Table 1 Socio-demographic Factors of the Prayer Group and the Control Group at Baseline

Variables	Values	Prayer	Control	Chi-square value	*p* value
Gender	n (%)				
	Male	74 (47.4%)	23 (44.2%)	0.161	0.680*
	Female	82 (52.6%)	29 (55.8%)		
Religion	n (%)				
	Christian	137 (87.8%)	44 (84.6%)	0.360	0.550*
	Muslim	19 (12.2%)	8 (15.4%)		
Hand dominance	n (%)				
	Right	141 (90.4%)	47 (90.4%)	0.000	1.000*
	Left	15 (9.6%)	5 (9.6%)		
Smoking	n (%)				
	No	115 (73.7%)	39 (75%)	1.067	0.780*
	1 pack /day	1 (0.6%)	1 (1.9%)		
	½ pack /day	39 (25%)	12 (23.1%)		
	1 pack/ week	1 (0.6%)	0 (0,0%)		
Alcohol	n (%)				
	No	134 (85.9%)	46 (88.5%)	11.283	0.010*
	2/ week	22 (14.1%)	3 (5.8%)		
	1/day	0 (0,0%)	2 (3.8%)		
	3/week	0 (0,0%)	1 (1.9%)		
Caffeine	n (%)				
	No	73 (46.8%)	22 (42.3%)	1.550	0.670*
	1/ day	78 (50%)	28 (53.8%)		
	2/day	3 (1.9%)	2 (3.8%)		
	3/day	2 (1.3%)	0 (0,0%)		
Menstrual phase	n (%)				
	Follicular	42 (56.8%)	11 (47.8%)	2.018	0.360*
	During menses	10 (13.5%)	6 (26.1%)		
	Ovulation	22 (29.7%)	6 (26.1%)		
Physical activity	n (%)				
	Yes	86 (55.1%)	30 (57.7%)	0.162	0.690*
	No	70 (44.9%)	22 (42.3%)		
Durel ORA	n (%)				
	Never	2 (1.3%)	2 (3.8%)	4.292	0.510*
	Once/year or less	7 (4.5%)	0 (0,0%)		
	Few times a year	57 (36.5%)	18 (34.6%)		
	Few times/month	43 (27.6%)	15 (28.8%)		
	Once/week	37 (23.7%)	12 (23.1%)		
	More than once/week	10 (6.4%)	5 (9.6%)		

Table 1 (continued)

Variables	Values	Prayer	Control	Chi-square value	*p* value
Durel NORA	n (%)				
	Few times/month	75 (48.1%)	18 (34.6%)	3.570	0.470*
	Once/week	13(8.3%)	5 (9.6%)		
	Two or more /week	22 (14.1%)	11 (21.2%)		
	Daily	34 (21.8%)	12 (23.1%)		
	More than once /day	12 (7.7%)	6 (11.5%)		
Durel IR Q1	n (%)				
	Definitely not true	1 (0.6%)	1 (1.9%)	4.060	0.400*
	Tends not to be true	1 (0.6%)	2 (3.8%)		
	Unsure	14 (9%)	6 (11.5%)		
	Tends to be true	32 (20.5%)	11 (21.2%)		
	Definitely true of me	108 (69.2%)	32 (61.5%)		
Durel IR Q2	n (%)				
	Definitely not true	5 (3.2%)	2 (3.8%)	1.239	0.870*
	Tends not to be true	11 (7.1%)	3 (5.8%)		
	Unsure	25 (16%)	7 (13.5%)		
	Tends to be true	70 (44.9%)	21 (40.4%)		
	Definitely true of me	45 (28.8%)	19 (36.5%)		
Durel IR Q3	n (%)				
	Definitely not true	10 (6.4%)	3 (5.8%)	4.300	0.370*
	Tends not to be true	15 (9.6%)	6 (11.5%)		
	Unsure	37 (23.7%)	6 (11.5%)		
	Tends to be true	55 (35.3%)	19 (36.5%)		
	Definitely true of me	39 (25%)	18 (34.6%)		
Age	Mean (SD)	20.39 (1.98)	20.27 (2.05)		0.630□
	Median (IQR)	20 (3)	20 (4)		
BMI	Mean (SD)	23.67 (3.98)	23.13 (4.21)		0.680□
	Median (IQR)	23.16 (4.54)	22.8 (4.8)		

% percentage; *: P-values were calculated using Chi-square tests; □: P-values were calculated using Mann–Whitney test; BMI: body mass index; Durel: Duke University Religion index; *IR* intrinsic religiosity; *n* frequency; *NORA* non-organizational religious activity; *ORA* organizational religious activity

Results to Answer the Second Research Question

Effects of active prayer versus passive prayer versus control on PPT, CPP, and NPRS

Descriptive statistics of PPT, CPM, and NPRS for the data related to the second research question are shown in Table 4.

Table 2 Socio-demographic Factors of the Active and Passive Prayer Group and the Control Group at Baseline

Variables	Values	Active	Passive	Control	Chi-square value	*p* value
Gender	n (%)					
	Male	47 (50%)	35 (56.5%)	23 (44.2%)	0.786	0.675*
	Female	47 (50%)	27 (43.5%)	29 (55.8%)		
Religion	n (%)					
	Christian	88 (93.6%)	49 (79%)	44 (84.6%)	7.390	0.025*
	Muslim	6 (6.4%)	13 (21%)	8 (15.4%)		
Hand dominance	n (%)					
	right	83 (83.3%)	58 (93.5%)	47 (90.4%)	1.185	0.550*
	left	11 (11.7%)	4 (6.5%)	5 (9.6%)		
Smoking	n (%)					
	No	68 (72.3%)	47 (75.8%)	39 (75%)	2.475	0.871*
	1 pack/day	1 (1.1%)	0 (0,0%)	1 (1.9%)		
	½ pack/day	24 (25.5%)	15 (24.2%)	12 (23.1%)		
	1 pack/week	1 (1.1%)		0 (0%)		
Alcohol	n (%)					
	No	77 (81.9%)	57 (91.9%)	46 (88.5%)	14.838	0.022*
	2 drinks/week	17 (18, 1%)	5 (8.1%)	3 (5.8%)		
	1drink/day	0 (0,0%)	0 (0%)	2 (3.8%)		
	3 drinks/week	0 (0,0%)	0 (0%)	1 (1.9%)		
Caffeine	n (%)					
	No	42 (44.7%)	31 (50%)	22 (42.3%)	2.152	0.905*
	1/ day	49 (52.1%)	29 (46.8%)	28 (53.8%)		
	2/day	2 (2.1%)	1 (1.6%)	2 (3.8%)		
	3/day	1 (1.1%)	1 (1.6%)	0 (0,0%)		
Menstrual phase	n (%)					
	Follicular	27 (57.4%)	15 (55.6%)	11 (47.8%)	2.370	0.668*
	During menses	7 (14.9%)	3 (11.1%)	6 (26.1%)		
	Ovulation	13 (27.7%)	9 (33.3%)	6 (26.1%)		
Physical activity	n (%)					
	Yes	49 (52.1%)	36 (58.1%)	30 (57.7%)	0.695	0.707*
	No	45 (47.9)	26 (41.9%)	22 (42.3%)		
Durel ORA	n (%)					
	Never	1 (1.1%)	1 (1.6%)	2 (3.8%)	5.710	0.839*
	Once /year or less	3 (3.2%)	4 (6.5%)	0 (0,0%)		
	Few times a year	34 (36.2%)	23 (37.1%)	18 (34.6%)		
	Few times/ month	27 (28.7%)	16 (25.8%)	15 (28.8%)		
	Once/week	23 (24.5%)	14 (22.6%)	12 (23.1%)		
	More than once/ week	6 (6.4%)	4 (6.5%)	5 (9.6%)		

Table 2 (continued)

Variables	Values	Active	Passive	Control	Chi-square value	*p* value
Durel NORA	n (%)					
	Few times/ month	43 (45.7%)	32 (51.6%)	18 (34.6%)	7.991	0.434*
	Once/week	9 (9.6%)	4 (6.5%)	5 (9.6%)		
	Two or more / week	16 (17%)	6 (9.7%)	11 (21.2%)		
	Daily	17 (18.1%)	17 (27.4%)	12 (23.1%)		
	More than once /day	9 (9.6%)	3 (4.8%)	6 (11.5%)		
Durel IR Q1	n (%)					
	Definitely not true	0 (0,0%)	1 (1.6%)	1 (1.9%)	5.847	0.664*
	Tends not to be true	1 (1.1%)	0 (0%)	2 (3.8%)		
	Unsure	8 (8.5%)	6 (9.7%)	6 (11.5%)		
	Tends to be true	21 (22.3%)	11 (17.7%)	11 (21.2%)		
	Definitely true of me	64 (68.1%)	44 (71%)	32 (61.5%)		
Durel IR Q2	n (%)					
	Definitely not true	5 (5.3%)	0 (0,0%)	2 (3.8%)	4.737	0.785*
	Tends not to be true	6 (6.4%)	5 (8.1%)	3 (5.8%)		
	Unsure	14 (14.9%)	11 (17.7%)	7 (13.5%)		
	Tends to be true	42 (44.7%)	28 (45.2%)	21 (40.4%)		
	Definitely true of me	27 (28.7%)	18 (29%)	19 (36.5%)		
Durel IR Q3	n (%)					
	Definitely not true	8 (8.5%)	2 (3.2%)	3 (5.8%)	7.395	0.495*
	Tends not to be true	10 (10.6%)	5 (8.1%)	6 (11.5%)		
	Unsure	21 (22.3%)	16 25.8%)	6 (11.5%)		
	Tends to be true	30 (31.9%)	25 (40.3%)	19 (36.5%)		
	Definitely true of me	25 (26.6%)	14 (22.6%)	18 (34.6%)		
Age	Mean (SD)	20.36 (1.99)	19.9 (1.91)	20.27 (2.05)	7.198	0.027□
	Median (IQR)	21 (3.00)	19 (3.00)	20 (4.00)		
BMI	Mean (SD)	23.53 (4.04)	23.25 (3.88)	23.13 (4.21)	1.476	0.478□
	Median (IQR)	23.37 (4.51)	23.1 (4.30)	22.9 (4.80)		

% percentage; * P-values were calculated using Chi-square tests; □ P-values were calculated using Mann–Whitney test; BMI body mass index; Durel Duke University Religion index; *IR* intrinsic religiosity; *N* frequency; *NORA* non-organizational religious activity; *ORA* organizational religious activity

Table 3 CPM, NPRS, and PPT of the Prayer Group and the Control Group

Outcomes	Prayer				Control			
	Mean(SD)	Median (IQR)	95% CI		Mean(SD)	Median (IQR)	95% CI	
			LB	UB			LB	UB
CPM pre	0.54(1.89)	0.39 (1.83)	0.25	0.84	0.72(2.27)	0.45 (2.08)	0.08	1.35
CPM post	0.15(1.80)	0.81 (1.54)	-0.13	0.43	0.38(1.54)	0.30(1.84)	−0.50	0.81
NPRS pre	54.80(25.6)	60.00(40.00)	50.78	58.88	52.54(24.35)	57.50(34.13)	45.76	59.32
NPRS post	45.06(24.59)	50.00(39.63)	41.17	48.90	45.47 (24.07)	49.25(34.38)	38.76	52.17
PPT pre	10.23(4.25)	9.10(5.55)	9.57	10.90	11.09 (4.51)	10.17(6.90)	9.82	12.33
PPT post	12.03 (5.90)	10.64(7.40)	11.10	12.97	11.76(5.25)	10.51(7.06)	10.30	13.22

CI confidence interval; *CPM* conditioned pain modulation; *IQR* interquartile; *LB* lower bond; *NPRS* numeric pain ration scale; *PPT* pressure pain threshold; *pre* pre-intervention; *post* post-intervention; *SD* standard deviation, *UB* upper bond

PPT The LMM analysis showed a significant group-by-time interaction for PPT ($p=0.005$). Bonferroni post hoc analyses for group-by-time interaction effects revealed a significant increase in the PPT following the active prayer intervention ($p<0.001$) (MD 2.21; 95% CI, 1.63 to 2.78) and the passive prayer intervention ($p=0.001$) (MD: 1.2; 95% CI, 0.49 to 1.9), compared to the control intervention ($p=0.082$) (MD: 0.682; 95% CI, -0.09 to 1.45). There was no significant difference ($p=0.165$) between the active (EM mean 16.45) and the passive prayer group (EM mean 14.84). The differences between the active prayer group and the control group (EM mean 15.13) did also not reach statistical significance ($p=0.400$). All results can be found in Table 5.

CPM No significant group-by-time interaction effects were found for CPM ($p>0.050$). However, a significant main effect for time was shown ($p=0.030$). Participants experienced a reduction in CPM scores following the intervention (EM mean post-intervention 0.968; 95% CI, 0.088 to 1.848; EM mean pre-intervention 1.350; 95% CI, 0.470 to 2.23) independent of their group allocation.

NPRS No significant group-by-time interaction effects were found for NPRS ($p>0.050$). However, a significant main effect for time was established ($p<0.001$). Participants experienced a reduction in NPRS scores following the intervention (EM mean post-intervention 30.82; 95% CI, 15.99 to 45.65; EM mean pre-intervention 39.92; 95% CI, 25.08 to 54.74), regardless of the group they were in.

Discussion

This study aimed at investigating the pain modulating effect of prayer in a sample of healthy religious individuals. The primary aim of this study was to determine the effect of prayer on mechanical pain sensitivity, endogenous pain modulation, and pain intensity compared to poem reading. It was hypothesized that engaging in prayer would lead to increases in PPT and CPM efficacy, and a decrease in NPRS,

Table 4 CPM, NPRS, and PPT of the Active and Passive Prayer Group and the Control Group

Outcomes	Active				Passive				Control			
	Mean(SD)	Median(IQR)	95% confidence of interval		Mean(SD)	Median(IQR)	95%CI		Mean (SD)(SD)	Median(IQR)	95% CI	
			LB	UB			LB	UB			LB	UB
PPT pre	10.64(4.80)	9.08(6.24)	9.65	11.62	9.6(3.18)	9.06(5.23)	8.80	10.42	11.09(4.51)	10.17(6.90)	9.82	12.33
PPT1 post	12.84(6.57)	10.81(8.34)	11.50	14.20	10.8(4.45)	10.20(6.04)	9.67	11.93	11.76(5.25)	10.51(7.06)	10.30	13.22
CPM pre	0.68(2.18)	0.38(2.18)	0.23	1.13	0.34 (1.32)	0.39(1.60)	0.11	0.68	0.72(2.27)	0.46(2.08)	0.08	1.35
CPM post	0.25(2.02)	0.12(1.93)	-0.16	0.66	0.065(1.42)	0.25(1.20)	-0.35	0.36	0.38(1.54)	0.30(1.84)	-0.50	0.81
NPRS pre	52.75 (26.86)	57.50(39.13)	47.24	58.25	57.99 (23.42)	65.00(37.50)	52.04	63.94	52.54(24.35)	57.50(34.13)	45.76	59.32
NPRS post	42.59(24.66)	45(37.75)	37.53	57.64	48.81(24.19)	55.00(37.50)	42.67	54.95	45.47(24.07)	49.25(34.38)	38.76	52.17

CI confidence interval; *CPM* conditioned pain modulation; *IQR* interquartile; *LB* lower bond; *NPRS0* pain numeric ration scale at baseline; *NPRS* numeric pain rating; *PPT* pressure pain threshold; *pre* pre-intervention; *post* post-intervention; *SD* standard deviation; *UB* upper bond

Table 5 Group-by-time Interaction for PPT, Comparing Active, Passive, and Control

Within-group differences					
Group	Time	EM mean (LB; UB)	Mean Difference (LB;UB)	SE	*p*
Active	Pre	14.25 (11.07; 17.43)	2.21 (1.63; 2.78)	1.61	< 0.001
	Post	16.45 (13.28; 19.63)		1.61	
Passive	Pre	13.63 (10.41; 16.86)	1.20 (0.49; 1.90)	1.64	0.010
	Post	14.84 (11.61; 18.10)		1.64	
Control	Pre	14.44 (11.41; 17.48)	0.68 (-0.09; 1.45)	1.54	0.082
	Post	15.13 (12.1; 18.16)		1.54	
Between-group differences					
Active vs. Passive			1.62 (−0.41; 3.64)	0.84	0.165
Active vs. Control			1.33 (−0.80; 3.46)	0.89	0.400
Passive vs. Control			−0.29 (−2.60; 2.02)	0.95	1.000

EM mean estimated marginal mean; *LB* lower bond; *PPT* pressure pain threshold, *pre* pre-intervention; *post* post-intervention; *UB* upper bond

while no prayer would not induce any changes, and that these increases would be greater following active prayer than when engaging in passive prayer. The findings provide some support for these hypotheses.

Concerning mechanical pain sensitivity, results showed a significant increase in PPT over time in the prayer groups, regardless of the type of prayer, and this effect was not present in the poem reading control group. However, when the types of prayer were compared to each other or with the poem reading control group, statistics did not reach significance.

Regarding endogenous pain modulation, and in contrast to our hypotheses, both prayer groups and the poem reading control group showed a decrease in CPM efficacy following the intervention. Their effects were similar between groups. To explain the reduced CPM following the intervention, several hypotheses can be proposed: (1) The decrease in CPM efficacy could be explained by the use of a fixed and not an adapted conditioning paradigm. Previous studies (Nir et al., 2011; Oono et al., 2011) showed that CPM could be intensity-dependent and thus an increase in the intensity of the CS would induce better CPM results. Prior studies also showed a decreased CPM efficacy during a second CPM testing (Coppieters et al., 2016; Meeus et al., 2015). It may be that each successive conditioned noxious stimulus decreases CPM efficacy. Coppieters et al. (2016) investigated the effect of relaxation on CPM in chronic whiplash and fibromyalgia patients compared to healthy controls and found a decreased CPM efficacy in the three groups after the intervention, regardless of the type of intervention. (2) It may be that the 10-min break maintained between the two CS could not have been enough to avoid a carry-over effect; therefore, a longer recovery period may be necessary after a previous CPM activation. It is possible that adequate CPM activation after the intervention was affected by all of these factors. (3) Additionally, it could be that prayer and CPM do not rely on the same mechanisms. Pain modulation through religious prayer like mindfulness meditation (Zeidan et al., 2016) seems to rely on non-opioidergic systems (Elmholdt

et al., 2017) which suggests the involvement of a non-opioidergic cognitive pain modulation system and the notion of multiple pathways in pain control independent of descending inhibitory mechanisms. Therefore, it was hypothesized that prayers and CPM might rely on different mechanisms and do not reinforce each other.

Regarding pain intensity, NPRS findings for both prayer groups and the poetry reading control group resulted in a significant decrease in scores over time, with no significant differences between groups. The decrease in the poem group could be explained by the distraction from hot water, causing pain by focusing on reading the poem. Distraction is an effective approach to reducing pain (Bukola & Paula, 2017).

As expected, and in line with earlier studies (Elmholdt et al., 2017; Meints et al., 2018), results showed that prayer decreases pain sensation for religious individuals regardless of the type of prayer. Active prayers are related to better health when compared to passive prayers (Bade & Cook, 2008; Tait et al., 2016), and active praying is considered an active or self-management approach to pain, while passive praying is considered a passive style of coping. However, in our study, there were no significant differences between the two styles of praying on pain sensitivity.

Although the exact underlying mechanisms are unclear, several hypotheses may explain how prayer reduces pain. Previous studies showed that the cognitive activity of positive re-appraisal mediated the relationship between prayer and pain. Positive reappraisal involves cognitively reframing an event as more positive or valuable allowing individuals to adapt successfully to stressful life events (Garland et al., 2009). Also, other theories have been elaborated, such as conscious re-appraisal, which can alter the meaning of pain without targeting the sensory aspects of the percept (Woo et al., 2015). Other studies (Elmholdt et al., 2017; Jegindø et al., 2013) highlighted the power of strong expectations driven by beliefs and previous religious coping experiences to explain ‘‘religion-induced analgesia.’’

Strength, Limitations, and Future Research

The present study has several strengths. This is the first study, to our knowledge, to investigate the effect of prayer on CPM. Participants were blinded to the study objectives, and the assessor of the outcome measures was blinded to the intervention allocation. However, when interpreting the results, some limitations must be considered. First, all participants were young and pain-free; thus, the findings cannot be generalized to all ages or individuals suffering from pain conditions. In addition, the prayer was not personalized, which could have reduced its meaning and effects. Future research is needed on the analgesic effect of praying in which it would be necessary to personalize the experiment by allowing the participant to pray in their way to reduce the pain and then allocate them to an active or a passive group, according to their style of praying. Moreover, research should focus on extending the follow-up period to observe the long-term effects of “religious induced analgesia.’’ Furthermore, it would be interesting to inventory expectations and previous religious coping experiences, to examine how these potentially influence the results. Also, subjects were selectively allocated using the prayer function scale to either an

active prayer group or to a passive prayer group, rather than being randomly allocated; self-selection bias may have affected the results.

Conclusion

The results suggest that prayer, regardless of the used style, reduces mechanical pain sensitivity and self-reported pain intensity in a healthy religious population. Endogenous pain modulation, assessed using a CPM paradigm, decreased in response to both prayer and poem reading, indicating that CPM and praying probably rely on different mechanisms which do not interact.

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Data Availability The data that support the findings of this study are available from the corresponding author (C.N).

Code Availability Not applicable.

Declarations

Conflict of interests The authors declare that they have no conflicts of interest.

Ethical approval The local ethics committees from Antonine University approved the trial. The authors certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki.

Consent to Participate All participants signed consent forms.

Consent for Publication Patients signed informed consent regarding publishing their data.

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