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Abstract

The effects of power posing on hormonal reactions such as testosterone and cortisol have been widely investigated, however, its effects on the autonomic nervous system are rather unknown. Consequently, the aim of this study was to investigate the influence of power posing on cardiac vagal activity (CVA), as indexed by heart rate variability. It was hypothesized that high power poses (HPP) would increase CVA, whereas low power poses (LPP) would decrease CVA, given power posing is expected to decrease stress. Participants (N = 56) performed a total four power poses, a combination of two power conditions (high vs. low) and two body positions (sitting vs. standing) for one minute each, in a randomized order. In addition, for each power pose participants were given a role description. Contrary to our hypothesis, CVA decreased significantly during HPP in comparison to the resting measures before and after HPP, and CVA did not change during LPP. Moreover, while holding the power pose, CVA was higher in the LPP than in the HPP condition. Regarding subjective measures our hypotheses were confirmed, felt power was significantly higher after HPP than after LPP. Additionally, perceived stress was higher after LPP than after HPP. Taken together, these results suggest that the immediate impact of PP on the autonomic nervous system is more likely to influence a higher state of activation within the body instead of increasing resources to cope with stress as indexed by CVA, which may be seen only on a more long-term basis.

Keywords	power posing; heart rate variability; parasympathetic nervous system; RMSSD; respiratory frequency

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Data for: The influence of power posing on cardiac vagal activity

Power posing and HRV

The influence of power posing on cardiac vagal activity

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Keywords: power posing, heart rate variability, parasympathetic nervous system, RMSSD, HF-HRV (FFT), HF-HRV (AR), respiratory frequency

The influence of power posing on cardiac vagal activity

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Abstract

The effects of power posing on hormonal reactions such as testosterone and cortisol have been widely investigated, however, its effects on the autonomic nervous system are rather unknown. Consequently, the aim of this study was to investigate the influence of power posing on cardiac vagal activity (CVA), as indexed by heart rate variability. It was hypothesized that high power poses (HPP) would increase CVA, whereas low power poses (LPP) would decrease CVA, given power posing is expected to decrease stress. Participants (N = 56) performed a total four power poses, a combination of two power conditions (high vs. low) and two body positions (sitting vs. standing) for one minute each, in a randomized order. In addition, for each power pose participants were given a role description. Contrary to our hypothesis, CVA decreased significantly during HPP in comparison to the resting measures before and after HPP, and CVA did not change during LPP. Moreover, while holding the power pose, CVA was higher in the LPP than in the HPP condition. Regarding subjective measures our hypotheses were confirmed, felt power was significantly higher after HPP than after LPP. Additionally, perceived stress was higher after LPP than after HPP. Taken together, these results suggest that the immediate impact of PP on the autonomic nervous system is more likely to influence a higher state of activation within the body instead of increasing resources to cope with stress as indexed by CVA, which may be seen only on a more long-term basis.

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Introduction

Power posing is the display of high or low power by positioning the body in specific poses that are held (Carney, Cuddy, & Yap, 2010). The effects of power posing on psychophysiological outcomes is currently a highly debated topic (Carney, Cuddy, & Yap, 2015; Jonas et al., 2017). The interest in the psychophysiological effects of power posing originated in 2010 where Carney, Cuddy, and Yap found effects of power posing at the hormonal level. However, evidence related to the autonomic nervous system is limited. Investigating the reaction of the autonomic nervous system during power posing would allow a better understanding for a more comprehensive reaction of the body, given the role of the autonomic nervous system within self-regulation, in particular concerning its parasympathetic branch (Thayer, Hansen, Saus-Rose, & Johnsen, 2009). Therefore the current study aims to clarify this issue.

Heart rate variability (HRV) is the physiological phenomenon of variation in the time interval between consecutive heart beats (Akselrod et al., 1981; Malik, 1996). HRV is acknowledged to index cardiac vagal activity, the activity of the vagus nerve regulating cardiac functioning (Berntson et al., 1997; Chapleau & Sabharwal, 2011; Malik, 1996). Cardiac vagal activity is assumed to be a marker of self-regulation, as depicted by the neurovisceral integration model (Thayer et al., 2009). More specifically, the neurovisceral integration model assumes that a higher resting cardiac vagal activity is linked to improved health, cognition, and executive performance (Thayer et al., 2009). Many physiological and environmental factors can affect HRV (Fatisson, Oswald, & Lalonde, 2016), and body position is one of those for example when sitting or standing. When sitting HRV is generally higher than while standing (Young & Leicht, 2011). Power poses can be realized while both sitting and standing, and one aim of this paper will be to clarify whether body position influences the effects of power poses on cardiac vagal activity.

At a behavioral level, high and low power status can be seen in one´s body language. Having high power, people tend to demonstrate postural expansion, whereas when having only little power, people tend to show postural constriction (Tiedens & Fragale, 2003). Consequently, high power poses occupy more space as widespread limbs are characteristic for them, for example a wide stance and puffed out chest. On the contrary, low power poses need little space, because the limbs are pulled towards the torso (Carney, Hall, & LeBeau, 2005), for example stooping. The first study on power posing (Carney et al., 2010) found that expansive, open (high-power) poses cause an increase in testosterone and a decrease in cortisol levels. Additionally, participants felt subjectively more powerful. On the other hand, contractive, closed (low-power) poses show a decrease in testosterone and an increase in cortisol levels. These first results were then highly debated, and an increasing number of studies investigated further the effects of power posing, with a focus on replication. Ranehill et al. (2015) replicated Carney´s study but with a much larger sample. Their results only showed an increased in feelings of subjective power, but no differences were found in cortisol nor in testosterone levels. A review highlighted several differences between Ranehill´s study and studies that reported changes in cortisol and testosterone levels (Carney et al., 2015). The main differences were the necessity for a cover story, the creation of a social context to strengthen the role identification when realizing the power poses, and a short holding duration of the poses (one minute each). Still, due to these controversial findings the conclusions of Carney et al. (2015) were further scrutinized. A search for evidence of selective reporting in Carney´s review could not be found based on p-curve analysis (Simmons & Simonsohn, 2017). Another paper used multiverse analysis to consider whether reported findings of the original study (Carney et al., 2010) were robust to alternative data analytic specifications (Credé & Phillips, 2017). The findings demonstrate that the original results are highly sensitive to data analytic specifications, which should encourage pre-registration of studies investigating power posing. Further, a special issue including only pre-registered studies could not replicate the effects expected by the researchers, but evidenced other effects that were not expected (Jonas et al., 2017). The preregistration process ensured that the original hypotheses were being tested, and not cherry-picked by researchers post-hoc. Still, a meta-analysis based on the results of the special issue on power posing (Gronau et al., 2017) found evidence for a small overall effect of power poses on felt power. However, if participants are unfamiliar with the expected effects of power posing, the effects on felt power are only moderate. Further research is encouraged to take into account the influence of moderators regarding the effects of power posing, such as cognitive flexibility (Jackson, Nault, Smart Richman, LaBelle, & Rohleder, 2017), participant gender (Bombari, Schmid Mast, & Pulfrey, 2017), and personality characteristics (Klaschinski, Schnabel, & Schröder-Abé, 2017). Taken together, these results may indicate that power posing triggers psychophysiological reactions only if certain criteria are met. The current study will integrate some of these criteria such as a cover story and the creation of a social role in order to investigate the effects of power posing on cardiac vagal activity.

A potential link between power posing and cardiac vagal activity might already be present through cortisol. Some studies found that high power posing was linked to a decrease in cortisol, the stress hormone, while cortisol was found to increase during low power posing (Carney et al., 2015). Overall, adopting a high power pose in comparison to a low power pose can be expected to decrease stress. Cardiac vagal activity is no stress marker per se, but an indicator of how well people can use effectively their resources to cope with stress (Laborde, Mosley, & Thayer, 2017; Thayer et al., 2009). It could potentially be expected that via its effect on felt power, high power posing would lead to an improvement of self-regulation mechanisms to cope with stress, depicted by an increase in cardiac vagal activity, and low power poses would be associated to a decrease in cardiac vagal activity.

In summary, the aim of our study was to investigate the effects of power posing (high vs. low) on cardiac vagal activity, in two body positions (sitting vs. standing). Performing power posing in the two body positions will enable to test in an exploratory way whether body position plays a moderator role on cardiac vagal activity, given cardiac vagal activity is higher in sitting in comparison to standing (Young & Leicht, 2011). Given the purported protective effects of power posing on stress (Carney et al., 2015), we hypothesize that in both body positions, high power pose will lead to an increase in cardiac vagal activity, in comparison to low power pose, which is expected to lead to a decrease in cardiac vagal activity. Further, we expect felt power to be higher after the high power pose in comparison to after the low power pose, and perceived stress to be lower after the high power pose than after the low power pose.

Methods

Participants

An a priori G*Power calculation (Faul, Erdfelder, Buchner, & Lang, 2009; Faul, Erdfelder, Lang, & Buchner, 2007) was carried out to estimate the sample size required for this study. Based on previous a previous review and meta-analysis (Carney et al., 2015; Gronau et al., 2017), a small effect size was expected for the effects of power posing on psychophysiological outcomes. Entering in G*Power an a priori effect size of $f = 0{,}15$ for a repeated-measures ANOVA, a sample size of $N = 50$ was found to be required. Fifty-eight participants (N male = 37, N female = 21) took part to the study. Two participants' datasets had to be excluded due to technical reasons. The final sample used for statistical analysis comprised 35 male and 21 female participants (age: $M = 22.96$, $SD = 2.53$, age range: 18 - 30). There were several prerequisites required to take part in the present study. Participants could not engage in intensive physical activity, and could not drink alcohol the 24 hours prior to testing. Two hours prior to testing participants did not partake in physical activity, smoking, eating and consumption of caffeinated drinks. The ethics committee of the local university approved the study.

Cardiac vagal activity assessment

Cardiac vagal activity can be inferred via HRV measurement. In this study, the root mean square of the successive differences (RMSSD) was chosen as the first indicator of cardiac vagal activity (Berntson et al., 1997; Malik, 1996). Additionally, as suggested by Laborde et al. (2017), analyses were also conducted with other variables expected to reflect cardiac vagal activity (for the full data set please see the supplementary material). The additional variables are based on the absolute power in the high-frequency (HF) band of HRV, 0.15 – 0.40 Hz (Berntson et al., 1997; Malik, 1996), calculated via both Fast Fourier Transform (FFT) and autoregressive (AR) modelling, with an order of p = 16 (Boardman, Schlindwein, Rocha, & Leite, 2002). An ECG-device (Faros 180°, Mega Electronics, Kuopio, Finland) was used during the experiment to assess HRV, with a sampling rate of 500 Hz. We used two disposable ECG pre-gelled electrodes (Ambu L-00-S/25, Ambu GmbH, Bad Nauheim, Germany). The negative electrode was placed in the right infraclavicular fossa (just below the right clavicle) while the positive electrode was placed on the left side of the chest, below the pectoral muscle in the left anterior axillary line. From ECG recordings we extracted the HRV variables via the use of Kubios© (University of Eastern Finland, Kuopio, Finland). The full ECG recording was inspected visually, and artefacts were corrected manually (Laborde et al., 2017). Recommendations for HRV measurement time is usually five minutes (Laborde et al., 2017; Malik, 1996), however this study used only one-minute intervals given Carney et al. (2015) recommends holding power poses for one minute. The Task Force of The European Society of Cardiology and the North American Society of Pacing and Electrophysiology acknowledge that one-minute measurements can be used for cardiac vagal activity analyses if the experimental design requires this procedure (Malik, 1996). As recommended by Laborde et al. (2017), respiratory frequency will also be assessed, and we do so in the current study via the ECG derived respiration algorithm of Kubios© (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014).

Power Poses

There were four different power poses used, two high power poses and two low power poses. Both had a sitting and standing variation. Additionally, there was a sitting and standing resting pose, enabling the measurement of HRV before and after posture manipulation without major changes in body positions, given body position influences HRV (Young & Leicht, 2011). Participants had their eyes closed for all poses, and all poses were hold for one minute, given this time was sufficient to trigger hormonal changes, and longer times were shown to be uncomfortable (Carney et al., 2015). Pictures of the poses can be seen in the Appendix.

Holding the standing resting pose, participants placed their feet hip-width apart, letting their arms hang relaxed aside. The head was held in a neutral position. During the standing high power pose, participants stood shoulder-width and with their hands resting on their hips, so the elbows pointed naturally outward. Their head was tilted a bit backwards (Cuddy, Wilmuth, Yap, & Carney, 2015). Holding the lower power pose, the feet were placed as close as possible to each other so that the feet were touching each other on the inside. The arms were crossed in front of their body and the head was tilted forward (Carney et al., 2010).

For resting measurements while sitting, participants sat on a chair with armrests. Hands were put on the middle of their thighs, so their arms were relaxed. The head was hold in a neutral position. While holding the sitting higher power pose, the left ankle was rested on the right thigh, while placing the left arm on the backrest of a chair next to them (Huang, Galinsky, Gruenfeld, & Guillory, 2011). In contrast, for the sitting lower power pose, hands were placed together between the thighs, while crossing the feet placed under the sitting surface (Carney et al., 2010).

Cover story and social context

The importance of cover stories as well as a social context was highlighted by the review of Carney et al. (2015). This means, participants should not be aware of the study real aim and hypotheses. Furthermore, holding power poses should take place in a social context to elicit effects on hormone levels and feelings of power. For this purpose, participants should either interact with other participants or with the experimenter. Alternatively, participants can also imagine a social situation during the posture manipulation (Carney et al., 2015). The cover story we used made participants believe the present study´s aim was to investigate the influence of different body postures on the perception of a video. The video lasted 20 min and was a recording of a talk given by a professor of medicine at a conference[1]. The application of the ECG device was justified with the need to measure the individual's heart rate during the experiment. To create a social context, participants were given one role description for each of the four power poses, for example imagining you are the head of a company. For this purpose, three role descriptions were created, and the one for the sitting low power pose could be taken from Cesario and McDonald (2013) study. The full descriptions can be retrieved in the Appendix. In order to ensure that participants were thinking about their role description while holding power poses for one minute, participants were reminded about their role via audio instructions while holding the power pose. The role information was repeated every 15 seconds, lasting approximately five seconds each.

Felt power, perceived stress, and role identification

Visual analogue scales (100 mm) were used to assess felt power (from very low to very high), perceived stress (from very low to very high), and how well they could identify themselves with the role (from very difficult to very well). Participants answered the visual analogue scales directly after the power posing holding time ceased.

Cover story manipulation check

Participants were also given a questionnaire about the film clip they watched to ensure the cover story was maintained. The questionnaire asked for: "How much did the talk motivate you to learn something new?"; "How informative was the talk?", "How emotional

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[1] Video retrieved on November 24th 2017 on http://www.youtube.com/watch?v=vujELzwcdpQ

was the talk?", "How inspiring was the talk?", and "How much would you like to watch the talk to its end?". All answers were given on a visual analogue scale with 100 mm length, anchored from 0 "not at all" to 100 "extremely".

Procedure

The full procedure can be seen in Figure 1. Participants were acquired via flyers on the university campus. Before the experiment, participants were informed about the procedure and signed an informed consent form. Participants started with a questionnaire asking for demographic data to control for confounding variables, such as smoking or intense physical activity (the form was based on the one displayed in Laborde et al., 2017). Following, the ECG device (Faros 180°) was attached via two electrodes on the participant´s upper body.

Insert Figure 1 near here

The power poses were realized in a block (either starting with the two high power poses or the two lower power pose) in order to increase cover story effectiveness. The starting order (sitting vs. standing) was counterbalanced. After changing body position, a short break (1 min) was introduced to enable the stabilization of physiological values. Before and after realizing each power pose, participants held a baseline pose, which was used as a resting measure, either standing or sitting to match the power pose realized directly afterwards. Before and during holding the pose, participants heard a role description to create a social context via speakers as recommended by Carney et al. (2015). After, the questionnaire about felt power, perceived stress, perceived control, and role identification was completed. Subsequently, a resting measurement was performed. Each resting measure and each power pose were held for one minute. The entire testing lasted approximately one hour.

To ensure a standardized execution of the required poses, participants were shown pictures (See Appendix). The pictures displayed the poses from the front and side views. If necessary, the experimenter corrected the poses of the participants.

As a transition between the high power poses and low power poses, participants had to watch a 20 min video recording of a talk given by a medicine professor at a conference. While watching the video sequence, the body position was the same as the sitting baseline pose. After watching the transition video, participants had to fill a questionnaire to evaluate how participants evaluated the talk according to several aspects (e.g., emotional, inspirational). The video sequence was shown for two main reasons. First, it was part of the cover story, since the participants were made to believe that the study´s aim was to investigate the influence of different poses on the perception of video sequences. Therefore, a questionnaire about their perception about the talk was shown just after watching the talk and after the second block of power poses. During the debriefing at the end of the experiment, all participants mentioned they believed in the cover story. Second, the video served as a transition between the high power pose and low power pose phases, in order for the participants to change their mindset linked to the role they had to imagine. In previous studies, participants either held higher power poses or lower power poses but not both in one testing, and we wanted to avoid carry-over effects from one block to another. After realizing the second power posing block, in order to strengthen the cover story participants filled out the questionnaire about their impressions regarding the talk again. Once the task had finished the electrodes were detached, and participants were thanked and debriefed.

Data analysis

Regarding the HRV data, they were not normally distributed. Data were log transformed to obtain a normal distribution, as usually done in HRV research (Laborde et al., 2017). After doing so, data was normally distributed as Shapiro-Wilk indicated (p > .05). Outliers (less than 1% of the data) were winsorized, meaning that values higher/lower than two standard deviations from the mean were transformed to a value of two standard deviations from the mean. A repeated measures ANOVA was run to investigate the influence of power posing on cardiac vagal activity, with power pose (high vs. low), body position (standing vs. sitting), and time (baseline, power pose, recovery) as independent variables. RMSSD, indexing cardiac vagal activity, was used as the dependent variable[2]. A similar analysis was run with the respiratory frequency. Given they may also influence the results, age, sex, BMI, and waist-to-hips ratio were entered as covariates. Finally, correlations will be run between respiratory frequency and RMSSD, HF-HRV (FFT) and HF-HRV (AR).

Concerning subjective variables, role identification data were not normally distributed, as indicated by Shapiro-Wilk Test ($p < .05$), therefore Wilcoxon signed-rank tests were performed. Regarding feelings of power, six outliers (±2 SD) were first winsorized. The data was not normally distributed, as indicated by the Shapiro-Wilk test (high power poses: p = .004 and low power poses: $p < .001$), therefore a Wilcoxon signed-rank test was ran. Regarding perceived stress, five outliers (±2 SD) were first winsorized. The data was not normally distributed (Shapiro-Wilk Test, high power poses and low power poses: $p < .001$), therefore a Wilcoxon signed-rank test was ran.

Results

Descriptive statistics can be seen in Table 1 for RMSSD and respiratory frequency, and in Table 2 for the subjective variables. For RMSSD, a repeated measures ANOVA was run. The assumption of sphericity was violated, therefore the Greenhouse-Geisser correction was applied. No main effect of power pose was found on RMSSD, $F(1.000, 55.000) = 0.286$, $p = .595$. There was a significant main effect of body position on RMSSD $F(1.000, 55.000) = 171.697$, $p < .001$, partial $\eta^2 = .757$. RMSSD was found to be significantly higher in sitting postures ($M = 1.70$, $SD = .27$) in comparison to standing postures ($M = 1.44$, $SD = .29$). No main effect of time was found on RMSSD, $F(1.567, 86.188) = 2.280$, $p = .119$. No significant interaction for power posing and body position was found, $F(1.000, 55.000) = 0.570$, $p = .453$. There was a significant interaction effect by power pose and time, $F(1.976, 108.679) =$

[2] As indicated earlier, the same analyses were conducted with HF-HRV (FFT) and HF-HRV (AR), but given they showed the same patterns as RMSSD, for clarity matters only the results with RMSSD are presented.

4.933, p = .009, partial η^2 = .082. In order to understand the interaction, we calculated the simple main effects for power pose and for time. In total 9 paired t-tests were ran, therefore we adjusted the alpha level via Bonferroni correction to .05 / 9 = .005. The full results can be seen in Table 3, here we only report significant relationships. Regarding the simple main effects for power pose, RMSSD was significantly higher in low power pose than in high power pose when holding the pose (p < .001, d = .58). Regarding the simple main effects for time, in high power pose, RMSSD was significantly lower when holding the high power pose in comparison to the resting measure taking place before (p < .001, d = .58) and after (p < .001, d = .43); and RMSSD was higher in the resting measure taken before the high power pose than the one taken after the high power pose (p < .001, d = .16). No significant interaction between time and body position was found, F(1.989, 109.387) = 0.046, p = .955. Finally, no three-way interaction effect (power posing, body position, time) was found, F(2,324, 102.100) = 4.933, p = .107. None of the covariates (i.e., age, sex, BMI, and waist-to-hips ratio) was found to influence the results. Similar patterns were observed with the two other variables expected to reflect cardiac vagal activity, HF-HRV (FFT) and HF-HRV (AR).

For respiratory frequency, a repeated measures ANOVA was run. The assumption of sphericity was violated, therefore the Greenhouse-Geisser correction was applied. No main effect of power pose was found, F(1.000, 55.000) = 3.530, p = .060. There was a significant main effect of body position on respiratory frequency, F(1.000, 55.000) = 18.539, p = .007, partial η^2 = .781. Respiratory frequency was found to be significantly higher while standing (M = 2.58, SD = .17) in comparison to sitting (M = 2.55, SD = .18). A main effect of time was found on respiratory frequency, F(1.953, 107.433) = 18.539, p < .001. Given the main effect of time was not our focus, we did not run further post-hoc analysis for this main effect. No significant interaction for power pose and body position was found, F(1.000, 55.000) = 2.790, p = .101. There was a significant interaction effect by power pose and time on respiratory frequency, F(1.990, 109.429) = 9.231, p < .001, partial η^2 = .144. In order to understand the interaction, we calculated the simple main effects for power pose and for time. In total 9 paired *t*-tests were ran, therefore we adjusted the alpha level via Bonferroni correction to .05 / 9 = .005. The full results can be seen in Table 4, here we only report significant relationships. Regarding the simple main effects for power pose, respiratory frequency was significantly higher in low power pose than in high power pose when holding the pose ($p < .001$, $d = .43$). Regarding the simple main effects for time, in low power pose, respiratory frequency was significantly higher when holding the low power pose in comparison to the resting measure taking place before ($p < .001$, $d = .48$) and after ($p < .001$, $d = .34$). No significant interaction for time and body position was found, $F(1.796, 98.807) = 0.559$, $p = .505$. Finally, no three-way interaction effect (power posing, body position, time) was found, $F(1{,}792, 98.563) = 0.878$, $p = .408$. None of the covariates (i.e., age, sex, BMI, and waist-to-hips ratio) was found to influence the results. Further, no significant correlations were found between respiratory frequency and RMSSD, HF-HRV (FFT), and HF-HRV (AR) (See Table 5).

Insert Table 1 near here

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Concerning the control variable role identification, it was found to be higher for standing high power poses (*Mdn* = 71.5) than for standing low power poses (*Mdn* = 63), $z = -3.566$, $p < .001$. In addition, role identification was significantly higher for sitting high power poses (*Mdn* = 72.5) than for sitting low power poses (*Mdn* = 62.5), $z = -2.941$, $p = .003$. Felt power was higher (*Mdn* = 60) after high power poses than after low power poses (*Mdn* = 16.5), $z = -8.450$, $p < .001$, and perceived stress was lower after high power poses (*Mdn* = 6) than after low power poses (*Mdn* = 20.5), $z = -7.489$, $p < .001$.

Discussion

The aim of our study was to examine the effects of power posing (high vs. low) on cardiac vagal activity, in two body positions (sitting vs. standing). This is the first study to investigate the effects of power posing on the autonomic nervous system. Contrary to our hypothesis, holding a high power pose led to a statistically significant decrease in cardiac vagal activity as indexed by RMSSD[3], while no change were found in low power poses. Respiratory frequency was found to be higher during the low power pose in comparison to high power pose, and to be higher while standing in comparison to sitting. At the subjective level, felt power was higher after high power poses in comparison to after low power poses, while perceived stress was lower after high power poses in comparison to after low power poses.

Our hypothesis regarding the decrease of cardiac vagal activity was based on the fact that high power poses are usually associated to a lowered psychophysiological reaction to stress, as identified by hormonal markers (i.e., cortisol) and subjective ones (Carney et al., 2015). Therefore, regarding the autonomic nervous system, we first assumed that high power poses would be linked to a higher cardiac vagal activity, which reflects higher self-regulation abilities, as detailed by the neurovisceral integration model (Thayer et al., 2009). We found the opposite, meaning that cardiac vagal activity decreased while holding the high power pose, in comparison to the resting measures before and after the power pose. Moreover, cardiac vagal activity did not change with the lower power pose, and it was higher when holding the low power pose as when holding the high power pose. These results may suggest that, concerning the autonomic nervous system, power posing creates an activation in the body, which is reflected in the inhibition of the parasympathetic system. This could match the preparation of the organism for the “fight or flight” reaction (Jansen, Nguyen, Karpitskiy, Mettenleiter, & Loewy, 1995) via power posing. Actually, with the benefit of the hindsight, we can speculate that the timing of cardiac vagal activity measurement may be important to

[3] Similar results were obtained with HF-HRV (FFT) and HF-HRV (AR)

take into consideration here. The stress hormone cortisol, on which the assumption that power posing may have protective effects against stress was based, needs 15 to 20 minutes after the event to reach its peak (Granger, Kivlighan, el-Sheikh, Gordis, & Stroud, 2007). In our case, we just assessed cardiac vagal activity one minute while participants were holding the power pose, and one minute after. Further research may definitely consider assessing a longer period of time after realizing the power pose, given the immediate and mid-term effects on the autonomic nervous system may differ.

Regarding body position, cardiac vagal activity was higher while sitting than while standing, which is in line with the results of earlier publications (Young et al., 2011). No further interaction effect was found with power posing, meaning that body position does not influence the effects of power posing on cardiac vagal activity.

Respiratory frequency was assessed in order to interpret further the results related to cardiac vagal activity (Laborde et al., 2017). Respiratory frequency was higher in the low power pose in comparison to the high power pose, which would actually suggest that the low power pose was the most stressful/activating condition, given higher respiratory frequency is usually associated with stress and increased arousal (Hoshikawa & Yamamoto, 1997; Lackner et al., 2011; Wientjes, Grossman, & Gaillard, 1998). However, it is important to notice that the power pose itself may influence directly the respiratory frequency without involving any stress, but due to anatomical considerations. Specifically, high power posing require expanding, while low power posing require constricting, which may provoke a diminished excursion of the chest wall and/or diaphram, and/or larger intrapulmonary blood volume (Allen, Hunt, & Green, 1985). This explanation also stands for the difference observed regarding body position, with respiratory rate being higher when sitting in comparison to standing. This may be linked to the fact that respiratory vital capacity is higher when standing than sitting, likely influenced by the anatomical considerations mentioned above (Lalloo, Becklake, & Goldsmith, 1991; Price, Schartz, & Watson, 2014), Due to these changes in respiratory frequency, the question whether the HRV markers supposed to reflect cardiac vagal activity (RMSSD, HF-HRV FFT, and HF-HRV AR) still provide a reliable indication of cardiac vagal activity may arise. On the one hand, some researchers suggest that HRV measurements supposed to reflect cardiac vagal activity should be systematically adjusted for respiration (e.g., Grossman & Taylor, 2007), while other researchers view a routine correction for respiration as highly problematic (e.g., Lewis, Furman, McCool, & Porges, 2012; Thayer, Loerbroks, & Sternberg, 2011), given the common basis for HRV and respiration (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). In line with Thayer et al. (2011) we see a systematic adjustment of cardiac vagal activity HRV markers for respiration as being problematic, and offer instead further analyses to address this issue. Regarding the respiratory frequency, one important consideration related to the interpretation of the HF-HRV variables is that the HF-HRV variables can be viewed as reflecting cardiac vagal activity only when respiratory frequency lies between 9 and 24 cycles per minute (Berntson et al., 1997). In our study, respiratory frequency was comprised in average between 12.5 and 14 cycles per minute (Table 1), meaning that this criteria was met. Further, no correlations were found between respiratory frequency and the HRV measures supposed to reflect cardiac vagal activity, suggesting that those were not influenced by respiratory frequency. Taken together, these findings would suggest that we could interpret the results of RMSSD, HF-HRV (FFT), and HF-HRV (AR) as reflecting cardiac vagal activity within our study. Additional evidence could be achieved in the future adopting a design specifically conceived to separate the effects of power posing on cardiac vagal activity and respiratory frequency, such as comparing power posing with spontaneous breathing or with paced breathing, like it was done for example in the experimental setting of Kuehl et al. (2015).

Regarding felt power, similar results were found as in previous studies (Carney et al., 2015), as felt power was higher after high power poses than after low power poses. This is also the only consistent result found in the special issue of Jonas et al. (2017), as identified in the meta-analysis of Gronau et al. (2017). This is directly linked to the non-verbal display of an expansive posture in comparison to a contractive one. Regarding perceived stress, it was also in line with previous research, given it was lower after the high power in comparison to after the low power pose. This result is in line with previous research (Carney et al., 2015), and confirm the protective effects of high power poses at the subjective level.

The difference in role identification, higher for the high power poses than for the low power poses, may represent an issue for the interpretation of the data. Optimally, there should be no difference in role identification between high and low power poses. As it appeared harder to the participants to identify themselves with the role associated to the low power poses, future studies may pay attention to this issue in allowing a longer time to identify with the role, or providing more vivid role descriptions for the low power poses.

Strengths of this study were the following. This is the first study to use a within-subject design with power posing. Within-subject designs are highly recommended when investigating HRV, given the inter-individual differences observed (Quintana & Heathers, 2014). The differences observed on both objective and subjective dependent variables show that even if participants realized the two conditions in a row (separated by a video serving the cover story), it was still possible for the participants to identify successfully with the social roles. Lastly, this study followed the recommendations from the review article of Carney et al. (2015), namely applying a cover story, creating a social context, as well as holding the poses for a short duration.

Limitations of our study were not taking hormone samples (e.g., cortisol and testosterone), and limiting the measurement duration of cardiac vagal activity to a short-term period that potentially hindered the influence of power posing on physiological systems.

Further, given we systematically associated a submissive role to the constricted pose and a dominant role to the expansive power pose, it is not possible to differentiate clearly the effects of power posing from the role of the imagined social contexts. Even if this choice was made to be in accordance with the recommendations of Carney et al. (2015), future studies should investigate the effects of power pose realized without imagining social contexts, or realized with imagining social contexts not matching the power poses.

To conclude, our study found that on a short-term basis, high power posing may create an activation state in the body, decreasing cardiac vagal activity, and matching the "fight and flight" reaction observed in stress situations (Jansen et al., 1995). Examining measurements of longer duration will prove useful to understand better the mid-term and long-term effects of power posing on cardiac vagal activity, which in turn may help us to link power posing to HRV theories such as the neurovisceral integration model (Thayer et al., 2009).

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Appendix

Standing High Power Pose

"While you´re holding this position, I´d like you to imagine that you´re standing at the entrance of a big party and you have the power to decide who´s allowed to come in and who isn't. All the people waiting in the queue are waiting on your decisions without hesitation. Try to really visualize this scene and put yourself in that role as much as possible, and really experience what it would feel like to be that person."

Standing Low Power Pose

"While you´re holding this position, I´d like you to imagine that you just gave a presentation, which your examiner obviously didn´t like. While all attendees look disappointed, some of them are also criticizing your deficient performance. Try to really visualize this scene and put yourself in that role as much as possible, and really experience what it would feel like to be that person.”

Sitting High Power Pose

“While you´re holding this position, I´d like you to imagine that you´re the boss of a big company. Hearing small businessmen ask for your support as an investor, you have the power to decide which one you´d like to help. Your decisions are accepted without protest. Try to really visualize this scene and put yourself in that role as much as possible, and really experience what it would feel like to be that person.”

Sitting Low Power Pose (based on Cesario & McDonald, 2013)

“While you’re holding this position, I’d like you to imagine that you’re at work and you’re sitting in front of your boss. Imagine your boss is standing across from you, on the other side of his desk, facing you with his hands on the desk. He’s making it clear to you that he isn’t satisfied with your latest job performance. Try to really visualize this scene and put yourself in that role as much as possible, and really experience what it would feel like to be that person.”

Standing Baseline Pose

Standing High Power Pose

Standing Low Power Pose

Sitting Baseline Pose

Sitting High Power Pose

Sitting Low Power Pose

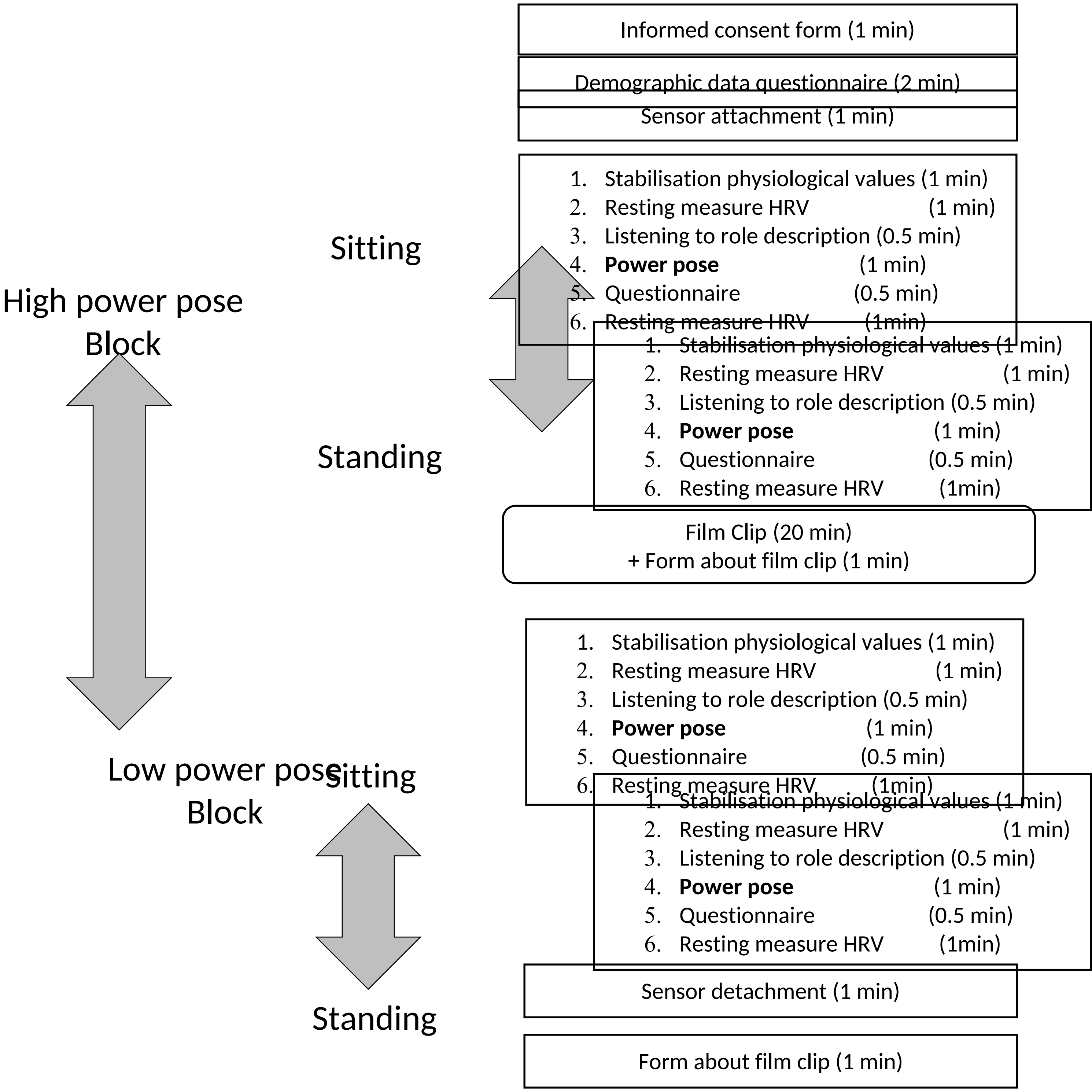

Figure 1. Experimental protocol

Note: The order of the high power pose block and low pose block was randomized, as well as the sitting and standing body positions. HRV: heart rate variability

Table 1

Descriptive statistics RMSSD and respiratory frequency

	High power pose												**Low power pose**											
	Sitting						**Standing**						**Sitting**						**Standing**					
	Baseline		**During**		**Recovery**		**Baseline**		**During**		**Recovery**		**Baseline**		**During**		**Recovery**		**Baseline**		**During**		**Recovery**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
RMSSD	64,5	45,6	58,7	35,6	56,6	34,0	34,4	21,0	32,0	22,9	31,0	18,8	61,6	41,7	62,1	44,3	60,5	42,0	33,8	25,5	39,6	33,7	34,3	27,1
Respiratory frequency	12,5	1,9	13,0	2,0	12,8	2,0	13,2	1,8	13,3	2,0	13,4	1,9	12,8	2,0	13,8	2,0	13,2	2,0	13,0	2,1	14,0	2,0	13,3	2,1

Note: RMSSD: Root mean square of successive differences

Table 2

Descriptive statistics for subjective variables

	High power pose				Low power pose			
	Sitting		Standing		Sitting		Standing	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Felt power	58.86	27.74	54.96	28.22	19.52	18.49	18.36	15.86
Perceived stress	8.64	8.77	10.30	13.54	25.16	20.28	20.09	20.00
Discomfort	19.11	18.83	16.50	18.02	36.20	32.06	35.64	31.96
Role identification	68.36	22.04	68.27	22.40	58.80	27.44	57.82	26.31

Table 3

Post-hoc tests (simple main effects) for the repeated measures ANOVA ran to investigate the interaction effect between power pose (high vs. low) and time (baseline, power pose, recovery) on cardiac vagal activity

		M1	*SD1*	*M2*	*SD2*	*M difference*	*SD difference*	*t*	*df*	*p*	*Effect size (Cohen's d)*
Simple main effects power pose	RMSSD_HPP_Baseline (M1) - RMSSD_LPP_Baseline (M2)	1.59	0.25	1.56	0.27	0.03	0.09	2.112	55	.039	0.10
	RMSSD_HPP_During (M1) - RMSSD_LPP_During (M2)	1.44	0.28	1.59	0.28	-0.15	0.13	-8.421	55	.000	0.58
	RMSSD_HPP_Recovery (M1) - RMSSD_LPP_Recovery (M2)	1.55	0.23	1.56	0.27	-0.01	0.15	-0.430	55	.669	0.04
Simple main effects time	RMSSD_HPP_Baseline (M1) - RMSSD_HPP_During (M2)	1.59	0.25	1.44	0.28	0.15	0.14	8.008	55	.000	0.58
	RMSSD_HPP_Baseline (M1) - RMSSD_HPP_Recovery (M2)	1.59	0.25	1.55	0.23	0.04	0.08	3.753	55	.000	0.16
	RMSSD_HPP_During (M1) - RMSSD_HPP_Recovery (M2)	1.44	0.28	1.55	0.23	-0.11	0.15	-5.608	55	.000	0.43
	RMSSD_LPP_Baseline - RMSSD_LPP_During	1.56	0.27	1.59	0.28	-0.02	0.12	-1.446	55	.154	0.12
	RMSSD_LPP_Baseline - RMSSD_LPP_Recovery	1.56	0.27	1.56	0.27	0.01	0.10	0.448	55	.656	0.03
	RMSSD_LPP_During - RMSSD_LPP_Recovery	1.59	0.28	1.56	0.27	0.03	0.13	1.797	55	.078	0.12

Note: RMSSD: Root mean square of successive differences, HPP: high power pose; LPP: low power pose; M1: Mean 1, M2: Mean 2

Table 4

Post-hoc tests (simple main effects) for the repeated measures ANOVA ran to investigate the interaction effect between power pose (high vs. low) and time (baseline, power pose, recovery) on respiratory frequency

		M1	*SD1*	*M2*	*SD2*	*M difference*	*SD difference*	*t*	*df*	*p*	*Effect size (Cohen's d)*
Simple main effects power pose	RF_HPP_Baseline (M1) - RF_LPP_Baseline (M2)	2.55	0.13	2.55	0.15	0.00	0.12	-0.060	55	0.95	0.08
	RF_HPP_During (M1) - RF_LPP_During (M2)	2.56	0.14	2.62	0.14	-0.06	0.12	-3.851	55	0.00	0.43
	RF_HPP_Recovery (M1) - RF_LPP_Recovery (M2)	2.56	0.13	2.57	0.15	-0.01	0.11	-0.766	55	0.45	0.08
Simple main effects time	RF_HPP_Baseline (M1) - RF_HPP_During (M2)	2.55	0.13	2.56	0.14	-0.02	0.08	-1.621	55	0.11	0.08
	RF_HPP_Baseline (M1) - RF_HPP_Recovery (M2)	2.55	0.13	2.56	0.13	-0.01	0.08	-1.238	55	0.22	0.08
	RF_HPP_During (M1) - RF_HPP_Recovery (M2)	2.56	0.14	2.56	0.13	0.00	0.08	0.305	55	0.76	0.08
	RF_LPP_Baseline - RF_LPP_During	2.55	0.15	2.62	0.14	-0.08	0.09	-6.458	55	0.00	0.48
	RF_LPP_Baseline - RF_LPP_Recovery	2.55	0.15	2.57	0.15	-0.02	0.07	-2.375	55	0.02	0.13
	RF_LPP_During - RF_LPP_Recovery	2.62	0.14	2.57	0.15	0.05	0.07	5.222	55	0.00	0.34

Note: RF: Respiratory frequency, HPP: high power pose; LPP: low power pose; M1: Mean 1, M2: Mean 2

Table 5

Correlations between respiratory frequency and RMSSD, HF-HRV (FFT), and HF-HRV (AR)

	High power pose						Low power pose					
	Sitting			Standing			Sitting			Standing		
	Baseline	During	Recovery	Baseline	During	Recovery	Baseline	During	Recovery	Baseline	During	Recovery
RMSSD	.09	-.06	-.02	-.15	-.19	-.18	-.10	-.03	.07	-.08	-.07	-.04
HF-HRV (FFT)	.06	-.09	-.08	-.02	-.07	-.09	-.15	-.12	.14	-.02	-.16	.02
HF-HRV (AR)	.06	.00	-.04	-.08	-.16	-.10	-.08	-.06	.16	-.13	-.08	.01

Note: AR: Autoregressive; FFT: Fast Fourier Transform; HF: High-frequency; HRV: Heart Rate Variability; RMSSD: Root mean square of successive differences