Accepted Manuscript

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PII: S0965-2299(17)30715-X
DOI: https://doi.org/10.1016/j.ctim.2017.11.018
Reference: YCTIM 1775

To appear in: *Complementary Therapies in Medicine*

Received date: 20-10-2017
Accepted date: 27-11-2017

Please cite this article as: Allende Santiago, Anandan Anita, Lauche Romy, Cramer Holger.Effect of Yoga on Chronic Non-specific Neck Pain: An Unconditional Growth Model.*Complementary Therapies in Medicine* https://doi.org/10.1016/j.ctim.2017.11.018

Effect of Yoga on Chronic Non-specific Neck Pain: An Unconditional Growth Model

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Research highlights

- ▸Longitudinal analysis on pain intensity of participants with chronic neck pain.
- ▸Significant individual differences in linear rates of change.
- ▸Participants varied significantly in quadratic rates of change.

ABSTRACT

Objective: Chronic neck pain is a common problem that affects approximately half of the population. Conventional treatments such as medication and exercise have shown limited analgesic effects. The original study of which this analysis is based on was conducted to investigate the physical and behavioral effects of a 9-week Iyengar yoga course on chronic non-specific neck pain. This secondary analysis uses linear mixed models to investigate the individual trajectories of pain intensity in participants before, during and after the Iyengar yoga course.

Method: Participants with chronic non-specific neck pain were selected for the study. The participants suffered from neck pain for at least 5 days per week for at least the preceding 3 months, with a mean neck pain intensity (NPI) of 40mm or more on a Visual Analog Scale of 100mm. The participants were randomized to either a yoga group (23) or to a self-directed exercise group (24). The mean age of the participants in the yoga group was 46, and ranged from 19 to 59. The participants in the yoga group participated in an Iyengar yoga program designed to treat chronic non-specific neck pain. Our current analysis only includes participants who were initially randomized into the yoga group. The average weekly neck pain intensity at baseline, during and post intervention, comprising 11 total time points, was used to construct the growth models. We performed a step-up linear mixed model analysis to investigate change in NPI during the yoga intervention. We fit nested models using restricted maximum-likelihood estimation (REML), tested fixed effects with Wald test p-values and random effects with the likelihood ratio test. We constructed 10 REML models.

Results: The model that fit the data best was an unconditional random quadratic growth model, with a first-order auto-regressive structure specified for the residual R matrix. Participants in the yoga group showed significant variation in NPI in their intercepts and linear rate of change. Most tellingly, the participants showed a variation in their quadratic rate of change.

Conclusions: While all participants benefitted from the yoga intervention, the degree to which they benefitted varied. They did not experience a consistent rate of reduction in NPI – their NPI fluctuated, either increasing and then decreasing, or vice-versa. We comment on the clinical and research implications of our findings.

Key Words: neck pain; pain; yoga; randomized trial; longitudinal; mixed model; mixed procedure; growth model; repeated measures; unconditional growth curve model; linear mixed model; variance components model

INTRODUCTION

Chronic pain is highly prevalent [1,2] and has deleterious effect on the physical [5,6] and mental health [4,5] of those suffering from it. Additionally, chronic pain has a socioeconomic impact, contributing to both direct (physicians' visits, hospital stays, prescription drugs) and indirect (work absenteeism, disability) costs [7,21]. Neck pain is a common medical problem affecting approximately every other person [1] in the population and has been particularly shown to be prevalent among women [1,2,3,26,27,28] and the elderly [26,27,28]. Neck pain is associated with a decline in health-related quality of life [29] and has a major economic impact on society [25]. Conventional non-invasive treatments for neck pain include exercise, physical therapy, medication and educational interventions that utilize home exercises to improve self-efficacy [31]. However, such treatments have shown either negligible or small analgesic effects [32], warranting the investigation of supplementary approaches to ameliorate pain.

Yoga has increasingly been shown to be effective in relieving pain and disability [10] that accompanies multiple physical ailments [8,9] such as cancer and chemotherapy [36, 53,54,55,56,72], migraine headaches [33], osteoarthritis [34] and rheumatoid arthritis [35]. Several studies have investigated the impact of yoga on musculoskeletal pain in general [11,12,13] and lower back pain in particular [14,15,16,17,73]. However, at the time of the original study [50] the impact of yoga on chronic non-specific neck pain had not yet been investigated. This secondary analysis investigated individual differences in chronic non-specific neck pain intensity during the 9-week Iyengar yoga course. While longitudinal analyses of pain in general [65,67], and back pain in particular [64,68,69], have become more common, longitudinal analyses of neck pain [70] are less common. Extant research has yet to investigate individual differences in chronic non-specific neck pain intensity (NPI) during a yoga intervention. The present study was conducted to address this void in the literature.

METHODS

Participants

Participants were recruited through a local newspaper advertisement. Responders were screened by a researcher. Participants that successfully passed the screening interview were examined in person by a physician. The physician made physical and neurological assessments and also recorded medical and medication histories. Participants then completed a psychosocial questionnaire.

Participants included in the study were between 18 and 60 years of age who had self-reported non-specific neck pain for a minimum 5 days per week for at least the preceding three months. Each included participant's mean NPI on a Visual Analog Scale of 100mm was at least 40mm. Participants with specific causes of neck pain, which included radicular syndrome, congenital spine deformity, whiplash, disc protrusion, spinal canal stenosis and neoplasm, were excluded as were participants with rheumatic or oncological diseases. Participants who reported invasive spinal treatment during the previous month or spinal surgery in the previous 12 months were excluded from the study—as were pregnant women and participants who were not able to practice yoga due to physical disabilities. Participants with severe psychiatric disorders and somatic comorbidity were also excluded. Participants who had started a new treatment during the previous month as well as those who were planning to start a new treatment in the subsequent nine weeks were also excluded from the study. Participants who met these criteria were provided detailed information regarding the study. Final participants provided signed, informed consent. Final inclusion age ranged from 19 to 60 years, with a mean of 47.8. Females comprised 82.4% of total participants.

Procedure

The study was conducted in the Department of Internal and Integrative Medicine, Kliniken Essen-Mitte, University of Duisburg-Essen in Essen, Germany. The study was approved by the local ethics committee (approval number 10-4358) and registered at https://clinicaltrials.gov (registration number NCT01171274). A non-stratified block randomization with randomly varying block length was used to assign participants. The RANUNI function of the SAS language (created by Anthony Barr at North Carolina State

University) was used to generate random numbers. The generated random numbers along with their respective assigned interventions were individually printed and sealed in envelopes. After each successful assessment, the physician opened the envelope with the lowest available number to discover which intervention the participant was to be assigned to. Of the 58 participants included in the study, seven dropped out prior to group randomization; of those remaining, 25 were randomized to the yoga group and 26 were randomized to the exercise group. Two students in each group dropped out prior to the start of the intervention, resulting in 23 participants included in the yoga group and 24 participants in the exercise group. The participants in the exercise group were offered the opportunity to participate in a yoga course upon completing the study. The current analysis focused on data collected in the yoga group.

Measures

Visual Analog Scale for Pain Intensity

Study participants recorded their current neck pain intensity (NPI) in a daily diary for one week prior to randomization and 10 weeks post randomization. NPI was measured on a Visual Analog Scale (VAS) of 100 mm (0 indicated no pain, and 100 indicated unbearable pain). The weekly average NPI was used for this analysis. Participants were also asked to journal their supervised and self-directed yoga practice, and any treatment received during the study period, including medications and physical therapies.

Interventions

Yoga Intervention

Iyengar Yoga [51] is a school of Yoga developed by B. K. S. Iyengar. Iyengar yoga is characterized by detailed attention to posture form and the use of props. Props, such as belts and blocks increase stability and alignment and also reduce the risk of injury. Each participant was assigned to cohorts of 10 to 15 participants. The classes met once per week for 90 minutes for a total of nine weeks. The primary instructor for the course was both a certified Iyengar yoga teacher as well as a physiotherapist who had experience treating participants with chronic neck pain. A psychologist with a master's degree and specific experience treating chronic non-specific neck pain with Iyengar yoga functioned as a secondary instructor.

The intervention was designed for participants with chronic non-specific neck pain and no prior yoga experience. A pool of 14 yoga poses was selected to improve the posture and stability of the neck and shoulders, to lengthen and strengthen the neck and shoulder muscles and to also relax these muscle groups. Each pose was to be practiced in the standing, sitting or supine position. Each week eight to 11 poses were selected from the pool. Every session began with the mountain pose (the most basic standing posture) and ended with the corpse pose (a guided relaxation performed in the supine position). Each week, selected poses became increasingly challenging.

Participants were also required to engage in home practice for at least 10 minutes daily. The required home practice sequence did not vary during the intervention. The sequence included basic standing (mountain posture, standing half forward bend, warrior pose II) and sitting postures (Bharadvaja's twist, prosperous posture with and without spinal twist). Participants journaled daily home practice. As this secondary analysis did not investigate variation related to the home exercise group, the reader may refer to the previous paper for further details [50]. Participants in both groups were asked to make no changes to their routine medical care and medication protocols.

Statistical Analysis

We implemented a step-up linear mixed model procedure to investigate nonlinear change in NPI during the 9-week yoga intervention (see appendix A). We used Java (developed by James Gosling and now developed by Oracle Corporation) to structure the data. We used R within the RStudio integrated development environment (IDE) (version 0.99.489) to analyze the data [62,63]. Specifically, we used the nlme package (version 3.1-131) for the linear mixed model procedure and the ggplot2 package (version 2.2.1) to produce accompanying graphs [60,61]. We conducted an intent-to-treat analysis and used all available data as opposed to establishing a criterion for the minimum number of classes attended per participant (i.e., treatment-completer analysis). Although we recorded daily NPI measurements using a visual analog scale (77 days), for computational purposes related to model convergence errors, we computed average neck pain intensity per week, which resulted in 11 time points. We then centered the predictor, time, so that time 0 represented time point 1 of 11 total time points (henceforth referred to as baseline), including pre-and-post assessments.

We fit nested models using restricted maximum-likelihood estimation (REML), tested fixed effects with Wald test p-values and random effects with the likelihood ratio test. We constructed a total of 10 REML models: (1) an empty intercept-only model that calculated a population intercept (i.e., mean NPI); (2) a random intercept model that computed an intercept deviation for participants; (3) a fixed linear time, random intercept model; (4) a random linear time model that computed a slope deviation term for time across participants; (5) a fixed quadratic time, random linear time model; (6) a random quadratic time model that computed a quadratic time variance for participants; (7) model 6 with a first-order autoregressive structure specified for the residual R matrix; (8) model 7 with a heterogeneous (non-constant) variance structure specified for time in the residual R matrix, which resulted in a convergence error possibly due to overfitting; (9) model 7 with a cubic fixed effect for time; and (10) model 9 with a cubic random effect for time across participants.

RESULTS

Overall, 23 participants were included in this analysis, ages ranged between 19 and 59 (*M* = 46.16), and 87% female. The intra-class correlation value (ICC) computed for model 2 indicated that 53% of the variance in NPI was attributable to constant (mean) level-2 between-participant differences in NPI and that the remaining 47% of variation was due to within-participant level-1 residual variance. We therefore proceeded with the linear mixed model procedure. As determined by $\chi^2(\sim 1) = 110.9$, $p < .0001$, the ICC value of .53 was significantly different than 0 when compared to model 1, which differed only in being absent of a random intercept term. Adding time as a fixed effect (level-1 predictor) in model 3 accounted for 29.26% (pseudo-R^2) of the level-1 within-participant residual variance in model 2 (empty random-intercept-only model), (b = -2.33, $t(199) = -9.21$, $p<.001$). At this stage in the step-up procedure, this result suggested that on average participants' NPI decreased by 2.33 from week-to-week. We calculated the pseudo-R^2 statistic with equation 1 [74,76], where model 1 is the residual variance from the model with fewer parameters (model 2) and model 2 is the residual variance of the model with more parameters (model 3).

$$pseudo - R^2 = \frac{\sigma^2_{e\,model\,1} - \sigma^2_{e\,model\,2}}{\sigma^2_{e\,model\,1}} \times 100 \qquad (1)$$

We found a significant improvement in fit statistics between model 4 (random linear time model) and model 3 (fixed linear time, random intercept model), $\chi^2(\sim 2) = 20.2$, $p < .0001$. That is, we found significant individual differences in the rate of change in NPI over time. We did not find the quadratic fixed effect of time to be significant in model 5, (b = 0.14, $t(198) = 1.63$, p=.104). That is, on average, there was no acceleration or deceleration of NPI from week-to-week.

However, the likelihood ratio test determined that including a random variance component of quadratic time (model 6) significantly improved model fit, χ^2 (~3) = 51.3, $p <$ .0001. Thus, we found significant individual differences in how much participants experienced acceleration and deceleration of NPI over time. Model 7, which included a first-order autoregressive correlation structure in the R matrix (residual within-participant level-1 variance), significantly improved model fit, χ^2(~1) = 6.8, p = .009. Model 7 determined that the within-participant residual correlation decreased from week-to-week with an initial Spearman's rho value of ρ = .32 (lag-2 $= .32^2$). As stated above, model 8, in which a heterogeneous error structure was specified for the within-participant R-matrix, resulted in a convergence error possibly due to overfitting. The fixed cubic model (model 9), was not significant, (b = 0.24, $t(197) = -0.78$, p = .437). Moreover, the random cubic model did not significantly improve model fit, χ^2(~4) = 0.59, p = .964.

Hence, the model that fit the data best was model 7, the random quadratic time model with a first-order auto-regressive structure specified for the level-1 (i.e., within-participant) R-matrix. Equation 2 specifies model 7:

$$y_{ti} = \gamma_{00} + \gamma_{10}x_{1ti} + \gamma_{20}(x_{1ti})^2 + u_{0i} + u_{1i}x_{1ti} + u_{2i}(x_{1ti})^2 + R_{t+1,i} \qquad (2)$$

with $R_{t+1,i} =$

$$\begin{pmatrix} \sigma_e^2 & \rho_e^1\sigma_e^2 & \rho_e^2\sigma_e^2 & \rho_e^3\sigma_e^2 & \cdots & \rho_e^{10}\sigma_e^2 \\ \rho_e^1\sigma_e^2 & \sigma_e^2 & r_e^1\sigma_e^2 & r_e^2\sigma_e^2 & \cdots & \rho_e^9\sigma_e^2 \\ \rho_e^2\sigma_e^2 & \rho_e^1\sigma_e^2 & \sigma_e^2 & \rho_e^1\sigma_e^2 & \cdots & \rho_e^8\sigma_e^2 \\ \rho_e^3\sigma_e^2 & \rho_e^2\sigma_e^2 & \rho_e^1\sigma_e^2 & \sigma_e^2 & \cdots & \rho_e^7\sigma_e^2 \\ \vdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ \rho_e^{10}\sigma_e^2 & \cdots & \rho_e^3\sigma_e^2 & \rho_e^2\sigma_e^2 & \rho_e^1\sigma_e^2 s & \sigma_e^2 \end{pmatrix}$$

where y_{ti} is the outcome, NPI, for individual *i* at time *t*; γ_{00}, given the model, is the fixed intercept (i.e., mean intercept) for NPI at baseline; $\gamma_{10}x_{1ti}$, is the fixed linear effect of time (i.e., mean regression coefficient for time); $\gamma_{20}(x_{1ti})^2$, is the fixed quadratic effect of time; u_{0i}, is the predicted random intercept deviation (from γ_{00}) for individual *i* at baseline; $u_{1i}x_{1ti}$, is the predicted random linear effect of time for individual *i* (i.e., individual *i's* predicted deviation from $\gamma_{10}x_{1ti}$) , which can also be expressed as a random interaction between the grouping variable, participant (*i*), and time; $u_{2i}(x_{1ti})^2$, is the random quadratic effect of time; and, $R_{t+1,i}$, is the first-order auto-regressive (AR1) R matrix for individual *i*.

It may be important to note that the model does not uniquely estimate individual u_{ni} and $R_{t+1,i}$ terms as model parameters but instead computes their variances (i.e., τ_n^2) from which individual weighted predictions, known as empirical Bayes estimates are derived [74]. Thus, the individual trajectories produced in the accompanying graphs are not to be interpreted as comprised of values uniquely estimated for each participant but instead as weighted predicted trajectories subject to shrinkage (i.e., regression to the mean) [74]. In the context of missing data, those with fewer observed values will be predicted to have trajectories more similar to the population trajectory (fixed estimates), which in turn is influenced by participants with more observed values [74]. We checked assumptions of normality, independence and constant variance at both level 1 and level 2 [77]. None of the diagnostic plots revealed aberrant deviations from these assumptions.

Using model 7 and equation 2 [74,75], we provide random effects 95% confidence intervals for how much participants were expected to vary around the fixed estimates.

$$Random\ Effect\ 95\%\ CI = fixed\ effect\ \pm (1.96\ \times \sqrt{random}\ variance \qquad (2)$$

At baseline, 95% of the of the sample intercepts were expected to vary around the mean NPI score (γ_{00}= 43.30) between 14.15 and 76.92. We found participant slopes to vary around the average rate of change in NPI (γ_{10}= -3.78) between -15.06 and 7.49. This suggests that at least one participant was predicted to experience an increase of NPI over time. Participants' quadratic rates of change varied between -1.02 and 1.32.

DISCUSSION

This secondary analysis demonstrates that the reduction in pain intensity which was observed in the original randomized controlled trial varied significantly among participants in the yoga group in 3 aspects: (1) the intercept, (2) the linear rate of change and (3) the quadratic rate of change. The intercept variance component (1), introduced in model 2 (random intercept model), refers to constant linear decrease in NPI over time; with some participants predicted to have an NPI consistently above the mean NPI and some below the mean NPI. The linear variance component (2) introduced in model 4 suggests that participants varied in their linear rates of change in NPI. Prototypically, some participants were predicted to experience a greater reduction of NPI than others, however, one participant was predicted to experience a linear increase in NPI (participant 18). The significant quadratic variance component (3) found in model 6 demonstrates differences across participants in the rate at which the NPI linear rate of change, changes. That is, the quadratic rate of change for NPI was not consistent across participants.

Two of the individual predicted trajectories in figures 2.1 through 2.3 (participants 11 and 20) help to elucidate these three findings. As illustrated by the random intercepts in figure 2.1, participant 11 was predicted to have an NPI trajectory consistently above the population average (black line) and participant 20 was predicted to have an NPI trajectory consistently below the population average. In figure 2.2, as indicated by the slopes, while participant 11 was predicted to have a greater reduction in NPI than the population mean, participant 20 was predicted to have a smaller reduction in NPI than the population mean. Interpolating this finding suggests that participant 11 experienced a greater reduction in NPI than participant 20. As depicted in figure 2.3, whereas participant 11 was predicted to have a negative quadratic coefficient, participant 20 was predicted to have a positive quadratic coefficient. The differences in the signs of the quadratic coefficients suggest that their linear rates of change were affected differently over time. Participant 20 was predicted to experience an initial decrease in NPI followed by a slight increase and participant 11 was predicted to experience an initial increase followed by a decrease. In other words, participant 20 experienced a deceleration in their reduction in NPI and participant 11 experienced an acceleration in their reduction of NPI.

Clinical Implications

This analysis shows that while yoga does alleviate NPI, its effect differs significantly across participants. In fact, some yoga practitioners with neck pain may first experience an *increase* in NPI and then experience a decrease. Others may experience a sharp decrease followed by a slight increase.

Yoga instructors aware of this variation among participants might choose to continually modify yoga sequences as they observe students' differing levels of pain. They might also train students to check in with themselves on their current level of pain, and not rely on the pain they experienced the previous week. This might help reduce adverse effects caused by attempting challenging postures on days where the pain has increased, and might help students progress to more challenging postures on days with low pain. Physicians aware of these variations could help patients control their analgesics intake by educating them on the dynamic nature of pain intensity. Educating patients on the fluctuating nature of pain while practicing yoga might also help them to build realistic expectations of the recurrent nature of pain, as well as make them aware that a setback could be temporary. A more realistic estimation of their pain might help patients improve their pain coping efficacy [71].

Research Implications

In addition to pre-to-post investigations of chronic pain, it is important to delineate how the pain trajectory fluctuates and recurs differently across individuals. However, longitudinal analyses in the field of chronic pain are relatively few. While longitudinal studies of pain have become more common [64,65,67,68,69], there is a paucity of longitudinal studies on neck pain [70]. The present study addressed this gap in the literature by testing an unconditional growth curve model of chronic non-specific neck pain intensity during a 9-week Iyengar yoga intervention. We believe that it is critical for future studies to determine predictors that explain the different sources of variance found in this analysis (i.e., intercept, linear, quadratic). A review of the literature suggests that occupation and workplace factors, psychosocial factors such as stress, anxiety and depression [40,41,44,49] and a history of neck or back pain [38] are strong candidates to predict these different sources of variance [39,42,43,45,46,47,48,50].

Conflicts of Interest: No authors on this manuscript have any conflicts of interest.

Funding: The original study was supported by a research grant from the Karl and Veronica Carstens Foundation, Essen, Germany. No external funding was received for this analysis.

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

Authorship

Dr. Holger Cramer designed and executed the study and managed the data collection and scoring processes. Romy Lauche designed the study and collected the data. Anita Anandan and Santiago Allende executed the statistical analyses, interpreted the results and drafted the paper. Each author listed reviewed all work and all authors hold equal responsibility for the accuracy and validity of the paper's content. If concerns arise regarding such matters, authors will collaborate to resolve the brought forth issues.

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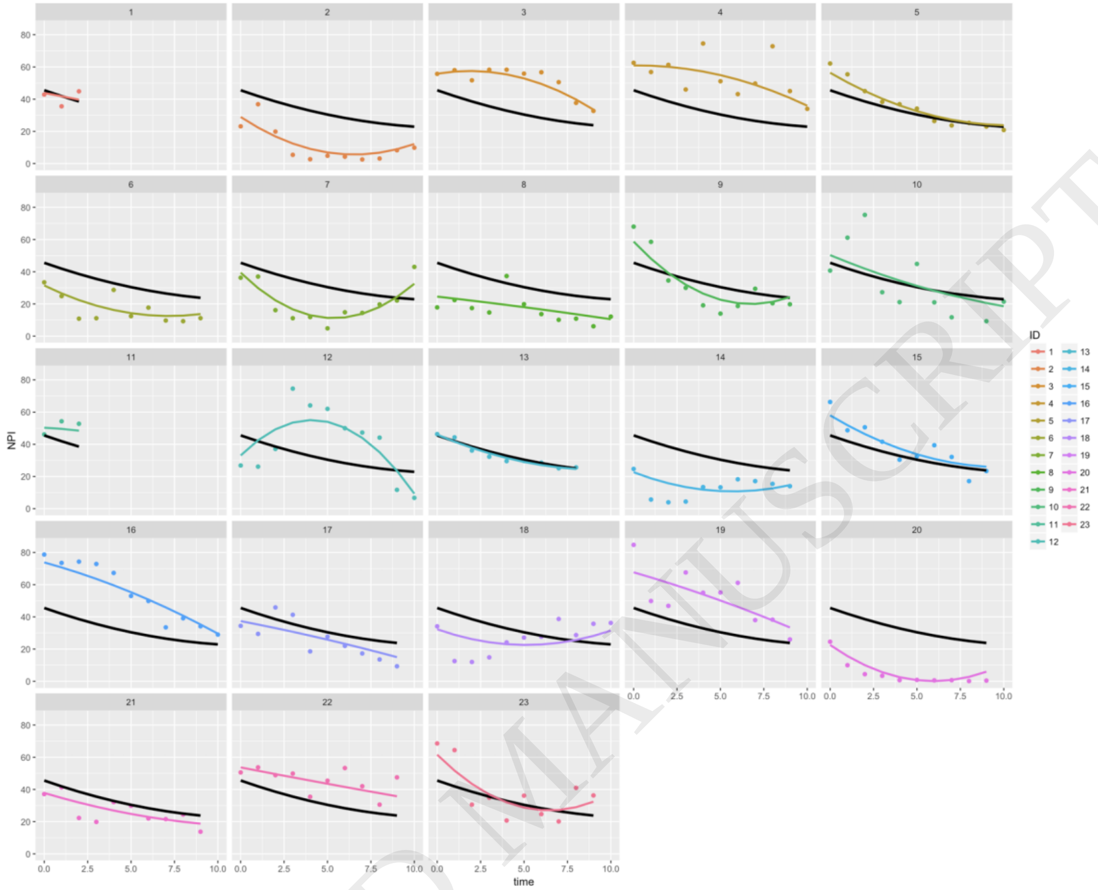
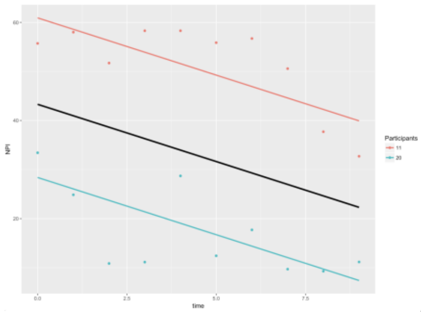
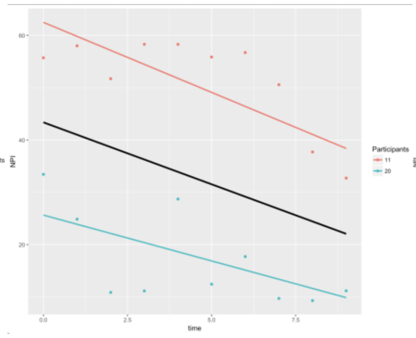


Figure 1. Model 7 predicted unconditional growth model trajectories for individual participants.





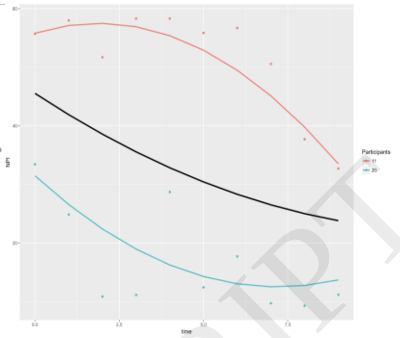


Figure 2.1 Model 3: Fixed Linear Time, Random Intercept

Figure 2.2 Model 4: Random Linear Time

Figure 2.3 Model 6: Random Quadratic *Note.* The black line represents the population mean.

Table 1.0

Postures in Yoga Course

POSTURE		**WEEK**								
(English)	*(Sanskrit)*	1	2	3	4	5	6	7	8	9
Bharadvaja's twist	Bharadvājāsana	x	x							
Bridge pose	Setu bandha sarvāngāsana	x				x	x	x		
Corpse pose	Shavāsana	x	x	x	x	x	x	x	x	x
Downward facing dog	Adho mukha svānāsana		x	x	x	x	x	x	x	x
Downward facing hero	Adho mukha virāsana		x	x		x			x	x
Extended side angle	Utthita pārshvakonāsana	x		x	x		x	x	x	x
Extended triangle	Utthita trikonāsana		x							
Mountain pose	Tādāsana	x	x	x	x	x	x	x	x	x
Prosperous pose	Svastikāsana			x	x	x	x	x	x	x
Reclining big toe	Supta pādāngusthāsana	x		x		x	x	x	x	x
Standing half forward bend (at wall)	Ardha uttānāsana	x	x	x	x	x	x	x	x	x

Thunderbolt pose	Vajrāsana		x	x		x	x	x	x	
Upward hand pose	Ūrdhva hastāsana				x	x				
Warrior pose II	Vīrabhadrāsana II	x	x	x	x	x	x	x	x	x