Delineating the Impact of Tai Chi Training on Physical Function Among the Elderly

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Background:
Through a re-analysis of a Tai Chi intervention data set, the study objective was to determine which, if any, subgroups of the study sample evidenced differential benefits from the intervention.

Method:
Re-analysis of a Tai Chi intervention study, a randomized controlled trial in Eugene and Springfield, Oregon. Physically inactive participants aged ?65 years were randomly assigned to one of two groups: Tai Chi (n=49) and a wait-list control (n=45). The main outcome measure was self-reported physical function.

Results:
Initial latent curve analyses indicated significant Tai Chi training effects: Participants in the Tai Chi group reported significant improvements in perceived physical function compared to those in the control group. However, there was significant interindividual variability in response to Tai Chi. The overall intervention effect was further delineated by identifying two subgroups. This delineation showed that Tai Chi participants with lower levels of physical function at baseline benefited more from the Tai Chi training program than those with higher physical function scores. Inclusion of additional measures of individual characteristics at baseline, change in movement confidence, and class attendance further explained differences in treatment responses.

Conclusions:
Findings from this study suggest that although an intervention may show an overall effect (or no overall effect), it may be differentially effective for subgroups of participants that differ in their pre-intervention characteristics. Examination of variability in outcome measures can provide important information for refining and tailoring appropriate interventions targeted to specific subgroups.
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Many Tai Chi intervention studies have demonstrated health benefits in older adults.'-12 However, it remains unclear which particular groups of elderly individuals are most likely to benefit from Tai Chi. The effectiveness of Tai Chi as measured in experimental studies is often declared on the basis of the observed significant mean difference between experimental and control groups on targeted outcomes of interest. This is because, with few exceptions, data from Tai Chi studies have been analyzed using the repeated-measures, analysis-of-variance model or some variation of it. However, this analytic approach is overly restrictive because it focuses primarily on the significance of group mean differences, with the variability around the means constituting error. The magnitude of the variability in the experimental and control group means is of special interest to researchers conducting ran;~omized control trials because it holds the key to identifying individual differences in response to targeted outcomes of interest.

There is considerable evidence in the behavioral science literature that individuals benefit differently from a given preventive intervention. [13-16] It is therefore important to determine which participants benefit most, least, or both from an intervention. Examining the heterogeneity of outcome can be vital for guiding decisions that will shape the design and evaluation of future intervention studies or for developing programs more finely tailored for specific subgroups.

This study used a general growth-mixture model (GGMM)[17,18] to examine more precisely the impact of a Tai Chi training intervention on physical function in older adults. We wished to determine which, if any, subgroups of our sample evidenced differential benefits from the intervention. The study primarily addressed two research questions: (1) Does Tai Chi improve physical function? (2) If so, do all participants benefit equally from the intervention? The GGMM methodology was chosen because it enabled us to determine heterogeneity concerning individual differences in responding to an intervention and to examine the impact of an intervention on subgroups of individuals identified on the basis of their response patterns to the intervention.

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Method

Study Data

The data were drawn from an experimental study examining the health benefits of Tai Chi. Details of the study design and recruitment are presented elsewhere. 7 Briefly, participants in the intervention group attended a 60-minute Tai Chi session twice a week for 6 months. Participants assigned to the control group were instructed to maintain their usual daily activities. Data on self-rated physical function were obtained on all subjects for intervention and control conditions at the baseline, midpoint, and endpoint of the study.

Sample

A total of 94 healthy, physically inactive older adults participated in the study. [7] Of these, 49 were assigned to the intervention group of Tai Chi practice (mean age=72.8, standard deviation [SD]=4.7) and 45 were assigned to a wait-list control group (mean age=72.7, SD=5.7).

Measures

Outcome measure. Physical function was assessed using a subscale from the Short-Form General Health Survey (SFGHS).[ly] This measure contains six items assessing the extent to which health problems limit daily living activities. Responses were originally reported on a 3-point scale (1=limited, 3=not limited). The total score was transformed to a 0-to-100 scale, with higher scores indicating better physical function. The Cronbach alpha (internal consistency coefficient) was satisfactory across the three time points (a?0.82).

Other measures. In addition to demographic measures (i.e., age and education), quality-of-life measures at baseline included perceptions of health and depression. Perceptions of health were assessed using a composite of three subscales of the SFGHS: (1) general health perceptions, (2) bodily pain, and (3) mental health. Each scale had an acceptable reliabiiiry (a coefficient?0.70) at baseline. Depression was measured via the 20-item Center for Epidemiological Studies-Depression scale. 2' The possible responses for this scale ranged from 0 to 60 with higher scores indicating depression. The Cronbach alpha for this scale measured at baseline was 0.86 for the sample.

Two additional intervention-related variables were also included: movement confidence and class attendance. Participants were asked to indicate, on a 0-to-10 confidence scale, the degree of confidence they had in their ability to successfully perform a series of slow, rhythmically changing, body position movements.' The alpha of ?0.92 was satisfactory at the baseline and endpoint. The difference score (endpoint-baseline) was used in the analyses. Class attendance was recorded by the instructor.

It is important to note that the demographic and two quality-of-life measures were unrelated to the intervention but may have moderated intervention trajectories. Also, the change in movement confidence and attendance measures were related to intervention (i.e., they occurred after the intervention) and therefore may have co-varied concomitantly with (or mediated) changes in the outcome variable.

Missing Values

Participants who dropped out prior to the midpoint assessment (n=5 in Tai Chi group; n=11 in control group) were assigned their baseline scores. Participants who dropped out before the endpoint assessment (n=4 in Tai Chi group; n=2 in control group) were assigned their midpoint scores. Analyses of the data from subjects who dropped out indicated that the results would be comparable whether their scores were excluded or whether the data were analyzed using the maximum-likelihood statistical method.[21]

Analysis

We analyzed the data in three steps. In Step 1, we assessed mean changes in physical function between the Tai Chi and control groups followed by the intervention-baseline (initial status) interaction analysis.[22] In Step 2, the core of the study analyses, we introduced a categorical latent variable (e.g., high, medium, and low), which represented latent class trajectories (i.e., groups), to determine if the intervention had a differential effect for these subgroups. 23 In Step 3, conditional analyses were conducted using regression analyses by linking demographic and quality-of-life variables, change in movement confidence, and class attendance to the identified class trajectories.

The Mplus software[2]l was used for all analyses. For the multigroup growth curve analysis in Step 1, a maximum-likelihood estimation procedure was used to fit models and obtain parameter estimates. Model fit statistics are based on the chi-square statistic and two goodness-0f-fit statistics: nonnormed fit index (NNFI)[24] and comparative fit index (CFI).[25] For the growth mixture analysis in Step 2, Mplus uses the principle of maximum likelihood estimation and employs the expectation maximization algorithm for maximization. 17,2s Model fit for a mixture analysis is defined by the log likelihood value. Additional measures include the following Bayesian information criteria-based measures: (1) Akaike information criterion (AIC)[27]; (2) Bayesian information criteria kBIC)[28]; and (3) a sample size-adjusted BIC (ABIC).[21] Choosing a model with the smallest AIC, BIC, or ABIC value is recommended.

Results

Conventional Growth Curve Analysis

The analysis in Step 1 indicated that the two-group intervention model fit the data reasonably well (X^2=37.255, df=9, p<0.001, NNFI=0.95, CFI=0.97). Of most importance was the significant mean estimate of the treatment growth factor, 8.452 (standard error [SE] =1.863, t=4.536, p<0.01). This significant positive mean estimate reflects a treatment effect over and above the normative developmental trajectory of the control group. The estimated mean trajectories across the three time points (baseline, midpoint, and endpoint) of the study are plotted in Figure 1 (figure is missed true transfer process), which shows that, compared to those in the control group, participants in the Tai Chi group reported significant improvements in their levels of physical function over the course of the study. 7 For each associated mean trajectory, there was a significant slope variance (for Tai Chi group: Var=90.06, p<0.05; for control group: Var=103.93, p<0.05), indicating there were significant individual differences in trajectories over the course of the 6-month intervention across both conditions.

Further analysis showed a significant treatment-byinitial-status interaction effect as indicated by the regression coefficient, (3=-0.679 (5E=0.195, t=-3.473, p<0.001). This indicated that participants in the Tai Chi group responded differently to the Tai Chi practice. The overall improvement in physical function varied as a function of initial status (i.e., level of physical function at baseline). The negative coefficient indicates that participants with a lower initial status (i.e., individuals who reported limitations in functioning) tended to improve at significantly steeper rates over the course of study (i.e., benefited more from the Tai Chi practice) compared to participants with a higher initial status.

Growth Mixture Analyses

The previous analyses confirmed that Tai Chi enhances physical function but also indicated that not all Tai Chi participants benefited equally from the intervention. In the Step 2 analyses, we tested two growth mixture models: (1) a two-class, growth mixture model, and
(2) a three-class, growth mixture model. These models consisted of distinct trajectory groups conditional on intervention status.

Model-fitting statistics indicate that both the two-class and three-class models fit the data equally well (log likelihood=-1212.61, AIC=2451.23, BIC=2484.29, ABIC=2443.25, for the two-class model; log likelihood=-1207.01, AIC=2446.03, BIC=2486.72, ABIC=2436.21, for the three-class model). However, the two-class model was preferred because it used fewer parameters and provided a better distinction between "improvement versus no improvement" trajectory groups. Therefore, the two-class model was retained for substantive interpretation of the intervention data.

The mixing proportions of the class memberships from the joint analysis of the control and Tai Chi groups were 64% (n=60) for Class 1 and 36% (n=34) for Class 2. This classification was made on the basis of the participants' repeated measure pattern on the outcome behavior (physical function) for the whole sample (n=94). Individuals identified in Class 1 tended to have high baseline scores on physical functioning and showed little change during the 6-month intervention period. Individuals in Class 2, however, had low baseline scores in physical function and showed a linear upward trajectory. Based on class-specific growth trajectorie~ conditional on intervention status, the two classes of study participants can be characterized as a "high initial status with no improvement" group (Class 1: "high, no change") and a "low initial status with improvement" group (Class 2: "low, change").

The magnitude of intervention effects is described by the coefficient (y_k) as a change in average growth rate that can be different for different classes lZ.23 Inspection
Figure 2(figure is missed true transfer process). Estimated, within-class growth mean trajectories across study conditions
of this coefficient, y_2=6.83, indicated a beneficial intervention effect for the "low, change" group (t=8.13, p<0.001), implying that participants in the experimental condition experienced a significant improvement in physical function over the 6-month intervention. The coefficient for the "high, no change" group, y_t=0.34, was not statistically significant (t=0.48, p=0.63. Figure 2 shows the estimated, within-class (group) growth means for the two-class model. These trajectories further delineated differences in the "low, change" group. Participants in the Tai Chi group improved their physical function scores more significantly than participants in the control group (n=16), who showed little or no improvement. Variance for each subgroup is also presented in Figure 2, with an indication of significant variation in the Tai Chi condition.

Conditional Analyses: Tai Chi Group Only

To gain an understanding of how levels of these measures might be associated with the identified class memberships, the variables of health perceptions, depression, class attendance, and movement-confidence change scores were dichotomized using a median split resulting in a dichotomous variable (low, high). We then constructed an interaction term of mixture group status (i.e., Class 1=high, no change; 2=1ow, change) by health perceptions (1=high, 2=1ow); depression (1=low; 2=high [clinical cutoff scores ?16])[2°]; change in movement confidence (1=1ow, 2=high); and class attendance (1=1ow, 2=high).

The regression model included health perceptions, depression, class attendance, and movement confidence, along with the interaction terms specified
above. Participants' age and education were also entered into the equation as control variables. The main results of the regression analyses are presented in Table 1 and show a significant effect for all the interaction terms. Results indicate that Tai Chi participants with initial low levels of physical function, who reported low levels of health perceptions and high levels of depression at baseline, tended to benefit more in terms of changes in physical function than those with higher perceptions of health and lower depression. In addition, results showed the influence of the two intervention-related variables (i.e., movement confidence and class attendance). Specifically, individuals in the "low, change" group who reported improved movement confidence (i.e., greater change scores) and had regular class attendance were shown to benefit more from the intervention than those with low improvements in movement confidence and less frequent class attendance.

Discussion

Table 1. Regression(not complete true transfer process)

Variables			
Perception of health by classes	26.88	9.14	0.00
Depression by classes	13.05	4.96	0.00
Change in self-efficacy by	23.70	2.15	0.04
Class attendance by classes	1.35	8.83	0.00

A number of implications can be drawn from this study. First, researchers should exercise caution when claiming the effectiveness of an intervention based solely on an index of the group average (i.e., mean level) or a simple effect-size statistic. Where there are substantial differences in outcome between the intervention conditions, a single estimate of the overall treatment may be misleading or overly simplistic. The individual variability associated with the intervention needs to be taken into account. Conversely, in the absence of a significant overall effect, an intervention may have had an impact on subgroups of individuals with varying background characteristics. Second, the finding that participants with initially low physical function scores benefited more than those with higher scores suggests that Tai Chi interventions may need to be further tailored to individuals with various baseline health related scores, trajectory classes, or both. For example, healthy individuals with little or no functional limitations may need to be placed in a training class that employs more intensive/vigorous practices to promote appreciable changes in health-related physical function. In contrast, those who have functional disabilities, impairments, or both may benefit from taking more frequent classes involving low-to-moderate movement activities. Third, the detection of differential intervention effects calls for consideration of group-specific covariates that account for the differences observed. These can be time-invariate background characteristic measures (e.g., gender), time-varying measures (e.g., medical conditions), or both. Fourth, the results from our conditional analyses showed that participants who reported increases in movement confidence tended to improve the most in physical function, indicating that changes in movement confidence as a result of the Tai Chi intervention may possibly mediate the relationship between Tai Chi and physical function.

The findings also raise questions about the doseresponse dimension (frequency, intensity, duration, and type) of physical activity in promoting certain aspects of health and physical functioning. [29] That is, it is assumed that different doses of activity have different effects on different outcome variables. What researchers often overlook regarding dose-response is the relationship between initial status and total improvement potential. Theoretically, the lower the initial status level the greater the improvement potential, which may mask or be masked by mean treatment effects. The growth potential issue is affirmed in the present analyses: Compared to the "high, no change" participants, the "low, change" participants in the Tai Chi condition moved from having lower scores in physical function to having higher function scores at the endpoint. Conversely, the healthiest subgroup in our sample evidenced little or no improvement as a result of Tai Chi exercise. This shows that there is often considerable

heterogeneity to account for when assessing dose-response of physical activity." Therefore, a closer examination and testing for pre-existing differences on baseline characteristics and their potential association with subsequent intervention response may be required. If necessary, pre-existing differences may need to be controlled for to prevent intervention effects from being masked or overestimated.

The current study is not without limitations. One limitation stems from the use of self-report measures of physical function. Self-reported measures are often the source of problems related to restricted scoring range and decreased sensitivity to change. It is plausible that participants in this study who had higher baseline values improved less (due to the ceiling effect) than did those with lower baseline values. Future studies that use objective physical health measures (e.g., functional tests) would not only help confirm the current findings but also provide a more rigorous examination of the effects of Tai Chi on physical function.

In summary, the results from this study indicate that Tai Chi has a main effect on physical functioning in the elderly and that these effects are most beneficial to participants who had low physical functioning at baseline. Evaluations of differential treatment effects can be used to refine future intervention efforts for those who have initial low levels of physical functioning at baseline.

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