Evaluation and Interpretation of 9 Body Constitution Scores of CCMQ-J by Seven Independent Questionnaires

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[ABSTRACT]
In this study, we proposed an approach to interpret the classification of body constitution based on the Japanese Version of Constitution in Chinese Medicine Questionnaire (CCMQ-J) in terms of an augmented questionnaire combining seven independent questionnaires. The augmented questionnaire consists of 254 questions in terms of seven categories of attributes, which are the (i) basic information (BI), (ii) disease (DI), (iii) social factors (SO), (iv) mental factors (ME), (v) dietary habits (DH), (vi) sleeping state (SL), and (vii) sub-health (SH). The partial least square (PLS) regression has been adopted to model the correlations between the scores of body constitutions and the questions, and their results show that the body constitution can be represented by the linear combination of the questions substantially (correlation coefficients between the true and predicted constitutions are all above 0.7). Moreover, by using the crowdsourcing technique in data collection, a total of 851 samples (350 males and 501 females between 20 and 85 years old) samples with diverse geographical backgrounds in Japan have been collected, from which new medical implications have been extracted through the discussion in a Traditional Chinese Medicine standpoint. This study serves as a crucial step for validating the philosophy of ancient Chinese medicine by the state-of-the-art information science techniques and facilitating the use of the CCMQ-J in public healthcare.

[Key words]
CCMQ-J, healthcare questionnaires, data science, crowdsourcing, Partial Least Squares method (PLS)

INTRODUCTION
The concept as a balance between a person and the environment, the unity of mind and body, and the natural origin of disease, was the backbone of the perception of health in ancient Greece and in...
Chinese traditional medicine systems based on body constitution that means body and quality or substance\(^2,7\) (morphological structure, physiological function, and psychological state). The constitution is partly genetically determined and partly acquired, which classifies individuals’ constitutions into nine types based on Chinese medical theory, multidisciplinary studies, and clinical practice.\(^2\). According to the shape of the human physical, functional, psychological, and other characteristics, an individual constitution can be assessed by the Constitution in Chinese Medicine Questionnaire (CCMQ) developed by Wang et al\(^3,5\) which has been translated in Japanese called Japanese version of CCMQ (CCMQ-J)\(^6,7\). The nine constitution types were classified into a balanced constitution (i.e. Gentleness type, abbreviated as GN), and the eight types of unbalanced types, (i) Qi-deficiency (QF), (ii) Yang-deficiency (YA), (iii) Yin-deficiency (YI), (iv) Phlegm-wetness (PW), (v) Wet-heat (WH), (vi) Blood-stasis (BS), (vii) Qi-depression (QD), and (viii) Special stasis (ST). The nine types of body constitutions of CCMQ-J are derived from Likert scales of 60 questions from 1 to 5 assigned as never, rarely, sometimes, often and always, respectively. Scores of the nine constitutions are calculated by nine equations for the body constitutions using the scores of the 60 questions\(^3,5\).

Currently, Meikirch proposed the definition of health integrating a new view in 2014 summarized as follows\(^8\), “Health is a dynamic state of well-being emergent from conductive interactions between an individual’s potentials, life’s demands, and social and environmental determinants. Life’s demands can be physiological, psychosocial, or environmental, and vary across individuals and contexts, but in every case, unsatisfactory responses lead to disease.” The theory of TCM constitution provides personalized services and different food properties, different guidance on diet habits, and always, respectively. Scores of the nine constitutions are calculated by nine equations for the body constitutions using the scores of the 60 questions\(^3,5\).

PLS Regression analysis

The PLS method has been widely used in medical imaging as well as the chemo- and bio-informatics fields because PLS models can be constructed even if there are more variables than observations\(^21\). In addition, this method can be applied if multi-collinearities are hidden between the independent variables\(^21\). PLS regression models were constructed for estimating the scores for nine body constitutions in CCMQ-J (Table 1) from questions in the seven questionnaires introduced above (Table 2). Here, scores for 9 body constitutions were calculated by using the scores for questions in CCMQ-J (Table 1) according to the calculation equation reported by refs\(^6,7\) and all body constitution scores and all values of the questions in the seven questionnaires other than CCMQ-J were normalized into zero for means and one for standard deviations.

The objective variable, \(Y\), corresponds to the score for one of the body constitution of CCMQ-J, and the interpretive variables \(X_1, X_2, \ldots, X_M\) corresponds to scores for questions of different questionnaires from CCMQ-J are correlated by a linear model as Eq. (1)

\[
Y = a_0 + a_1X_1 + \ldots + a_jX_j + \ldots + a_MX_M
\]

Here M represents the total number of the questions. The PLS model is represented in Eqs (2) and (3).

\[
y = \bar{y} + \sum_{k=1}^{M} t_ikq_k + e = \bar{y} + T\cdot q + e \quad (2)
\]

\[
X = \bar{X} + \sum_{k=1}^{M} p_kq_k + E = \bar{X} + P\cdot q + E \quad (3)
\]

where \(q_k\) is the coefficient of \(y\) for the \(k^{th}\) component, \(p_t\) is the loading vector of \(X\), \(A\) is the number of components, and \(t_t\) is a score vector for the \(k^{th}\) component. The residual matrix and vector are represented by \(E(M\times N)\) and \(e(M\times 1)\), respectively. Eqs (2) and (3) can be combined to create Eq (4).

\[
Y = \bar{y} - \bar{X}'W(P'W)^{-1}q + X'(P'W)^{-1}q \quad (4)
\]

The number of PLS components was determined by maximizing the \(Q^2\), which was calculated by a leave one out cross-validation for each component, as shown in Eq (5).

\[
Q^2 = 1 - \frac{\sum_{i=1}^{N} (y(i) - y_{cr})^2}{\sum_{i=1}^{N} (y(i) - \bar{y})^2} \quad (5)
\]
### Table 1 The questionnaire of CCMQ-J

| ID  | Questions                                                                 |
|-----|---------------------------------------------------------------------------|
| C1  | SH: Were you energetic?                                                   |
| C2  | SH: Did you get tired easily?                                             |
| C3  | SH: Did you suffer from shortness of breath?                              |
| C4  | SH: Do you get nervous easily?                                            |
| C5  | SH: Did you get dizziness easily or become giddy when standing up?        |
| C6  | ME: Did you prefer quietness and do not like talk?                        |
| C7  | SH: Do you feel feeble when talking?                                      |
| C8  | ME: Did you feel gloomy and depressed?                                    |
| C9  | ME: Do you get nervous and worried easily?                                |
| C10 | ME: Do you feel sensitive, vulnerable or emotionally upset?              |
| C11 | ME: You easily scared or frightened?                                     |
| C12 | SH: Did you experience distention in the underarm or breast?             |
| C13 | SH: Did you feel chest or stomach stuffiness?                            |
| C14 | ME: Did you sigh for no reason?                                           |
| C15 | SH: Did your body feel heavy or lethargic?                                |
| C16 | SH: Do the palms of your hands or soles of your feet feel hot             |
| C17 | SH: Did your hands or feet feel cold or clammy?                           |
| C18 | SH: Did you feel cold easily in your abdomen, back, lower back or knees? |
| C19 | SH: Were you sensitive to cold and tend to wear more clothes than others |
| C20 | SH: Did your body and face feel hot?                                      |
| C21 | SH: Did you feel more vulnerable to the cold than others                  |
| C22 | SH: Did you catch colds more easily than others                           |
| C23 | SH: Did you sneeze even when you did not have a cold?                    |
| C24 | SH: Did you have runny or stuffy nose even when you did not have a cold? |
| C25 | SH: Did you cough due to seasonal change, temperature change, or unpleasant odor?|
| C26 | SH: Did you sweat easily when you had a slightly increased physical activity?|
| C27 | SH: Did you forget things easily?                                        |
| C28 | SH: Did you have an excessively oily forehead and/or t-zone?             |
| C29 | SH: Were your lips redder than others?                                    |
| C30 | SH: Do you get allergies easily(are you allergic to medicine, food, odor, flower powder, or during seasonal or weather change)? |
| C31 | DI: Did your skin get hives/urticaria easily?                            |
| C32 | DI: Did your skin have purpura (purple spots, ecchymosis) due to allergies?|
| C33 | SH: Does black or purple ecchymosis(spots) appear on your skin for no reason?|
| C34 | SH: Did your skin turn red and show traces when you scratched it?         |
| C35 | SH: Did your skin or lips feel dry?                                       |
| C36 | SH: Did you have visible capillary thread veins on your cheeks?           |
| C37 | SH: Did you feel pain somewhere in your body?                            |
| C38 | SH: Do you have blush or red traces on your cheeks (hot flashes)?         |
| C39 | SH: Did your nose or your face feel greasy, oily, or shiny?               |
| C40 | SH: Did you have a dark face or get brown spots easily?                   |
| C41 | SH: Did you get acne or sores easily?                                     |
| C42 | SH: Did you have upper eyelid swelling?                                  |
| C43 | SH: Did you get dark circles under the eyes easily?                       |
| C44 | SH: Did your eyes feel dry and use eye drops?                             |
| C45 | SH: Did your lips darker, more blue or purple than usual?                 |
| C46 | SH: Did you often feel parched and need to drink water?                   |
| C47 | SH: Did your throat feel strange(e. e., Like something was stuck or there was a lump in your throat)? |
| C48 | SH: Did you have bitterness or a strange taste in your mouth?            |
| C49 | SH: Did your mouth feel sticky?                                          |
| C50 | SH: Was your stomach/belly flabby?                                       |
| C51 | SH: Did you have lots of phlegm, especially in your throat?              |
| C52 | SH: Did you feel uncomfortable when you drank or eat something cold, or do you avoid to drinking or eating something cold? |
| C53 | SO: Could you adapt yourself to external natural or social environment change?|
| C54 | SL: Did you suffer from insomnia?                                        |
| C55 | SH: Did you easily contract diarrhea when you were exposed to cold or eat(or drink) something cold? |
| C56 | SH: Did you pass sticky stools and/or feel than your bowel movement is incomplete? |
| C57 | SH: Did you get constipated easily or have dry stools?                   |
| C58 | SH: Did your tongue have a thick coating?                                |
| C59 | SH: Did your urethral canal feel hot when you urinated, or did your urine have a dark color? |
| 60a | SH: Was your scrotum always wet(only for male interviewees)?             |
| 60b | SH: Was your vaginal discharge yellowish(only for female interviewees)?  |
Table 2 Questions other than CCMQ-J

| ID | Questions                                                                                       | Refs. |
|----|--------------------------------------------------------------------------------------------------|-------|
| Q2 | SO: Life events: Death of a spouse or relatives, bankruptcy, family ceremonies, separation, divorce, occupation change, retirement, house-moving, childbirth, hospitalization. |       |
| Q5 | BI: nationality                                                                                 |       |
| Q7 | ME: K6: (Anxiety) nervous                                                                        | 10-12 |
| Q8 | ME: K6: (Depressed mood) hopeless                                                                  | 10-12 |
| Q9 | ME: K6: (Motor agitation) restless                                                                | 10-12 |
| Q10| ME: K6: (Depressed mood) depressed that nothing could cheer you up                               | 10-12 |
| Q11| ME: K6: (Fatigue) feel that everything was an effort                                             | 10-12 |
| Q12| ME: K6: (Fatigue) worthless                                                                       | 10-12 |
| Q22| ME: Job Stress: I am loaded with a lot of work.                                                   | 13, 14|
| Q23| ME: Job Stress: I cannot get the job done in time.                                               | 13, 14|
| Q24| ME: Job Stress: I have to work very hard.                                                        | 13, 14|
| Q25| ME: Job Stress: My job requires strong powers of concentration.                                  | 13, 14|
| Q26| ME: Job Stress: My job requires specialized knowledge and skills.                                | 13, 14|
| Q27| ME: Job Stress: I always have to keep my mind on the job during my duty hours.                   | 13, 14|
| Q28| SO: Job Stress: I am a physical worker.                                                          | 13, 14|
| Q29| ME: Job Stress: I can do my job at my own pace.                                                  | 13, 14|
| Q30| ME: Job Stress: I can decide where to start and how to do my job by myself.                      | 13, 14|
| Q31| ME: Job Stress: I can have my opinions reflected on the work policy at my office.                 | 13, 14|
| Q32| ME: Job Stress: I have little opportunities to use my skill and knowledge in my job.              | 13, 14|
| Q33| ME: Job Stress: There is a difference of opinions in my department.                              | 13, 14|
| Q34| ME: Job Stress: My department doesn’t get along with other departments.                          | 13, 14|
| Q35| ME: Job Stress: My office has a comfortable atmosphere.                                          | 13, 14|
| Q36| ME: Job Stress: The work environment of my office (noise, lighting, temperature, ventilation) is not good. | 13, 14|
| Q37| ME: Job Stress: What I am doing in my job matches me.                                             | 13, 14|
| Q38| ME: Job Stress: My job is rewarding.                                                              | 13, 14|
| Q39| ME: Job Stress: conditions for the past month: Invigorated.                                      | 13, 14|
| Q40| ME: Job Stress: conditions for the past month: Energetic.                                        | 13, 14|
| Q41| ME: Job Stress: conditions for the past month: Active.                                           | 13, 14|
| Q42| ME: Job Stress: conditions for the past month: Angry.                                             | 13, 14|
| Q43| ME: Job Stress: conditions for the past month: Irritated.                                        | 13, 14|
| Q44| ME: Job Stress: conditions for the past month: Annoyed.                                          | 13, 14|
| Q45| ME: Job Stress: conditions for the past month: Exhausted.                                        | 13, 14|
| Q46| ME: Job Stress: conditions for the past month: Worn out.                                         | 13, 14|
| Q47| ME: Job Stress: conditions for the past month: Dull.                                              | 13, 14|
| Q48| ME: Job Stress: conditions for the past month: Tense.                                             | 13, 14|
| Q49| ME: Job Stress: conditions for the past month: Nervous.                                          | 13, 14|
| Q50| ME: Job Stress: conditions for the past month: Restless.                                         | 13, 14|
| Q51| ME: Job Stress: conditions for the past month: Depressed.                                        | 13, 14|
| Q52| ME: Job Stress: conditions for the past month: I am not up for doing anything.                    | 13, 14|
| Q53| ME: Job Stress: conditions for the past month: I cannot concentrate on anything.                  | 13, 14|
| Q54| ME: Job Stress: conditions for the past month: I am depressed.                                   | 13, 14|
| Q55| ME: Job Stress: conditions for the past month: I am distracted.                                  | 13, 14|
| Q56| ME: Job Stress: conditions for the past month: I feel sad.                                       | 13, 14|
| Q57| SH: Job Stress: conditions for the past month: I feel dizzy.                                     | 13, 14|
| Q58| SH: Job Stress: conditions for the past month: I feel a pain in my joints.                       | 13, 14|
| Q59| SH: Job Stress: conditions for the past month: I feel heavy in the head or have a headache.      | 13, 14|
| Q60| SH: Job Stress: conditions for the past month: I have bad stiff neck and shoulders.               | 13, 14|
| Q61| SH: Job Stress: conditions for the past month: I have a backache.                                | 13, 14|
| Q62| SH: Job Stress: conditions for the past month: I have eyestrain.                                 | 13, 14|
| Q63| SH: Job Stress: conditions for the past month: I feel my heart pounding or I get out of breath.   | 13, 14|
| Q64| SH: Job Stress: conditions for the past month: My stomach is not in good shape.                   | 13, 14|
| Q65| SH: Job Stress: conditions for the past month: I have no appetite.                               | 13, 14|
| Q66| SH: Job Stress: conditions for the past month: I suffer from diarrhea or constipation.            | 13, 14|
| Q67| SL: Job Stress: conditions for the past month: I cannot sleep well.                               | 13, 14|
| Q68| SO: Job Stress: How casually can you talk with your boss?                                       | 13, 14|
| Q69| SO: Job Stress: How casually can you talk with your colleagues?                                 | 13, 14|
| Q70| SO: Job Stress: How casually can you talk with your spouse, families, friends?                   | 13, 14|
| Q71| SO: Job Stress: When you are in a trouble, how much can you rely on your colleagues?             | 13, 14|
| Q72| SO: Job Stress: When you are in a trouble, how much can you rely on your spouse, families, friends? | 13, 14|
| Q73| SO: Job Stress: If you talk to your boss about your personal things, how much does he listen to? | 13, 14|
| Q74| SO: Job Stress: If you talk to your colleagues about your personal things, how much do they listen to? | 13, 14|
| Q75| SO: Job Stress: If you talk to your colleagues about your personal things, how much do they listen to? | 13, 14|
### Questionnaire Items

#### Q212-210: During the past month

| Question | Description |
|----------|-------------|
| Q212 | SL: PSQI: How long have you been able to fall asleep each night? |
| Q214 | SL: PSQI: How many hours of actual sleep did you get at night? |
| Q215 | SL: PSQI: You had trouble in sleep because you cannot get to sleep within 30 minutes. |
| Q216 | SL: PSQI: You had trouble in sleep because you wake up in the middle of the night or early morning. |
| Q217 | SL: PSQI: You had trouble in sleep because you have to get up to use the bathroom. |
| Q218 | SL: PSQI: You had trouble in sleep because you cannot breathe comfortably. |
| Q219 | SL: PSQI: You had trouble in sleep because you coug or snore loudly. |
| Q220 | SL: PSQI: You had trouble in sleep because you feel too cold. |
| Q221 | SL: PSQI: You had trouble in sleep because you feel too hot. |
| Q222 | SL: PSQI: You had trouble in sleep because you have bad dream. |
| Q223 | SL: PSQI: You had trouble in sleep because you have pain. |
| Q224 | SL: PSQI: How would you rate your sleep quality overall? |
| Q225 | SL: PSQI: How often do you take medicine to help you sleep? |
| Q226 | SL: PSQI: How often do you have trouble staying awake while driving, eating meals, or engaging in social activity? |
| Q227 | ME: PSQI: How much of a problem has it been for you to keep up enthusiasm to get things done? |
| Q228 | ME: Do you smoke? |
| Q229 | SH: How many teeth of your own do you have? |
| Q230 | SH: About how you chew, please choose one applicable to you. |
| Q231 | SH: Do you eat slowly and chew well? |
| Q232 | SH: Did you find it more difficult to eat hard things compared to six months ago? |
| Q233 | DH: Are you sometimes choked on tea or soups? |
Q218 DH: Do you feel dry in your mouth? 18
Q219 DH: Can you chew well with molars on the both sides? 18
Q220 DH: How often do you eat out? 18
Q221 DH: How often do you take out? 18
Q222 DH: Do you have an appetite? 19
Q223 DH: Do you have as much appetite as you had when you were young? SU
Q224 DH: Do you have difficulty eating well? SU
Q225 DH: Do you want lose more weight? SU
Q226 DH: How much do you eat until you feel satisfied? SU
Q227 DH: Do you eat well? SU
Q228 DH: Do you want to eat more than now? SU
Q229 ME: Stress: Are you worried or stressed in your daily life now? SU
Q230 DH: How many times do you drink Chinese tea(Oolong, Jasmine, Pu’re)? SU
Q231 DH: How much Chinese tea (Oolong, Jasmine, Pu’re tea) do you drink per time? SU
Q232 DH: How many times do you drink water, mineral water? SU
Q233 DH: How much water, mineral water do you drink per time? 20
Q234 DH: How many times do you eat light-colored vegetables and mushrooms at dinner? 20
Q235 DH: Amount of light-colored vegetables and mushrooms you eat per time at dinner. 20
Q236 DH: How many times do you eat light-colored vegetables and mushrooms at lunch? 20
Q237 DH: Amount of light-colored vegetables and mushrooms you eat per time at lunch. 20
Q238 DH: How many times do you eat light-colored vegetables and mushrooms at breakfast? 20
Q239 DH: Amount of light-colored vegetables and mushrooms you eat per time at breakfast. 20
Q240 DH: How many times do you eat green vegetables at dinner? 20
Q241 DH: Amount of green vegetables you eat per time at dinner. 20
Q242 DH: How many times do you eat green vegetables at lunch? 20
Q243 DH: Amount of green vegetables you eat per time at lunch. 20
Q244 DH: How many times do you eat green vegetables at breakfast? 20
Q245 DH: Amount of green vegetables you eat per time at breakfast. 20
Q246 DH: How many times do you eat small fish? 20
Q247 DH: Amount of small fish you eat per time. 20
Q248 DH: How many times do you eat algae? 20
Q249 DH: Amount of algae you eat per time. 20
Q250 DH: How many times do you eat dairy products? 20
Q251 DH: How many glasses of milk do you drink in a week? 20
Q252 DH: How many times do you eat soy or soy products at dinner? 20
Q253 DH: Amount of soy or soy products you eat per time at dinner. 20
Q254 DH: How many times do you eat soy or soy products at lunch? 20
Q255 DH: Amount of soy or soy products you eat per time at lunch. 20
Q256 DH: How many times do you eat soy or soy products at breakfast? 20
Q257 DH: Amount of soy or soy products you eat per time at breakfast. 20
Q258 DH: How many times do you eat sea food at dinner? 20
Q259 DH: Amount of sea food you eat per time at dinner. 20
Q260 DH: How many times do you eat sea food at lunch? 20
Q261 DH: Amount of sea food you eat per time at lunch. 20
Q262 DH: How many times do you eat sea food at breakfast? 20
Q263 DH: Amount of sea food you eat per time at breakfast. 20
Q264 DH: How many times do you eat meat or meat products at dinner? 20
Q265 DH: Amount of meat or meat products you eat per time at dinner. 20
Q266 DH: How many times do you eat meat or meat products at lunch? 20
Q267 DH: Amount of meat or meat products you eat per time at lunch. 20
Q268 DH: How many times do you eat meat or meat products at breakfast? 20
Q269 DH: Amount of meat or meat products you eat per time at breakfast. 20
Q270 DH: How many times do you eat curry rice or Hayashi rice in a week? 20
Q271 DH: How many times do you eat rice dishes you eat in a week? 20
Q272 DH: How many times do you eat curry rice or Hayashi rice in a week? 20
Q273 DH: How many times do you eat curry rice or Hayashi rice in a week? 20
Q274 DH: How many times do you eat curry rice or Hayashi rice in a week? 20
Q275 DH: How many times do you eat curry rice or Hayashi rice in a week? 20
Q276 DH: How many times do you eat curry rice or Hayashi rice in a week? 20
Q277 DH: How many times do you eat curry rice or Hayashi rice in a week? 20
Q278 DH: How many times do you eat curry rice or Hayashi rice in a week? 20
Q279 DH: How many times do you eat curry rice or Hayashi rice in a week? 20
Here, $y$ and $y^{(i)}$ are original and predicted $y$-values in the cross-validation for every $i$th individual, respectively and $\bar{y}$ represents the average for all $y$-values. We determined the number of components so that $Q^2$ value reaches the maximum. Then after determining the number of components, we also calculated the $R^2$ for examining prediction accuracy for the PLS model.

$$R^2 = 1 - \frac{\sum_{i=1}^{N} (y_{i}^{(i)} - \bar{y})^2}{\sum_{i=1}^{N} (y_{i}^{(i)} - \bar{y})^2} \quad (6)$$

Here, $y^{(i)}$ represents the predicted $y$-value for the $i$th individual when the PLS model using all individuals in selecting the number of components by $Q^2$.

### Subjects

Crowdsourcing makes it possible to accumulate data from the large network of potential participants and bring people together to harness their collective information. Therefore, it is an efficient methodology to verify an important scientific assumption. We used crowdsourcing to recruit participants because of its diverse population, low cost and less required time and collected those who could read Japanese questions and write their answers, which consist of 851 answers (350 males and 501 females between 20 and 85 years.
old). The collection of the data was approved by the Ethics Review Committees of Nara Institute of Science and Technology and Suntory Global Innovation Center Limited. All participants agreed with the purpose of the present research via the Internet.

**RESULTS**

**PLS regression models of nine body constitution scores in CCMQ-J by 254 questions in the seven questionnaires**

Initially we compared questions of CCMQ-J and those of the seven questionnaires based on 7 types of attributes of traditional Chinese medical theory as follows: (1) basic information (BI; height, weight, age, gender, etc.), (2) disease (DI; a disorder of structure or function in a human, especially one that produces dominant symptoms or that affects a specific location and is not simply a direct result of physical injury), (3) social factors (SO; habits, lifestyle, living environments, working environment, social relations, etc.), (4) mental factors (ME; cognition, tenacity and emotion, etc.), (5) dietary habits (DH; preference on foods and drinks (including the cooking style, flavor, and sided supplements), eating/drinking time, speed, relevant favors), (6) sleeping state (SL; quality, time, timing, etc.), and (7) sub-health (SH, an intermediate stage between health and disease, which is not quite either status, with no typical pathologic features and corresponds to “mibyou” in Japan) \(^{22-25}\).

The major difference between the questions of the CCMQ-J and those of the seven questionnaires is that the questions of CCMQ-J in Table 1 are mainly sub-health (SH) questions, i.e., 55 for SH, and the others belongs to ME (2 questions), DI (2), SO (1) and 1 SL (1). In contrast, the seven questionnaires consist of a variety of questions concerning DH (110), ME (52), SO (21), SH (15), SL (15), DI (4), and BI (4). Thus it can be expected that the nine body constitution scores in CCMQ-J can be explained by different factors other than SH attributes.

Multivariate linear regression models of 9 body constitution scores in CCMQ-J based on scores of the 254 questions in the seven questionnaires (Table 2) were built by PLS. We selected the optimal number of components by \(Q^2\) values for the 9 regression models, respectively, i.e., 3 components for all body constitutions except QD and SD scores (2 and 4 components, respectively; Figure 1). The relationships between the true scores according to the CCMQ-J and the predicted scores with the PLS models are represented in Figure 2. Then we constructed the 9 regression models. Figure 3 shows \(R^2\) values and Pearson coefficients between the original and predicted scores for the nine physical constitutions. High correlations between original and predicted scores were obtained in GN \((r = 0.90)\), QD \((0.86)\) and QF \((0.86)\), and those of others are all higher than 0.70. Thus, it should be noted that the nine physical constitutions scores can be estimated by the scores of the questions in the seven questionnaires, Table 3 lists the questions with the highest 5% coefficients (both positively and negatively) in all 9 body constitutions. In average for the 9 regression models, there are 14 (from 3 to 33), and 13 (from 4 to 20) questions contribute positively and negatively, respectively. Figure 4 shows the histogram of the questions in Table 3 according to the number of related body constitutions (Figure 5). Figure 5 shows the effects of the questions with the highest 5% coefficients in terms of their categories. Though most of the questions are associated with single body constitutions, 16 questions are also associated with body constitutions larger than or equal to 5.

Figure 6 shows the effects of the questions with the highest (positively and negatively) 5% coefficients in terms of the seven types of attributes of traditional Chinese medical theory. Y-axis represents the number of questions with the highest 5% coefficients. Negative coefficient corresponding to Figure 6a means that the question prevents the body from turning into the corresponding body constitution. Many questions belonging to mental factor (ME) are inhibitory for gentleness type (GN). In contrast, many sub-health (SH) questions contribute positively to 6 types of body constitutions Blood stasis (BS), Yin-deficiency (YI), Wet-heat (WH), Phlegm-wetness (PW), Yang-deficiency (YA) and Qi-deficiency (QF) and disease factors (DI) are also associated with YA and QF (Figure 6b).

**DISCUSSION**

Top ten key-questions

We obtained regression models for the nine body constitutions from the scores for the 254 questions of the seven questionnaires \(^{10-20}\). Those regression models can provide interpretation for the nine body constitutions from multifaceted viewpoints of lifestyle in sense of medical analysis. Table 3 lists the questions with the top 5% highest weights on any constitution (both positively and negatively). The top ten key-questions are ranked as follows along with their most relevant body constitutions; Q63 for QF \((0.132)\),
Figure 1 Selection of the component number for 9 scores of CCMQ-J according to the trend of $Q^2$ ($n = 851$). Gentleness type (GN), Qi-deficiency (QF), Yang-deficiency (YA), Yin-deficiency (YI), Phlegm-wetness (PW), Wet-heat (WH), Blood-stasis (BS), Qi-depression (QD), and Special diathesis (SD).

Figure 2 Scatter plots for the nine types of body constitutions ($n = 851$). X-axis represents the true scores according to the CCMQ-J; while Y-axis represents the predicted the scores with the PLS models. The values in the titles within parentheses represent Pearson correlations.
Figure 3 Prediction ability for PLS models in terms of the R² and correlation coefficients ($r$) ($n = 851$).

Gentleness type (GN), Qi-deficiency (QF), Yang-deficiency (YA), Yin-deficiency (YI), Phlegm-wetness (PW), Wet-heat (WH), Blood-stasis (BS), Qi-depression (QD), and Special diathesis (SD).

Table 3 Questions with the top 5% significances QIDs correspond to those in Tables 1 and 2.

|      |          | Negative          |          | Positive          |
|------|----------|-------------------|----------|-------------------|
| Total| #of QID  | QID               | #of QID  | QID               |
|      |          | Q7, Q9, Q10, Q11, Q12, Q45, Q46, Q47, Q50, Q51, Q52, Q53, Q54, Q55, Q60, Q164, Q182, Q195, Q196, Q197, Q201, Q207, Q209, Q210, Q228, Q293, Q306 | 4 | Q41, Q148, Q156, Q143 |
| GN   | 37       | Q62, Q67, Q142, Q145, Q147, Q149, Q164, Q182, Q195, Q196, Q197, Q201, Q207, Q209, Q210, Q228, Q293, Q306 | 15 | Q57, Q58, Q59, Q60, Q61, Q62, Q63, Q141, Q142, Q147, Q153, Q199, Q201, Q202, Q204 |
| BS   | 27       | Q217, Q218, Q230, Q278, Q289, Q304, Q320 | 15 | Q57, Q59, Q60, Q62, Q63, Q64, Q66, Q142, Q187_15, Q187_16, Q187_18, Q187_24, Q198, Q199, Q201 |
| SD   | 28       | Q187_34, Q217, Q218, Q242, Q311, Q312, Q319 | 15 | Q10, Q44, Q49, Q50, Q51, Q54, Q56, Q142 |
| QD   | 11       | Q41, Q148, Q218 | 8 | Q43, Q44, Q60, Q62, Q63, Q64, Q66, Q141, Q142, Q147, Q201, Q202, Q219, Q224, Q237, Q306 |
| WH   | 35       | Q32, Q33, Q37, Q70, Q76, Q77, Q78, Q187_12, Q187_19, Q214, Q217, Q218, Q228, Q247, Q252, Q267, Q282, Q290, Q319 | 16 | Q11, Q28, Q57, Q58, Q60, Q61, Q62, Q63, Q64, Q66, Q141, Q142, Q147, Q156, Q199, Q201, Q202, Q210, Q211, Q237 |
| PW   | 30       | Q32, Q68, Q140, Q214, Q216, Q217, Q218, Q228, Q231, Q280 | 20 | Q11, Q28, Q57, Q58, Q60, Q61, Q62, Q63, Q64, Q66, Q141, Q142, Q147, Q156, Q199, Q201, Q202, Q210, Q211, Q237 |
| YI   | 24       | Q32, Q76, Q155, Q156, Q160, Q187_33, Q217, Q218, Q252, Q253, Q328 | 13 | Q57, Q59, Q61, Q62, Q63, Q66, Q142, Q199, Q200, Q201, Q202, Q210, Q211, Q237 |
| YA   | 36       | Q8, Q43, Q155, Q156, Q187_11, Q187_12, Q187_19, Q212, Q214, Q217, Q218, Q228, Q247, Q252, Q267, Q282, Q290, Q319 | 18 | Q142, Q153, Q187_17, Q187_16, Q187_18, Q187_24, Q198, Q199, Q201, Q202, Q228, Q306 |
| QF   | 26       | Q31, Q40, Q143, Q187_25, Q187_12, Q217, Q218, Q224, Q227, Q317, Q333 | 15 | Q47, Q57, Q59, Q60, Q61, Q62, Q63, Q64, Q65, Q66, Q145, Q182, Q183, Q198, Q228 |
Figure 4 Relationship between the number of body constitutions (X-axis) and the number of questions (Y-axis) with the top 5% significances ($n = 851$).

Figure 5 Frequency questions occurring in CCMQ-J with the 5% significances ($n = 851$).
Q187-16 for SD (0.106), Q201 for YA (0.100), Q57 for QF (0.105), Q66 for YI (0.090), Q218 for YI (-0.087), Q228 for PW (-0.084), Q62 for YI (0.080), Q156 for YA (-0.076) and Q153 for BS (0.075).

Q63 (SH, “I feel my heart pounding or I get out of breath”) associates with the fact that palpitation and asthma are typical symbols of hypo-functioning of hearts and lungs, which indicates the weakness in blood circulation. From TCM theory, they are very strong evidence for QF, which leads to “Speaking weakly, sweating easily, shortness of breath, often tired and weak.” This statistical result correctly matches the clinical diagnosis.

Q187-16 (DI, Allergic rhinitis) reflects SD constitution, in which symptoms related to asthma, itching of pharynx, nasal congestion, and sneezing are frequently seen.

Q201 (SL, trouble of sleep in because of feeling of too cold) is medically categorized into YA constitution with typical clinical manifestations of chilly feeling on hands and feet, antagonism to cold foods. The chilly feel is physically caused by the decrease in metabolic rate; greater caloric dissipation than the production.

Q57 (SH, feel dizzy) could be caused by many complicated reasons, in which the central nervous system injury caused by peripheral vestibular dysfunction and trauma is not considered in this study. Naturally, the dizziness is often seen as the result of the insufficiency of blood supply in the brain. This manifestation is due to (1) excessive oxygen consumption in the brain, mental tension or sustained excitement, which may lead to WH constitution; and (2) weakness of blood circulation, obstruction of arterial blood supply due to cardio-cerebral vascular diseases or cervical vertebra deformation, which may lead to QF constitution. In Q66 (SH, I suffer from diarrhea or constipation), diarrhea or constipation are both gastrointestinal dysfunctions due to water imbalance. In Chinese medical theory, the inadequacy of water is a typical symbol of YI constitution. Pieces of evidence are seen as fear of heat, fever in the hands and feet, flushing or redness on the cheeks, dry skin, dry mouth and being prone to be insomnia, and dry stools.

Q218 (feel dry in mouth) is also associated with water inadequacy as well as Q66.

As natural comprehensions, the wish of “lose more weight” corresponding to Q228 (DH) indicates the overweight problem, which is the most obvious evidence of PW constitution. The manifestations are: the abdomen is soft and fatty; the skin is oily, sweaty; the eyes are swollen, and sleepy.

The TCM theory points out that “over-use of eyes...
is harmful to blood circulation” which corresponds to Q62 (SH, eyestrain) and that “liver performs the storage and balance of blood”. Thus, the eyestrain indicates the deficiency of liver and blood leads to the dehydration in skin, mouth, stools, and even insomnia, which are typical evidence of YI constitution.

Q156 (BI, Weight (Body-Mass)) is relevant to body constitutions in many senses. For instances, obesity is positively correlated to QF and PW, while negatively correlated to YA, BS, and QD. However, the relation between weight and YA is still unknown in medical science. From the statistical results, the weight index strongly impacts YA prediction.

It has been clearly reported that the males and females correspond to different body constitutions in physiologic pathology. For instance, males incline towards higher risks of severe respiratory infection, central nervous virus infection, viral gastroenteritis and hepatitis. However, there is no well proven theory explaining that gender (Q153, BI) particularly impacts BS body constitutions.

In summary, most of the very-high-valued Key-questions can be perfectly or indirectly explained by the medical theory. However, several ones such as obesity and weight are difficult to match to the existing clinical theory in details. There are open challenges to explore the sophisticated mechanisms on the basis of statistical results from this paper.

**Ranking in order of appearance-counting**

Some questions are identified as “key” in the prediction of not only one but multiple body constitutions (Figures 4 and 5). Obviously, the frequency of appearance reflects the generality of a specific question. This fashion of ranking offers a different point of view for medical analysis. Not only the absolute impact of one specific condition/lifestyle but also the generality should be concerned. For instance, Q218 (“Do you feel dry in your mouth?”) which reflects the water inadequacy is effected for the eight body constitutions except for GN type. It is well accepted highly advocated that the water balance should be paid more attention in the clinical treatment. In contrast, this analysis shows some features that are different from current medical theory, which might inspire some re-considerations on the medical side. For instance, the age factor is widely and strongly considered as a general factor on the body constitution prediction. This is due to the senescence of organs is irreversible and unavoidably during human life. However, from the statistical results, age is not a universal key factor. In this sense, there is a possibility (or even evidence) to compensate for the aging through lifestyles such as those factors in Figure 5.

**Categorization in the medical sense**

Several medical implications are found based on the body constitution investigation. Firstly, the diseases (DI) are widely considered as one of the strongest signs of health status as they are reflected in YA and QF (Figure 6). On the other hand, the mental factors (ME) have the most significant impacts on the body constitution balance, especially, several questions of ME are inhibitory for GN.

On the basis of above analysis, some medical explanations are made as: (1) for the body constitution balance, mental management (ME) is the most significant, even feasible to compensate for the effects of aging (BI) and disease (DI); (2) mental management (ME) strongly impacts each of the body constitutions as either positive or negative factors, which means that each body constitution manifests explicit mental feature. (3) It has been indicated by the medical theory that the impacts of sleep state (SL) and dietary state (DH) are complementary, which means the collaborative mediation is an efficient manner to escape from/ or to drop into a specific body constitution.

**Gentleness Constitution**

Among the nine body constitutions, GN is especially noticeable in terms of both statistics and medical science. From the medical point of view, GN is considered as an expected “healthy” status; and all other eight body constitutions are considered as “biased” constitutions. From our statistical results (Table 3 and Figures 6), it is also found that GN shows very different features from the others and leads to some noticeable medical hints, i.e., (1) The number of negative factors for GN is much more than the positive ones (Figure 6). (2) Mental and sleep relevant issues have considerable influence in making individuals escape from GN to biased body constitutions; in contrast, it is difficult to turn back to GN by only mental and sleep efforts; and (3) in general, mental status is most significant to distinguish GN against the others.

**CONCLUSION**

The statistical results from our proposed method are correctly explainable for the nine types of body constitutions in multifaceted viewpoints of health conditions and understandable through existing medical theory; moreover, new medical hints, which
have not been explicitly indicated by traditional medical researches, have been extracted from our data analysis. As described above, crowdsourcing is a considerably important information technology to accumulate data from the large network of potential participants and bring people together to harness their collective information. Therefore, it should be utilized for statistically assessment of healthcare in several communities or geographical region based on health questionnaire involving CCMQ-J.

**SUBVENTION**

Suntory Global Innovation Center Research Group

**CONFLICTS OF INTEREST**

The authors declare that there is no conflict of interest for this work.

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要 旨

ヘルスケアにかかわる 7 種の質問票による CCMQ-J の体質の推定と解釈法

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本研究では、個人の基本情報、病気、社会的因子、精神的因子、食習慣、睡眠状態、未病などの関連因子、計 254 個の質問スコアにより日本語版中医体質 9 分類 (CCMQ-J) における体質スコアの推定を試みた。ここでの質問項目は、一般に多くの研究で活用されている (i) 心理的負荷、(ii) 仕事ストレス、(iii) 性格を特徴づける 5 因、(iv) 睡眠の質的評価、(v) 生活評価、(vi) 飲食および (vii) 食品における指向性にかかわる 7 種の質問票にもとづいて構築した。クラウドソーシングを活用し、日本全国の広範な地域から 851 人の回答が得られた。その内訳は、20-85 歳の 350 人の男性と 501 人の女性であった。これらの回答をもとに、254 種の質問項目により CCMQ-J 体質スコアを推定する数理モデルを開発した。それぞれのモデルのピアソン相関係数は 0.7 以上の精度であった。以上により、他の健康質問票による CCMQ-J における体質スコアの推定が実現された。

キーワード：日本語版中医質問票 (CCMQ-J), ヘルスケア質問票, データサイエンス, クラウドソーシング, 部分最小二乗法 (PLS)