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Review

Utilization of the Concentric Circle Model in Clinical Nursing: a Review

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In this article, I review applications of the concentric circle model in clinical nursing. The concentric circle model is based on the cross-sectional shape of the body extremities at several points, and can be used in the areas of both kinesiology and nutritional science. This model makes it possible to calculate the cross-sectional area of muscles from measurement of the circumference of the extremities and the thickness of adipose (fatty) tissue. Then, changes in muscle strength or nutritional status can be inferred or assessed from these data. This model requires only simple and non-invasive measurements, and this is a significant and essential characteristic for its use by nurses, both in clinical and research applications.

Key words: concentric circle model; physical measurements; nutritional assessment muscle strength

1. Introduction

Recently, practice based on evidence is being emphasized in the fields of nursing and medicine. In nursing, there are two domains of evidence: 1. subjective data obtained from patients themselves and 2. a variety of objective data obtained from nurses' observations and measurements, of patients' physical condition and behavior. In the subjective domain, nursing science has developed many psychosocial scales based on psychometric measurements. In the objective domain, however, unlike the case in medicine, nursing science has hardly any physical tests or measurement tools that are used independently or devised by nurses, possibly because nursing is non-invasive by nature.

The concentric circle model, of which utility I reported in 1998[1] briefly, is one of the few objective, non-invasive tools available for application in nursing. In this article, I will review studies using the concentric circle model in nursing.

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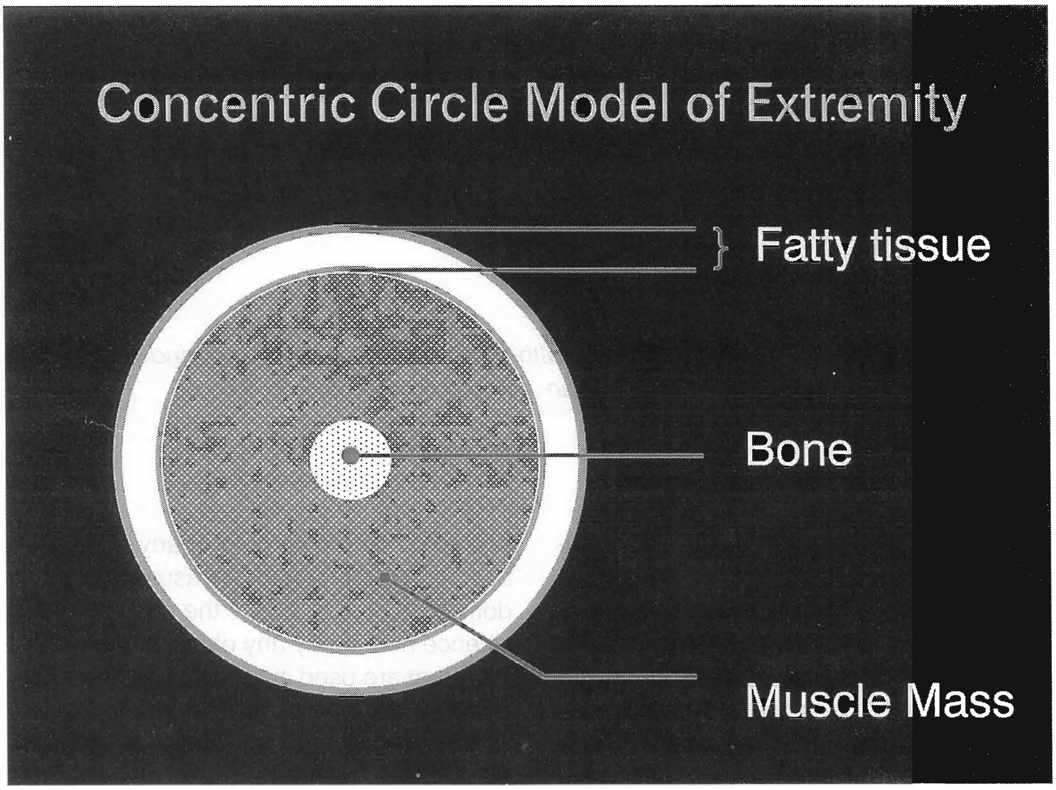
What is the concentric circle model?

The "concentric ci\ıcle model" has been uesd to represent concepts in different disciplines where the same tool is applied. The figure shows an example of the concentric circle model used to express the cross-sectional area of the extremities of the human body. The extremities comprise a bone at the center, various muscles or muscle mass around the bone, and adipose (fatty) tissue. The circumference of the extremity and the thickness of the adipose tissue layer under the skin are easily measured with a measuring tape and skinfold device, respectively. The circumference of the muscle and volume of muscle mass can then be calculated from the data for circumference and adipose tissue obtained at the same point along the extremity.

This model is suitable for measuring certain areas of the human body where the cross-sectional shape of the area satisfies the premise of a concentric circle. For example, the femur satisfies the premise, but the lower leg does not, because the bones in the lower leg are not located in the center of the extremity. For the



Figure

arm, the mid point of the upper arm is generally used.

The concentric circle model can be used to estimate muscle strength or nutritional status. The theory of physiological muscle strength is used to calculate the former; that is, muscle strength per 1 cm^2 depends on the particular characteristics for each person[2,3,4], and thus it varies in proportion to the size of the cross-sectional area of the muscle.

To estimate a patient's nutritional status, the thickness of adipose tissue and the cross-sectional area of the muscle (or the circumference of the muscle) at the mid point of upper arm are used as indicators for volume of body fat and body protein, respectively. These values are known as nutritional indexes[5,6,7].

The advantage of using this model to assess the nutritional status is that the physical components of the human body: body fat and body protein, can be estimated separately, as noted above.

Application of the model in nursing

1. *Evaluation of nursing intervention for early ambulation in the postoperative period*

The effect of early ambulation after surgery has been well documented; it prevents pulmonary complications, facilitates recovery from bowel paralysis, thereby preventing ileus, and stops deterioration of muscle strength in the lower extremities.

Experimental research on normal men has shown that decreased muscle function/strength results from bed rest alone[8,9]. The muscle function of postoperative patients was investigated in relation to studies on the mechanisms of fatigue after surgery[10,11,12].

These studies can be criticized, however, in that the methods used for measuring muscle strength were unsatisfactory. First of all, the measurement devices were unsuitable. The above studies used dynamometers or power-analyzers, and the data obtained with them would have been affected by the patients' fear of the measurement or wound pain. The second cause of dissatisfaction was the measurement procedure, itself. Dynamometers and power-analyzers require maximum voluntary muscle contraction at the time of measurement. Muscle contraction itself is training for the muscle, and the data will reflect the effects of that training, if measurements are repeated on the same subject.

In contrast, the cross-sectional area or circumference of muscle can be measured without any of the above disadvantages.

Onishi et al.[13] conducted a preliminary investigation of the post-surgical decrease in femoral muscle circumference in 29 surgical patients over 40 years of age with gastrointestinal diseases. The longer the period of bed rest after surgery, the smaller the circumferences of femoral muscles became, and this circumference decreased more in patients with malignant diseases than in patients with benign diseases. These findings were considered to be related to differences in surgical stress, such as the volume of blood loss and the length of time required for the surgical procedure.

In the next series of studies, the concentric circle model was used to calculate the cross-sectional area of femoral muscle mass. The influence of exercise in bed and ambulation on femoral muscle mass was investigated in an experimental group (18 patients) and control group (24 patients) operated on for gastrointestinal diseases[14]. Active exercise, including "femoral muscle setting" in bed, was routinely programed and encouraged by nurses from the day after surgery for patients in the experimental group, whereas the control group members were left to their own motivation following an explanation about the effects of ambulation.

The postoperative decreases in cross-sectional area in both groups were compared day by day. The decrease in cross-sectional area of the femoral muscles before ambulation was greater in the patients over 60 years of age in both groups, and the muscles volume was not influenced by exercise in bed. Femur measurements were continued after ambulation in the same subjects in both groups.

In both groups, the decrease in femoral muscle mass was shown to be less in the ambulatory patients than in the non-ambulatory, and the differences were statistically significant around by 1 week after surgery.

Based on the above findings, the next question was whether the effect of ambulation would appear during the first postoperative phase, when body protein was drastically catabolized[15]. The subjects were limited to those patients with a blood loss of less than 500 ml during the surgical procedure. The research was conducted by using a semi-experimental design on two groups of patients in two hospitals that used different policies and methods of management after surgery. One group of patients was encouraged to ambulate with active intervention by the nurses beginning the day after surgery in accordance with the surgeon's standing order. The control group patients were in the other hospital, where ambulation was not facilitated but was left to the patients' own motivation for recovery. The data were classified according to age group and analyzed.

The ambulatory group showed a smaller decrease in cross sectional area in both the 40 to 59-year-old group and the over 60-year-old group. These two groups both showed similar curves for the decrease in cross-sectional area. In the control group, however, the decrease in cross-sectional area for the patients over 60 years old was greater than the decrease in the patients who were 40 to 59 years old. Furthermore, the later the over 60-year-old control group patients began to walk, the greater the cross-sectional area of their femoral muscles decreased, and the differences were statistically significant.

This study was followed by an exploration into the magnitude of the influence of ambulation on femoral muscles among various other factors[16]. Using data from earlier studies[14,15], we performed multiple regression analysis of the decrease in femoral muscle mass from day 3 to 1 week after surgery. Seven independent variables were tested: age, day of ambulation after surgery, surgery-related blood loss, percent standard body weight before surgery, serum albumin, and nutritional intake, including both oral feeding and intravenous alimentation. Of these independent variables, day of ambulation and surgery-related blood loss were adopted as significant variables throughout the period. It was surprising to find that ambulation had a greater effect than blood loss, and that this tendency gained in prominence as time went on. These quantitative studies showed that decrease in femoral muscle mass could be greatly reduced or prevented by nursing intervention that encouraged early ambulation.

2. Nutritional assessment and intervention

According to the US and European nursing literature, it has been common since the 1970s to assess nutritional status based on physical measurements by nurses, in both the fields of research and practice. In professional nursing magazines, nutritional assessment was introduced, and the utilization and significance of upper arm measurements were stressed[17,18]. For upper arm measurements, triceps skin-fold thickness has been adopted as one of the major defining characteristics of the diagnostic labels for nursing diagnosis; "Altered Nutrition: More than Body Requirements" and "Altered Nutrition: Less than Body Requirements"[19].

In the area of acute and critical care nursing, upper arm measurements were recommended as a more convenient indicator than body weight, which was not always easy to measure in those patients[20,21]. Another main area in which upper arm measurements are used is cancer nursing.

Anorexia, often thought to result from cancer chemotherapy, is a common problem in cancer patients, and the malnutrition related to anorexia can lead to immune suppression and susceptibility to infection. Descriptive studies used with upper arm measurements have been conducted in regard to the nutritional status of allogenic bone marrow recipients[22] and patients undergoing cancer chemotherapy[23]. Other studies indicated the effectiveness of nursing intervention to maintain nutritional status on the basis of upper arm measurements[24,25].

In Japan, a few studies have used the concentric circle model of upper arm as a nutritional index. I and my colleagues have continuously used this model to assess recovery of nutritional status after gastrectomy for cancer during long-term care. Gastrectomy is one of the most invasive operations in terms of recovery of nutritional status. Nutritional status was assessed in 71 post-gastrectomy patients without recurrence of cancer 6 months to 3 years after their discharge from hospital[26]. Recovery of body weight was poor with a marked reduction in percent of triceps skin-fold thickness (TSF), whereas percent arm muscle circumference (AMC) kept up a slight decline. These findings support the hypothesis that the decrease in body weight resulted from depletion of fatty tissue secondary to reduction of food intake.

Next, it was necessary to prospectively determine which indicator of the upper arm measurements is most suitable for evaluating nutritional recovery after gastrectomy. Sixty-four gastrectomy patients without recurrence were followed for one year after hospital discharge[27]. Upper arm measurements were performed four times: before surgery, at the time of discharge, 6 months after discharge, and one year after discharge. Four indicators were studied: body weight, mid-arm circumference (AC), TSF, and AMC. The data were compared with the standard values for males or females.

The decreasing changes in the indicators were prominent until 6 months after discharge, but after 1 year the decreases became slight, except for those of TSF. The changes in AMC were correlated with the quantity of energy intake, and it was assumed that AMC (body protein) was the most appropriate indicator of nutritional recovery.

The recovery index [RI = 100 $(X_3 - X_2)/(X_1 - X_2)$] was developed to describe the degree of recovery of body protein lost because of surgery, by using data measured at the following times: before surgery: X_1, the time of discharge: X_2, and 6 months after discharge: X_3[28]. The RI showed that in about one-third of the patients, AMC had decreased to below the level at the time of discharge (RI < 0). In half of the patients it exceeded the values at discharge, but it did not recover to the level prior to surgery ($0 <$ RI < 100). Finally, in some patients, it exceeded the preoperative value ($100 <$ RI).

To facilitate nutritional recovery, it is necessary to know which factors influence recovery. Many factors should be considered in addition to surgical stress, such as the reduction or loss of gastric volume, the variety of complications or disorders after gastrectomy, chemotherapy for advanced cases, social support related to diet, and patients' attitude and behavior related to diet.

To identify the factors relating to the RI and to study the relative magnitude of their effect, path-analysis based on multiple-regression analysis was adopted with the following results[28]. Several factors were adopted for the RI of AMC. Regarding dietary behavior, intake compared with that before surgery and time spent in postprandial rest were adopted. Other factors were frequency of ileus attacks, patient age, extent of gastrectomy, and preference for fatty foods before surgery. Next, multiple-regression analysis was also performed concerning dietary intake. Dietary intake was less among patients who had experienced ileus attacks, spent time in postprandial rest, had severe complications, or exhibited an avoidance coping style. Material support and severity of complications were adopted as factors for postprandial rest. Concerning severity of complications, it was suspected that patients experienced dumping syndrome and needed to lie down. The dumping syndrome can be prevented, however, by an effective dietary pattern. This indicates the significance of patient education in the recovery of nutritional status.

In addition to this follow-up study, another study[29] indicated that the number of meals was related to constraints with family members concerning dietary behavior.

The results of the above studies quantitatively clarified the factors and the magnitude of their influence on recovery after gastrectomy. Of these factors, extent of gastrectomy has been reported in the surgical literature, but the other factors have not been discussed in terms of research on nursing intervention to facilitate adaptive behavior after surgery.

Another study with upper arm measurements was carried out in cancer nursing by Tonosaki et al.[30]. They assessed the nutritional status of 15 patients with lung cancer receiving cisplatin therapy. Among several nutritional indicators, TSF proved to be the most sensitive for representing changes in nutritional status in cancer patients during chemotherapy. Multiple-regression analysis revealed that TSF was influenced by dietary intake, which in turn was related to nausea, vomiting, anxiety level, and body temperature associated with infection.

Conclusion

The concentric circle model is based on the theory of kinesiology and nutritional science, and the data obtained from the model are reliable and useful. The concentric circle model, which is non-invasive, can be easily applied for both clinical care and research. These characteristics are significant and essential for its use by nurses to assess a patient's condition and evaluate interventions.

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