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# DEVELOPMENT OF ANTHROPOMETRIC CHAIR BASED ON ARM SPAN, KNEE HEIGHT, AND SITTING HEIGHT FOR ELDERLY

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**ABSTRACT:** Elderly with less nutritional status would be susceptible to get infectious disease, immune deficiencies, reduced productivity, high risk of various complications of disease, and can even cause death. Height as the one indicator of nutritional status assessment in elderly is difficult to measured due to such conditions as osteoporosis, scoliosis, kyphosis, etc. Arm span, knee height and sitting height can be used to predict the height. However, some anthropometric measurements with different positions are not effective because of discomfort. Three anthropometric measurements in one tool like a chair can overcome the problems. The study aimed to develop the anthropometric chair (Body Mass Index/BMI Meter) for elder's nutritional status assessment with an easy, practical measurement. The study design was cross sectional using survey method toward 300 healthy older people. Upper leg length, lower leg length, pelvic width, shoulder width, elbow height, shoulder height and patellar height were measured to design the chair. The study revealed that the male elderly had higher data anthropometric than female. The mean of anthropometric data decreased with age. The validity of anthropometric chair from the sensitivity (85-100%), specificity (70-80%), Positive Predictive Value (80-90%) and Negative Predictive Value (80-100%). The anthropometric chair can be used for assessing elders nutritional status.

*Keywords: Anthropometric Chair, Arm Span, Knee Height, Sitting Height, Elderly*

## 1. INTRODUCTION

Malnutrition remains a major nutritional problem commonly found in groups of elderly such as under-nutrition and overnutrition. Combination of changes in physiology and psychology also contributes in the development of malnutrition cases in the elderly. Therefore, early screening of elderly malnutrition is urgently needed in assessing nutritional status through the calculation of Body Mass Index (BMI) with height and weight as indicators [1]. However, height in elderly is difficult to measured because changes in posture due to aging; abnormalities of the spine due to osteoporosis, kyphosis, or wheelchair-bound or bedridden Inappropriate height measurements may lead to inaccurate assessment of the nutritional status in elderly [2]. Currently, geriatric service workers in health centers and hospitals in Indonesia has difficulty in measuring height in elderly who are unable to stand up. They are still using a device made by wood and aluminum to measure knee height. The results then are to be converted to height prediction with Eleanor's formula as defined in The Guidance of Elderly Management for Dietitian at the Health Center [3]. Meanwhile, this formula developed in Caucasian elderly who have differences in posture and height with Indonesian, so that the results are not accurate. One recent and sophisticated discovery to assess the nutritional status of elderly who can not be measured in upright position is the use of Nutrition Status Assessment (NSA) Card from predicted height using arm span, knee height and sitting height [4]. This card has been developed and validated in 2009 towards 560 elderly in Depok, Jakarta, and Bogor respectively [5]. Validation test for predictive HB model of this card revealed that all three aspects had the highest sensitivity and specificity rather than Eleanor S. and Chumlea model so it is accurate enough in determining the predicted height in elderly. As many as 33 cadres of integrated training post (as called "*Pos Pembinaan Terpadu"* or *Posbindu*) and nutrition workers of health center or hospital in the District of Pancoran Mas Depok in 2009 had previously been trained. The aims of this training were to measure and interprete anthropometric nutritional status in elderly with NSA cards, as well as to provide a set of anthropometric tool for several integrated training posts selected to be applied in the field. However, the study showed that elderly cadres of integrated service post and nutrition workers or clinic midwifes in Depok still have problems using anthropometric predictors for all models with tool made by wood. While using the tool, the elderly have to undergo three times measurement in two different positions i.e. standing and lying down. This anthropometric tool is also quite heavy when taken to a field that is not practical to use and requires four people to operate it. Whereas the elderly activities in integrated training post were in high level of mobility that was often moved from one place to another with the same tools and different schedules, even in a limited number of field workers. Therefore, there should be a study available in designing or developing the tools of anthropometric which may cover all of three predictors of height for elderly with ergonomic beneficial and practical on hand. The aim of this study was to develop a digitally anthropometric tool which capable to analyze (integrated analysis) of arm span, sitting height and knee height, namely BMI Meter in assessing the nutritional status in elderly to meet the ergonomic value as needed based on physical condition of them.

## 2. MATERIAL AND METHODS

### 2.1 Study Design

This descriptive analytical study described the relationship inter-variables. Hypothesis was tested to assess the association between anthropometric chair ergonomically with the validity of the nutritional status of elderly based on height prediction of arm span, knee height and sitting height. The study was cross sectional method using observation approaches [6].

### 2.2 Subject and Data Collection

The subject was elders (senior citizens) with the inclusion criteria: men and women, aged over 60 years, able-bodied, stand still and resided in Jakarta and Depok. At the beginning, anthropometric database was collected using a form that embraces measurement of upper and lower legs length, shoulder width and height, hip width, elbow and patella height. The anthropometric data collection was conducted to determine the shape, size and exact dimensions related to product designed and to specify individuals who will operate or use the product. As many as 200 elderly in Jakarta and Depok have been chose as samples for this study. The chair will be designed within 6 months based on anthropometric dimensions of data. Validity test for the chair conducted on 100 elderly whom resided in Jelambar district, Grogol Petamburan subdistrict, West Jakarta. The test included the measurement of body weight, sitting height, knee height, and arm span using the form. The measurement of anthropometric data conducted by five students who had been trained for using anthropometer.

### 2.3 Data Analysis

Furthermore, data were analyzed and processed with SPSS for Windows 13$^{rd}$ version. Univariate analysis of data was presented to describe the frequency distribution, maximum-minimum value and the mean value of all variables studied. The data(s) resulted from validation test of the chair were analyzed with the chair sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV).

## 3. RESULT AND DISCUSSION

Mean age of respondents was 61.6 years with 87 years age as the highest while 48 years age as the lowest. Elderly women had a mean of age slightly less than men. The anthropometric data for appropriate chair design was depicted in Table 1. It showed that elderly men have greater results than women related to the upper and lower legs length, shoulder width and height, and patellar and elbow height. The mean of anthropometric parameters measured in elderly men had a value greater than the elderly women, unless the width of the pelvis. Male posture was higher and larger than female. Since body dimensions was took into account, male generally larger than women, except for several particular parts such as hip, etc. [7]. Table 2 showed the distribution of anthropometric measures decreased with age. The size of the human body varies according to age. As advanced age, the value of anthropometric parameters measured in the elderly is low. Physical development in both men and women continued to increase until adolescence. However, around aged of 40, it tends to decrease or depreciate until old age. BMI is an indicator for assessing obesity and CED (Chronic Energy Deficiency) risks in elderly. However, it is difficult to measure stature of elderly due to kyphosis and scoliosis. To overcome the problem, we can measure the predicted height of elderly using arm span, knee height, and sitting height [8, 9]. Table 3 showed that the mean of height and weight, arm span, knee height and sitting height in elderly men were greater than women. This result supported the studies conducted in elderly Chinese in South America [10] and Chile [11]. Elderly men were taller and heavier than women because both groups experienced a loss of fat-free mass is greater. Reduction in height of men is lower than female.

Table 1. Anthropometric data for appropriate chair design according to gender

| Sex | Statistic | Age (years) | Knee height (cm) | Lower leg length (cm) | Pelvis width (cm) | Shoulder width (cm) | Shoulder height (cm) | Patella height (cm) |
|---|---|---|---|---|---|---|---|---|
| Male | Mean | 62.8 | 39.5 | 48.7 | 29.8 | 39.0 | 57.9 | 49.4 |
| | Median | 64.0 | 39.0 | 49.1 | 29.9 | 39.1 | 58.4 | 49.0 |
| | Minimum | 49.0 | 32.0 | 36.0 | 24.1 | 32.5 | 43.5 | 43.0 |
| | Maximum | 81.0 | 50.0 | 53.0 | 32.7 | 43.3 | 65.5 | 58.9 |
| | SD | 7.1 | 3.8 | 2.7 | 1.7 | 2.0 | 3.9 | 3.2 |
| | n | 68 | 68 | 68 | 68 | 68 | 66 | 66 |
| Female | Mean | 61.0 | 38.1 | 45.1 | 30.3 | 35.4 | 52.9 | 45.8 |
| | Median | 60.0 | 38.1 | 45.0 | 30.1 | 35.5 | 53.3 | 46.0 |
| | Minimum | 48.0 | 30.2 | 38.8 | 25.5 | 30.9 | 43.0 | 39.0 |
| | Maximum | 87.0 | 55.0 | 52.5 | 35.5 | 39.0 | 60.5 | 52.0 |
| | SD | 7.3 | 3.4 | 2.2 | 2.1 | 1.8 | 3.4 | 2.6 |
| | n | 141 | 141 | 141 | 141 | 141 | 134 | 134 |
| Total | Mean | 61.6 | 38.6 | 46.2 | 30.2 | 36.6 | 54.6 | 47.0 |
| | Median | 61.0 | 38.2 | 46.0 | 30.0 | 36.5 | 54.2 | 46.8 |
| | Minimum | 48.0 | 30.2 | 36.0 | 24.1 | 30.9 | 43.0 | 39.0 |
| | Maximum | 87.0 | 55.0 | 53.0 | 35.5 | 43.3 | 65.5 | 58.9 |
| | SD | 7.3 | 3.6 | 2.9 | 2.0 | 2.5 | 4.3 | 3.3 |
| | n | 209 | 209 | 209 | 209 | 209 | 200 | 200 |

Table 2. Anthropometric data for ergonomically design of chair according to age group

| Age group | Statistic | Knee height (cm) | Lower leg length (cm) | Pelvis width (cm) | Shoulder width (cm) | Shoulder height (cm) | Patella height (cm) | Elbow height (cm) |
|---|---|---|---|---|---|---|---|---|
| 45-59 y.o | Mean | 38.8 | 45.9 | 30.2 | 36.6 | 55.5 | 46.6 | 23.2 |
| | Median | 38.5 | 46.0 | 29.9 | 36.7 | 55.0 | 46.0 | 23.0 |
| | Minimum | 30.6 | 36.0 | 24.1 | 31.1 | 45.8 | 39.0 | 16.2 |
| | Maximum | 55.0 | 53.0 | 35.0 | 43.3 | 65.5 | 58.6 | 53.0 |
| | SD | 3.8 | 2.7 | 2.1 | 2.2 | 3.6 | 3.3 | 4.4 |
| | n | 89 | 89 | 89 | 89 | 85 | 85 | 85 |
| 60-74 y.o. | Mean | 38.4 | 46.7 | 30.2 | 36.8 | 53.9 | 47.4 | 21.1 |
| | Median | 38.0 | 46.1 | 30.1 | 36.6 | 53.7 | 47.0 | 21.1 |
| | Minimum | 30.2 | 41.2 | 26.0 | 31.7 | 43.0 | 40.0 | 2.0 |
| | Maximum | 50.0 | 53.0 | 35.5 | 43.3 | 64.0 | 58.9 | 29.5 |
| | SD | 3.3 | 2.9 | 1.9 | 2.7 | 4.7 | 3.3 | 3.2 |
| | n | 112 | 112 | 112 | 112 | 107 | 107 | 107 |
| 75-89 y.o | Mean | 37.3 | 44.7 | 29.6 | 34.0 | 52.6 | 45.8 | 22.6 |
| | Median | 38.0 | 45.5 | 30.0 | 34.2 | 51.1 | 45.5 | 22.0 |
| | Minimum | 31.1 | 38.8 | 25.5 | 30.9 | 49.8 | 42.0 | 20.0 |
| | Maximum | 41.8 | 49.0 | 31.4 | 37.3 | 61.5 | 50.0 | 26.0 |
| | SD | 3.8 | 3.4 | 1.8 | 2.0 | 3.9 | 2.5 | 2.0 |
| | n | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Total | Mean | 38.6 | 46.2 | 30.2 | 36.6 | 54.6 | 47.0 | 22.0 |
| | Median | 38.2 | 46.0 | 30.0 | 36.5 | 54.2 | 46.8 | 22.0 |
| | Minimum | 30.2 | 36.0 | 24.1 | 30.9 | 43.0 | 39.0 | 2.0 |
| | Maximum | 55.0 | 53.0 | 35.5 | 43.3 | 65.5 | 58.9 | 53.0 |
| | SD | 3.6 | 2.9 | 2.0 | 2.5 | 4.3 | 3.3 | 3.8 |
| | n | 209 | 209 | 209 | 209 | 200 | 200 | 200 |

Table 3. Mean of height (H), weight (W), arm span (AS), knee height (KH) and sitting height (SH) in centimeter

| **Sex** | **Statistic** | **H** | **W** | **AS** | **KH** | **SH** |
|---|---|---|---|---|---|---|
| Male | Mean | 159.,2 | 61.9 | 161.4 | 48.7 | 83.3 |
| | Minimum | 150.,0 | 43.1 | 130.5 | 45.0 | 76.0. |
| | Maximum | 170.,5 | 81.0 | 183.0 | 53.0 | 88.5 |
| | SD | 5.3 | 9.4 | 11.6 | 2.5 | 3.0 |
| Female | Mean | 149.1 | 58.5 | 152.9 | 44.9 | 78.4 |
| | Minimum | 136.5 | 34.0 | 134.4 | 38.0 | 72.0 |
| | Maximum | 166.0 | 88.4 | 170.0 | 50.5 | 85.2 |
| | SD | 6.2 | 11.6 | 7.9 | 2.6 | 3.5 |
| | n | 72 | 72 | 72 | 72 | 72 |
| Total | Mean | 151.9 | 59.5 | 1553 | 46.0 | 79.8 |
| | Minimum | 136.5 | 34.0 | 130.5 | 38.0 | 72.0 |
| | Maximum | 170.5 | 88.4 | 183.0 | 53.0 | 88.5 |
| | SD | 7.5 | 11.1 | 9.8 | 3.1 | 4,0 |
| | n | 100 | 100 | 100 | 100 | 100 |

Table 4. Mean difference of predicted height of arm span (AS), knee height (KH), sitting height (SH) with actual height according to gender (in centimeter)

| Sex | Statistic | AS | KH | SH |
|---|---|---|---|---|
| Male | Mean | 2.6 | 0.5 | 0.3 |
| | Minimum | -14.5 | -15.6 | -7.8 |
| | Maximum | 24.1 | 10.4 | 6.6 |
| | SD | 9.1 | 5.0 | 3.4 |
| | n | 28 | 28 | 28 |
| Female | Mean | 0.9 | 1.6 | -0.1 |
| | Minimum | -16.8 | -8.8 | -6.7 |
| | Maximum | 23.2 | 12.1 | 12.6 |
| | SD | 5.4 | 4.1 | 3.7 |
| | n | 72 | 72 | 72 |
| Total | Mean | 1.4 | 1.3 | 0.1 |
| | Minimum | -16.8 | -15.6 | -7.8 |
| | Maximum | 24.1 | 12.1 | 12.6 |
| | SD | 6.7 | 4.4 | 3.6 |
| | n | 100 | 100 | 100 |

Table 5. Sensitivity, specificity and predictive value of estimating height in elderly according to anthropometric chair (arm span, knee height and sitting height)

| Indicator | Normal nutrition | | | |
|---|---|---|---|---|
| | Sensitivity | Specificity | PPV | NPV |
| Male | | | | |
| Arm span | 75.0 | 41,7 | 63.2 | 55.6 |
| Knee height | 87.5 | 58.3 | 73.7 | 77.8 |
| Sitting height | 100.0 | 75.0 | 84.2 | 100.0 |
| Female | | | | |
| Arm span | 93.2 | 82.1 | 89.1 | 88.5 |
| Knee height | 93.2 | 85.7 | 91.1 | 88.9 |
| Sitting height | 97.7 | 75.0 | 86.0 | 95.5 |
| Total | | | | |
| Arm span | 88.3 | 70.0 | 81.5 | 80,0 |
| Knee height | 91.7 | 77.5 | 85.9 | 86,1 |
| Sitting height | 98.3 | 75.0 | 85.5 | 96,8 |

Note:
PPV : *Positive Predictive Value*
NPV: *Negative Predictive Value*

Fig.1 Anthropometric chair for elderly

The decreasing of height in elderly associated with posture, osteoporosis, spinal damage, kyphosis and scoliosis. Male commonly have mean knee height, arm span, and sitting height higher than female. It is consistent with two studies who found that the mean height of the three predictors in elderly male was larger than the female [12], [13]. It may be caused by the differences in posture and physical activity between them. Mean difference of prediction height for the three predictors with actual height is presented in Table 4. Sitting height has the lowest distinction rather than arm span and knee by gender and wholly, as followed by knee height in elderly men and arm span in elderly women. Table 5 showed the validity of the test is based on four indicators of anthropometric chair i.e. the sensitivity, specificity, PPV (Positive Predictive Value), and NPV (Negative Predictive Value). Sitting height is a predictor that has the highest sensitivity in the group of elderly men and women which subsequently followed by a knee height and arm span. Moreover, that predictor may become a filter to screen whether elderly are under nutrition or over nutrition among those with normal status nutrition during assessment. In contrast, knee height has the greatest level of specificity rather than arm span and commonly sitting height. It means that the first predictor is able to recognize the elders with normal nutritional status among those with malnutrition. Positive Predictive Value (PPV) is the measurement parameter to find the likelihood that the patients were 'true positive' disease [14] Knee height is the most precise predictor to assess the probability of elderly malnutrition whether in over nutrition and under nutrition to both elderly men and women. Afterwards, the sequential predictors are sitting height and arm span. In elderly men, sitting height more precisely measure the likelihood of malnutrition cases in well-nourished elderly. Meanwhile knee height becomes the most accurate predictor to assess the likelihood of malnutrition status among elderly women with normal nutritional status. Negative Predictive Value (NPV) describes the likelihood that the patients are really free from disease or in healthy status [14]. Sitting height has the largest NPV value among all elderly and as gender accordingly. It is the most accurate way to assess the likelihood of elderly people with actually normal nutritional status. Based on the results of validity test above, it can be concluded that the anthropometric chair has been tested and valid in assessing the nutritional status of elderly people whom their actual height was unmeasured manually by measuring arm span, knee height, and sitting height. Thus, it was practical tool to measure the nutritional status of the elderly at once without the need to change the measurement in varying position, as it merely done while sitting. The reading of the NSA can be seen in BMI meter which denotes the value of IMT elderly of all three predictors. In addition, over 300 grams Load Cell can be used to solve the difficulty of weighing the elderly who unable to stand up during weighing due to disability or paralysis. All tool components such as sensor at the three-point anthropometric measurements, BMI meter and load cell have been calibrated to obtain the exact value of BMI.

## 4. CONCLUSION AND SUGGESTION

The type of chair as an anthropometric tool for assessing nutritional status in elderly was selected based on practical reasons i.e. it measured nutritional status in elderly at once in sitting position since the convenience of the elderly was also considered. The verification of the estimating body height of such predictors, as arm span, knee height, and sitting height with anthropometric chair to nutritional status of elderly people showed that the results of nutritional status of older adults extracted from the three predictors as measured proved to be representative or may represent the BMI value of the actual body height. It is suggested that the validity test of anthropometric chair for elderly can be performed widely with greater number of elderly either in urban and rural for the variances of the sensitivity, specificity, PPV, and NPV.

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