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Diurnal variation in aviation significant gravity-dependent and gravity-independent anthropometric parameters

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ABSTRACT

Introduction: Anthropometric parameters need to be accurately measured because of their direct implications in selection of aircrew, aircrew-cockpit compatibility, and cockpit workspace design. Some of these parameters have significant diurnal variation, hence, measurement of these parameters in particular time of day becomes important. Quantification of these diurnal variations among some of the aviation significant parameters was the desired objective of the study.

Material and Methods: In a prospective repeated measure design, anthropometric parameters of a total of 35 volunteers were measured in the standard defined protocol from 0800h to 1600h, at an interval of every 2h, using Institute of Aerospace Medicine (IAM) Anthropometry Platform. The data were analyzed to observe and quantify changes in diurnal variations in both gravity-dependent and gravity-independent parameters. A maximum value of 0.4 cm was taken as intraobserver variations based on the results of a pilot study.

Results: There was a statistically significant decrement in the values of gravity-dependent anthropometric parameters from morning to evening; the difference being more after 1200h. Most of the gravity-independent parameters did not show any significant changes from 0800h to 1600h, except leg length, which showed a decrement overtime, the difference being statistically significant after 1200h.

Conclusion: The study revealed a statistically significant variation of gravity-dependent anthropometric parameters from the baseline which could be because of the effect of erect posture on the intervertebral disc height and axial compressive loads on the spine. This became practically significant after 1200h. However, most of the gravity-independent parameters did not show any significant variations. Based on the results of this study, anthropometric measurements should be done in the morning hours preferably before 1200h.

Keywords: Anthropometry, Diurnal variation, Aircrew-cockpit compatibility, Cockpit workspace design, Gravity-dependent parameter, Gravity-independent parameters

INTRODUCTION

Anthropometry is the study of measurements pertaining to human beings. It deals with the measurement of the dimensions and certain other physical characteristics of the body such as volumes, center of gravity, inertial properties, and masses of body segments.[1] Anthropometric measurement of a given population provides a standard statistical description of that population which is utilized by researchers and designers to achieve accommodations, compatibility, integration, safety, improved performance, and logistic efficiency in human-equipment system.[2] In aviation, anthropometry has significant applications which include selection of candidates for aircrew duty, aircrew-cockpit compatibility, cockpit workspace design, and design and manufacturing of aircrew equipment assembly. In short, anthropometry in aviation strives to ensure aircrew aircraft compatibility.

Various measurement techniques have been used across the Air Forces in the world for aircrew anthropometry. In the Indian Air Force (IAF), Institute of Aerospace Medicine (IAM) Anthropometry Platform is used for measurement of anthropometric parameters, in addition to measuring tapes and calipers. At present, 57 anthropometric parameters are being recorded during selection of flying aspirants for cockpit compatibility and sizing and fitment of aircrew equipment assembly.[3] Four anthropometric dimensions are considered critical for entry during selection of flying aspirants. These include stature, sitting height, leg length, and thigh length.[4]

Some of the anthropometric parameters are known to have diurnal variation as they are influenced by the effect of gravity. The study by Reilly *et al*. has reported diurnal variation in stature to be a biological norm in the human body and its effects could be reflected in the reliability of anthropometric data.[5] Over the period, researchers have attempted to quantify this diurnal variation in anthropometric parameters which have shown varying results. Literature survey reveals that there is expected behavior for the different measurements, that is, some measurements are expected to increase (as the girths and the weight) while others are expected to decrease (as the heights).[6] Thus, based on the above literature, parameters which are likely to show diurnal variations due to gravity can be referred to be as "Gravity-Dependent Parameters" and those not affected are known as "Gravity-Independent Parameters." Hence, time of measurement of few of the parameters becomes time critical.

As per the existing practices at IAM, the anthropometric measurements are undertaken in the morning hours. Although the empirical reason behind this time limitation is understood, the change in the anthropometric parameters during the day (morning to evening) has not been quantified and validated. A longitudinal study on repeated measurements of some important gravity-dependent and -independent parameters on diurnal variation would not only answer the above query but also quantify the variation. This was the desired objective of the present study.

MATERIAL AND METHODS

Subjects

Thirty-five healthy volunteers between the age group of 20 and 40 years participated in the study. This included 30 males and 05 females. The exclusion criteria were (a) clinically diagnosed cases of spinal disorders, (b) history of any musculoskeletal diseases including spine, (c) orthopedic disabilities involving any part of the body, (d) deformity of the skeletal system, if any (e) perceptible stiffness of joints due to any reasons.

Calculation of sample size

In a previous study on inter- and intra-observer variations, it was found that the maximum mean standard deviation (SD) possible was 0.4 cm; hence, any parameters showing more than 0.4 cm was taken as significant change. A pilot study was undertaken, in which, sitting height, the parameter most likely affected by axial loading of gravity, was measured every 2h from 0800h to 1600h by the same experimenter. The SD was found to be 0.68 cm. The calculated effect size was 0.58. With the above inputs, the calculated sample size to determine a difference of 0.4 cm was 33. Hence, 35 subjects were included for the study.

Anthropometric parameters

The parameters studied included four gravity-dependent parameters (standing height, sitting height, sitting eye level height, and shoulder height) and five gravity-independent parameters (leg length, arm reach fingertip, shoulder width, knee height, and thigh length).

Equipment

IAM anthropometry platform, short anthropometer, long anthropometer, spreading caliper, and measuring tape were used for recording various measurements.

Experimental protocol

The study was designed as a prospective longitudinal experimentation with repeated measures design. The study was conducted at the Department of Human Engineering, IAM. All volunteers were measured for gravity-dependent parameters and then out of these volunteers, 10 were measured for gravity-independent parameters. The subjects reported to human engineering department in the morning and anthropometric parameters defined above were measured at 0800h which was labeled as "Baseline Measurements." The measurements were recorded every 2h thereafter till 1600h. During this period, subjects were allowed to do normal routine activities. All measurements were recorded by a single observer to avoid inter-observer variation.

Statistical analysis

Paired sample *t*-test was used to find the difference in the anthropometric parameters at different time intervals against the baseline value of 0800h only. The level of significance was set at $P < 0.05$.

RESULTS

The mean age of male subjects was 30.8 ± 6.70 years and that of female subjects was 27.2 ± 4.95 years. The mean difference in gravity-dependent anthropometric parameters taken at different points of time with that of baseline values (0800h) is depicted in Table 1. It is evident from the table that there was a significant difference in diurnal variations among gravity-dependent anthropometric parameters. Analysis of gravity-independent parameters showed a significant difference in leg length after 1200 h as compared to baseline values. However, other gravity-independent parameters did not show any significant diurnal variation [Table 2]. Graphical representations of the changes across the day in the parameters which showed significant diurnal variations from baseline are shown in Figures 1-5.

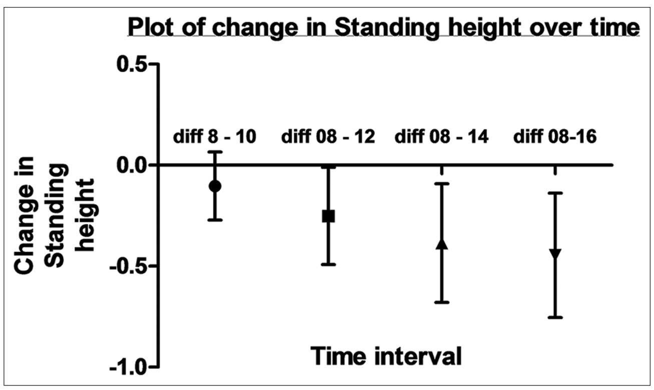

Figure 1: Graphical representation of the difference in measurement of standing height at different time intervals.

DISCUSSION

Anthropometry has significant applications in aerospace environment from selection of aircrew to aircraft cockpit workspace design.[7] Hence, anthropometric parameters need to be accurately measured. Whereas, few modifiable factors such as inter- and intra-observer variations could be minimized with appropriate training; there are certain factors which cannot be controlled. One of such factors is the time of measurement since few anthropometric parameters are known to change with the progression of day.[8] At this institute, to minimize the above changes, all measurements are taken in the morning hours before 1100h. However, there is no study in the IAF which quantifies this diurnal variation. With this objective, the present study was undertaken to study the diurnal variations in few important anthropometric parameters in a cohort of 35 subjects in a prospective, longitudinal, repetitive measure design.

We chose a total of nine such aviation significant anthropometric parameters and divided into two groups: Four gravity-dependent and five gravity-independent parameters. Gravity-dependent parameters formed those which were likely to change with the exposure to gravity. This is attributed to axial loading of spine on erect posture and desiccation of intervertebral disc IVD).[9,10]

Our study revealed some important findings. The gravity-dependent parameters showed a consistent decrement with time as compared to baseline values [Table 1] which were statistically significant. The variations were more of magnitude (more than 0.4 cm) in most of the parameters in the later part of the day after 1200h. This is in consonance with results from other studies. The variation is likely to be due to continuous

Table 1: Mean difference and SD of paired sample test for gravity-dependent anthropometric parameters at different time intervals.

Time interval (hour)	0800–1000	0800–1200	0800–1400	0800–1600
Standing height (cm)	0.10±0.23*	0.16±0.30*	0.38±0.45*	0.40±0.47*
Sitting height (cm)	0.18±0.50*	0.39±0.54*	0.50±0.59*	0.61±0.68*
Sitting eye level height (cm)	0.21±0.46*	0.47±0.55*	0.60±0.59*	0.73±0.67*
Sitting shoulder height (cm)	0.13±0.39	0.46±0.64*	0.54±0.71*	0.73±0.93*

*$P<0.05$

Table 2: Mean difference and SD of paired sample test for gravity-independent anthropometric parameters at different time intervals.

Time interval (hour)	0800–1000	0800–1200	0800–1400	0800–1600
Leg length (cm)	0.11±0.39	0.20±0.54	0.32±0.54*	0.39±0.57*
Arm reach fingertip (cm)	0.48±1.51	0.48±1.51	0.47±1.52	0.56±1.51
Shoulder width (cm)	0	0	0	0.01±0.03
Knee height (cm)	0.01±0.03	0	0	0
Thigh length (cm)	0.01±0.03	0.02±0.04	0.03±0.06	0.03±0.06
Calf circumference (cm)	0	0.05±0.15	0	0

*$P<0.05$

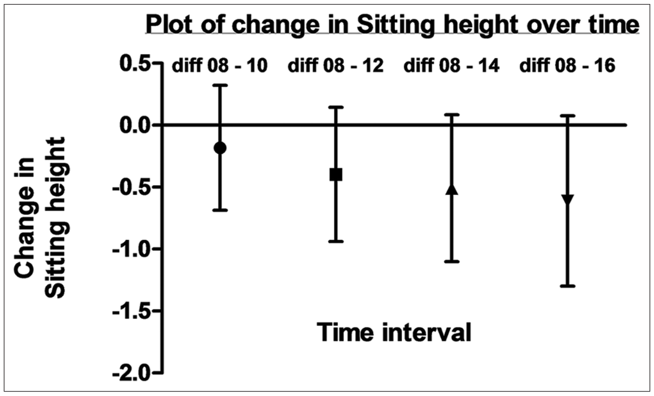

Figure 2: Graphical representation of the difference in measurement of sitting height at different time intervals.

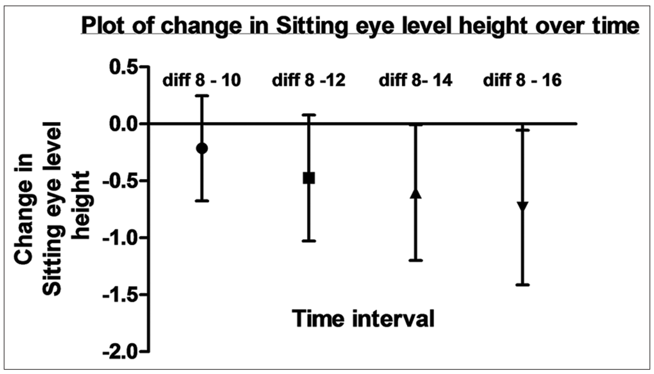

Figure 3: Graphical representation of the difference in measurement of sitting eye level height at different time intervals.

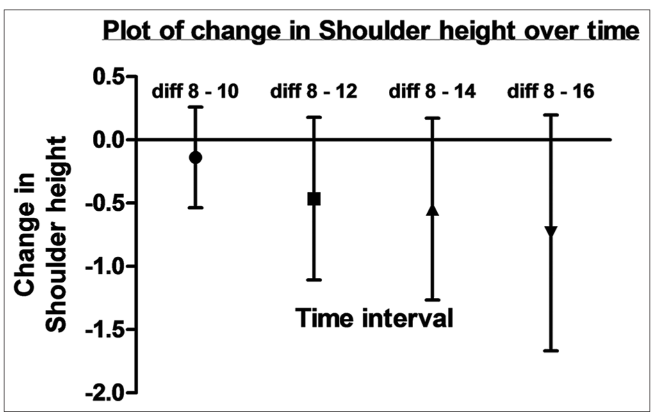

Figure 4: Graphical representation of the difference in measurement of sitting shoulder height at different time intervals.

axial loading of the spine and consequent effects thereof. Fluid is expelled from the nucleus pulposus of the IVDs, which leads to a decrease in stature.[11] Kourtis *et al*. confirmed that the amount of height loss is proportional to the amount of fluid loss and degree of compressive loads on the spine.[12] According to Corlett, the stature decreases quickly after people get out of bed and depending on the pattern of work and

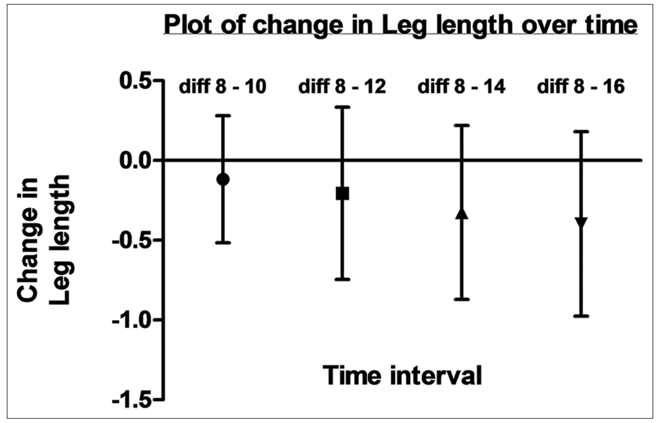

Figure 5: Graphical representation of the difference in measurement of leg length at different time intervals.

rest, continues to reduce during the day, and then recovers overnight to its natural state. This diurnal variation in stature results from changes in the height of the intervertebral discs (IVDs); compressive load on the spine causes osmotic pressure over the discal tissues, making them expel a fluid that makes intervertebral joint change its dynamic response.[13,14]

The results of the present study also confirmed no significant difference in diurnal variations in most of the gravity-independent parameters. Only, leg length showed a significant change after 1200h from baseline. The procedure of leg length standardized at the institute mandates adopting sitting posture with the buttocks fully pressed against the backrest without any gap and legs kept absolutely horizontal on the platform with knees fully extended. In our experience, we have noticed that adopting such a posture becomes difficult for the subject. With increase in flexibility of the spine and hip in the later part of the day possibly due to increased physical activities, they were able to adopt the posture better. The closer the buttocks are to the backboard, less is the value of leg length. This could be the possible reason why we found a significant decrease in leg length in the later part of the day.

In a previous study on inter- and intra-observer variations, it was found that the maximum mean SD possible was 0.4 cm;[15] it meant that if the difference between measurements of two intervals was more than 0.4 cm then that variation could be due to diurnal changes. In the present study, we found that measurements of different parameters (standing height, sitting height, sitting eye level length, shoulder height, leg length, buttock vertex length, and buttock shoulder length) had crossed the difference of 0.4 cm mostly after 1200h. Thus, based on the results of this study, ideally, the anthropometric measurements should be undertaken in the morning hours preferably before 1200h. This supports the IAM practices of undertaking anthropometric measurements before 1100h of the day.

CONCLUSION

Diurnal variation in anthropometric parameters may substantially affect the reliability of their data and careful consideration should be given to the time at which the measurements are recorded. Following conclusions could be made from the results of the study; (a) gravity-dependent parameters showed significant diurnal variations; whereas most of the gravity-independent parameters did not show any significant changes, (b) the diurnal variations were more significant in the later part of the day, and (c) the findings support IAM practices of undertaking anthropometric measurements in the morning hours up to 1100h.

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Declaration of patient consent

Participant's consent not required as participants identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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