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Segmental Proportions Based on Anthropometry of Female Agricultural Workers, India

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Research Article

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Abstract

Women play a major role in the development of rural and national economies of India through their agricultural operation. For proper design of farm equipment for women workers, it is necessary to collect anthropometric data on farm women. But not much of information is available regarding their anthropometric data. Therefore, an anthropometric survey was carried out for female agricultural workers of Gujarat state, wherein 382 female agricultural workers were selected and 38 body dimensions were precisely measured and recorded from each subject. The data measured were statistically analyzed for mean, standard deviation, 5th and 95th percentile values which are used in design. For making the data comprehensive and more useful, a set of 19 body dimensions, which are having direct implications on agricultural tool/implement design were selected, and compared with data of different states of India and also with other countries female workers. The mean weight and stature of female agricultural workers were found to be 48 kg and 1522 mm, respectively. A large variation in anthropometric dimensions was observed in the anthropometric data of female farm workers of different states of India and other countries. The data as obtained are intended to be used for the design and modifications of agricultural hand tools/implements with a view to reduce drudgery and at the same time increase efficiency, safety and comfort of operators in agriculture operation.

Keywords: Anthropometry; Body Dimensions; Female Agricultural Worker; Tool Design

Introduction

The word 'anthropometry' means measurement of the human body. Anthropometry is the science of measurement and the art of application that establishes the physical geometry, mass properties, and strength capabilities of the human body [1]. It involves the systematic measurement of the physical properties of the

human body, primarily dimensional descriptors of body size and shape. The knowledge of body dimensions is essential for designers of equipment and work places. The anthropometric measurements are essential for the correct design of the work areas [2-4].

India is an agriculture-based country. A large section of Indian population engages in agriculture. Although agriculture is generally recognized as the nation's most hazardous industry and displays high rates of MSDs with evidence in which the ergonomic risk factors are involved and be pointed out, there is very little history of application of ergonomic approaches in agricultural equipment design. About 6.5% of the power used in crop production and related activities in the country is contributed by about 241 million workers, of which about 42% (i.e. 101 million) are female workers. Thus, the human workers play a major role in the country's agriculture and due to that, attention needs to be given to their capabilities and limitations during design and operation of various farm equipment's, so as to get higher productivity, enhanced comfort and ensure better safety [5,6]. Manually operated equipment's are extensively used in Indian agriculture for various farm operations starting from seedbed preparation to post-harvest operations.

The ergonomic principles or human factors are considered in machine design to enhance effectiveness, efficiency, safety and comfort of the users/operators of the equipment. In most cases, constraints are been experienced in adoption of improved machineries being utilized in other parts of the country; the adopted equipment at times need to be modified before being introduced into other countries or regions to suit agricultural workers of the region for which body dimensions limits of local populations was required. Because of Yadav, et al. [7] pointed out that there was considerable difference between the anthropometric data of Indian and westerns. To design any product for human use, engineers have to rely on anthropometric data, otherwise the resulting product may turn out to be ergonomically incompatible [8].

Gite and Yadav [9] noted that the design and dimensions of agricultural tools and implements have great bearing on the body dimensions and physical built of the users, requiring compatibility essentially between machine devices and worker body dimensions. Dewangan, et al. [10] suggested that the only way to fulfill this objective is to create database of anthropometric dimensions of the user population. Therefore, a sample study was conducted to collect and analyse the anthropometric data of female agricultural workers of Gujarat state for the ergonomic design of farm equipment and workplaces.

Materials and Methods

An anthropometric survey was carried out in Gujarat states of India. For the collection of data, survey was carried out in all the districts of the Gujarat states. Total 382 subjects in the age group 22–54 years of age were randomly chosen from state. Simple random sampling was used to select farm women. The selected female workers were engaged in various agricultural operations on the farms. Subjects were screened so that those in normal health without any serious disease or physical handicapped were selected. Total 38 body dimensions including weight were identified for measurement, which were important in the design of agricultural equipment and workplace.

The standard terminologies of selected anthropometric dimensions and measurement landmarks for as suggested in the anthropometric source book are shown in Figure 1 [11,12]. The team of researchers was trained for a week on how to recognize the dimensions to be measured, to use measuring instruments and to record data into a log sheet. Subjects were chosen randomly, having normal appearance and having no physical disabilities. Before the measurements were made, the subjects were given an explanation about the purpose of the study. Only subjects who gave their consent were considered further. All subjects wore light clothing without foot wears. For standing dimensions, subjects were asked to stand upright on the base of the anthropometer, facing forward, and arms hanging beside the body. For sitting dimensions, subjects were asked to sit erect on a chair without armrests, with knees bent 90°and feet flat on the surface, facing forward, and arms hanging beside the body.

Forty (40) anthropometric body dimensions considered useful for design of agricultural equipment/machines. There were 17 body measurements in standing posture, 15 measurements in sitting posture and six measurements in either sitting or standing posture. In addition, two antropometric indices viz. body mass index (BMI) and relative sitting height (RSH) were calculated from the measured anthropometric data. The BMI is defined as the body mass (kg) divided by the square of the stature (m), whereas the RSH is the ratio of sitting height to stature. All the measurements of each subject were taken three times.

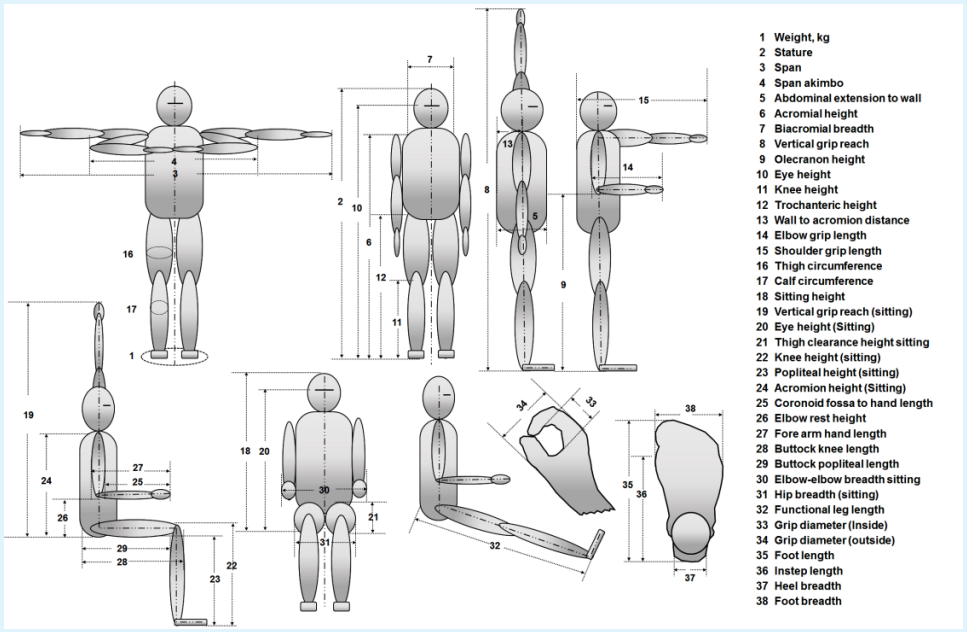

Figure 1: Anthropometric dimensions in standing and sitting postures.

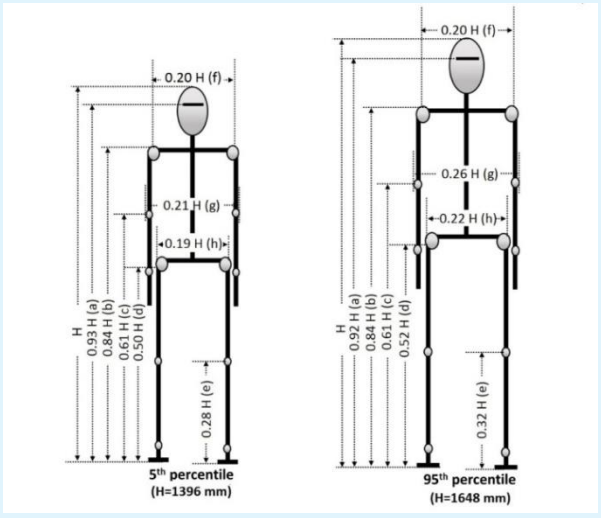

Figure 2: Segmental proportions as a function of stature (H) for different percentile female agricultural workers of central India in standing posture (a: eye height, b: acromial height, c: olecranon height, d: trochanteric height, e: knee height, f: biacromial breadth, g: elbow-elbow breadth, h: hip breadth).

The data was further analysed and in addition to the descriptive values, 5thand 95thpercentile values were also calculated. Each group of data was included in statistical analysis. Collected data were first entered in Microsoft Excel and then for statistical analysis were transferred to the SPSS (Statistical Package for Social Science). At first all the socio-economical variable were summarized.

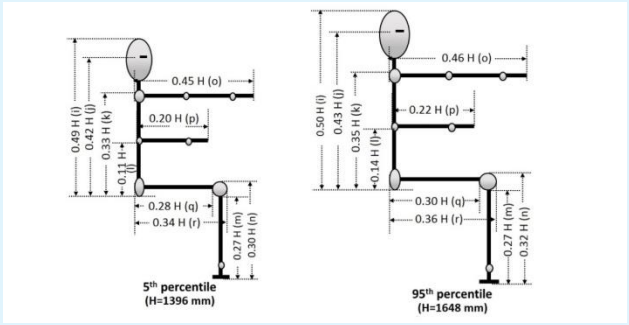

Figure 3: Segmental proportions as a function of stature (H) for different percentile female agricultural workers of central India in sitting posture. (i: sitting height, j: eye height (sitting), k: acromion height (sitting), l: elbow rest height, m: popliteal height (sitting), n: knee height (sitting), o: shoulder grip length, p: elbow grip length, q: buttock popliteal length, r: buttock knee length).

The data set for each dimension in the sample's group were checked to ensure that they represent a normal distribution. Furthermore, 18 particular body dimensions were chosen to illustrate the differences of segment proportions of 5th and 95th percentile female agricultural

workers in both standing posture namely eye height, acromial height, olecranon height, trochanteric height, knee height, biacromial breadth, elbow-elbow breadth and hip breadth were selected (Figure 2). In addition, ten body dimension measured in sitting posture namely sitting height, eye height (sitting), shoulder grip length, elbow grip length, buttock popliteal length and buttock knee length were selected (Figure 3).

Results and Discussion

Anthropometric Data of Female Agricultural Workers

Various Anthropometric Measurements had been taken for the designing of Agricultural tools and equipment for the drudgery reduction of Farm women. Further, observations were analysed and mean, standard deviation (SD), percentile values (5^{th} and 95^{th}) of anthropometric data of selected female agricultural workers are calculated and shown in Table 1.

Mean stature of farm women in Gujarat was found 1536 mm whereas, 5^{th} and 95^{th}percentile were 1396 and 1648 mm respectively. Mean weight of farm women was found 48 kg, however 5^{th} and 95^{th} percentile of weight were 35 kg and 62 kg respectively. The mean span, acromial height, eye height, olecranon height, trochanteric height and knee height of selected female agricultural workers in standing posture were 1562 (±76), 1274 (±62), 1410(±67), 929 (±47), 777 (±48) and 458 (±40) mm, respectively. The mean vertical grip reach, shoulder grip length and elbow grip length in standing posture were 1863 (±84), 690 (±38) and 321 (±27) mm, respectively. The mean sitting height, eye height, acromion height, elbow rest height, knee height and popliteal height of selected female agricultural workers in sitting posture were 750 (±40), 651 (±37), 513 (±36), 191 (±24), 475 (±30) and 416 (±21) mm, respectively. The mean vertical grip reach, fore arm hand length, buttock knee length and buttock popliteal length were 1097 (±56), 321 (±29), 529 (±36) and 439 (±30) mm, respectively.

Sr. No.	Acronym	Measurement	Mean	SD (±)	5th per	95th per
1	WT	Weight, kg	48	82	35	62
2	ST	Stature	1522	76	1396	1648
3	SP	Span	1562	76	1437	1687
4	SPA	Span akimbo	776	62	674	878
5	AE	Abdominal extension to wall	219	37	159	280
6	AH	Acromial height	1274	62	1171	1377
7	BB	Biacromial breadth	303	18	273	332
8	VGR	Vertical grip reach	1863	84	1802	2080
9	OH	Olecranon height	929	47	851	1006
10	EH	Eye height	1410	67	1300	1519
11	KH	Knee height	458	40	392	525
12	TH	Trochanteric height	777	48	698	856
13	WAD	Wall to acromion distance	95	12	74	115
14	EGL	Elbow grip length	321	27	275	366
15	SGL	Shoulder grip length	690	38	627	754
16	TC	Thigh circumference	410	42	341	480
17	CC	Calf circumference	276	26	234	319
18	SH	Sitting height	750	40	685	816
19	VGRS	Vertical grip reach (sitting)	1097	56	1004	1190
20	EHS	Eye height (Sitting)	651	37	590	712
21	TCH	Thigh clearance height sitting	132	19	101	163
22	KHS	Knee height (sitting)	475	30	424	525
23	PHS	Popliteal height (sitting)	416	21	381	451
24	AHS	Acromion height (Sitting)	513	36	454	572
25	CFHL	Coronoid fossa to hand length	367	33	312	421
26	ERH	Elbow rest height	191	24	152	230
27	FAHL	Fore arm hand length	321	29	365	460
28	BKL	Buttock knee length	529	36	470	589
29	BPL	Buttock popliteal length	439	30	389	488
30	EEBS	Elbow-elbow breadth sitting	363	39	299	426

31	HBS	Hip breadth (sitting)	316	27	272	360
32	FLL	Functional leg length	906	46	829	983
33	GDI	Grip diameter (Inside)	53	6	43	63
34	GDO	Grip diameter (outside)	85	8	72	98
35	FL	Foot length	228	14	204	251
36	ISL	Instep length	147	12	128	167
37	HL	Heel breadth	59	6	50	69
38	FB	Foot breadth	89	7	78	100
39	BMI	Body mass index	20.7	4.7	17.9	22.8
40	RSH	Relative sitting height	0.49	0.03	0.49	0.52

Table 1: Anthropometric data of female agricultural workers (n = 382).
Measurement unit: mm, unless otherwise specified

During the design of equipment or workplace, the 5th percentile value should be used, where lower limit is the restrictive factor such as control reach, height of display, operating forces etc. The 95th percentile value should be used in design where the upper limit is restrictive factor such as design of clearances, seat dimensions, height of the door etc. According to Pheasant [13], the smaller subjects having values of relative sitting height (RSH) less than 0.50 are categorized as "long legged", whereas the taller ones having RSH between 0.53-0.55 are categorized as "short legged". The average group having RSH between 0.51-0.53 is categorized as between short and long legged. From the Table 1, it is observed that subjects (Mean, 5thand 95thpercentile) having RSH less than 0.50 so they categorized as "long legged" persons.

Segmental Proportions of Different Anthropometric Dimensions as a Function of Stature

The segmental proportions of 5th and 95th percentile values of different anthropometric data as function of stature (H) of selected female agricultural workers in both standing and sitting postures are depicted in Figure 2 and 3, respectively. Figure 2 indicated that the segmental proportions of selected subjects in standing posture namely knee height, elbow-elbow breadth and hip breadth increased considerably with increase in percentile values of stature from 5th to 95th. Similarly, Figure 3 indicated that the segmental proportions of selected subjects in sitting posture namely elbow rest height increased with increase in stature (5th to 95th percentile values). However, there is no significant difference in segmental proportions of other body dimensions with increase in stature of subjects.

Comparison of Anthropometry Data across States of India and Other Countries

Nineteen different anthropometric data of female agricultural workers were compared with data of 14 states of India and presented in Table 2. From the Table 2, it was observed that the statures of female workers of Maharashtra, Meghalaya, Odisha, Sikkim, Tamil Nadu, Uttar Pradesh and west Bengal are smaller than the stature of selected workers in the study. However, female farm workers of Himachal Pradesh, Madhya Pradesh, Mizoram, Jammu and Kashmir and Punjab are taller in stature as compared to female farm workers of Gujarat collected in the study. The RSH value for Gujarat, Punjab state is 0.49 indicating that they are "long legged". Similarly, the RSH value for Arunachal Pradesh state is 0.53 indicating that they are "short legged". For rest of the states, the RSH value ranges within 0.50-0.52 indicated that they may be categorized between short and long legged.

The mean values of anthropometric data collected in the study were also compared with anthropometric data of female workers of 14 countries and reported in Table 3. It can be seen that the Gujarat female workers are smaller in stature, sitting height, buttock knee length, buttock popliteal length and hip breadth than the American, British, Polish, Dutch, Portuguese, Swedish, Turkish and Nigerian population. This variation among anthropometric data could be due to the differences in body build-up of female workers from other countries. The differences found in the anthropometric dimensions of the different population groups emphasize the usefulness of this study in the context of design of agricultural hand tools and implements. Most of the agricultural tools/machinery used in India are based on body dimensions of foreign workers. Designs that once suited the British population are followed in India [14]. This implies that the devices and implements designed abroad should be suitably modified before introducing these to the Indian farm workers.

Anthropometric dimensions	Present study	Arunachal Pradesh	Himachal Pradesh	Jammu & Kashmir	Madhya Pradesh	Maharashtra	Meghalaya	Mizoram	Odisha	Punjab	Rajasthan	Sikkim	Tamil Nadu	Uttar Pradesh	West Bengal
Stature	1522	1525	1573	1538	1538	1504	1507	1552	1516	1542	1528	1510	1508	1508	1499
Sitting height	750	801	787	777	784	767	784	804	784	763	782	789	754	780	764
Wall to acromion distance	95	118	103	101	96	97	105	116	76	105	92	103	107	101	92
Sitting acromion height	513	548	549	531	534	518	534	547	541	541	532	538	521	522	513
Elbow rest height	191	236	216	200	205	206	228	230	221	207	222	231	187	208	210
Shoulder grip length	690	672	647	686	670	676	667	655	630	706	685	698	619	698	680
Elbow grip length	321	330	344	324	328	310	305	323	335	332	329	325	329	332	299
Biacromial breadth	303	335	351	315	292	272	287	336	281	331	262	300	282	284	288
Elbow-elbow breadth	363	374	398	338	366	323	349	382	351	406	363	418	357	357	330
Abdominal extension	219	212	245	238	226	209	185	208	209	213	228	267	196	217	213
Thigh clearance sitting	132	140	126	124	117	131	135	151	104	144	128	140	110	123	117
Knee height sitting	475	448	472	484	473	461	469	463	475	460	492	465	475	470	450
Popliteal height sitting	416	351	423	404	392	386	395	356	415	359	416	375	394	402	384
Buttock-knee length	529	504	486	499	522	519	512	512	460	521	483	503	525	509	524
Buttock-popliteal length	439	378	429	419	450	438	424	391	399	435	415	425	441	435	408
Foot length	228	227	208	236	229	223	221	226	223	234	231	219	218	228	227
Hip breadth sitting	316	307	332	330	312	296	310	323	267	331	314	363	286	304	310
Foot breadth	89	91	87	92	88	91	88	86	91	88	94	90	83	88	88
Functional leg length	906	898	881	931	939	935	958	907	910	968	960	866	987	934	899
RSH*	0.49	0.53	0.50	0.51	0.51	0.51	0.52	0.52	0.52	0.49	0.51	0.52	0.50	0.52	0.51

Table 2: Mean values of important standing and sitting anthropometric dimensions of female agricultural workers of different states of India (Gite, et al. 2009)

Measurement unit: mm, unless otherwise specified. *Ratio of sitting height to stature (unitless)

Body feature	Present study	USA[a]	UK[ab]	Poland[b]	Holland[b]	Portugal[b]	Sweden[c]	Turkish[e]	Nigeria[f]	Indonesia[e]	Taiwan[d]	China[d]	Japan[d]	Korea[d]	Filipino[e]
Stature	1522	1626	1610	1575	1650	1565	1674	1598	1600	1525	1573	1576	1569	1588	1539
Sitting height	750	861	850	825	875	865	892	848	770	774	848	855	850	866	799
Wall to acromion distance	95	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sitting acromion height	513	564	555	565	565	595	577	558	560	506	NA	NA	NA	NA	NA
Elbow rest height	191	236	235	230	240	250	238	232	170	205	254	251	253	263	219
Shoulder grip length	690	711	705	735	705	675	NA	695	670	667	NA	NA	NA	NA	NA
Elbow grip length	321	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biacromial breadth	303	NA	355	350	360	300	356	NA	240	NA	331	351	348	352	NA
Elbow-elbow breadth	363	NA	NA	NA	NA	NA	444	NA	NA	NA	NA	NA	NA	NA	NA
Abdominal extension	219	NA	255	250	295	260	227	NA	250	NA	NA	NA	NA	NA	NA
Thigh clearance sitting	132	NA	155	140	150	165	145	NA	14.2	NA	NA	NA	NA	NA	NA
Knee height sitting	475	505	500	485	505	480	521	494	490	490	472	458	NA	470	470
Popliteal height sitting	416	NA	400	420	405	365	444	NA	420	NA	379	382	362	384	NA
Buttock-knee length	529	574	570	565	600	570	596	NA	590	527	530	529	531	528	527
Buttock-popliteal length	439	490	480	450	495	470	477	NA	490	451	439	433	437	449	451
Foot length	228	239	NA	NA	NA	NA	243	232	235	223	NA	NA	NA	NA	NA
Hip breadth sitting	316	376	370	360	395	400	416	308	410	299	322	317	333	319	364
Foot breadth	89	8.9	NA	NA	NA	NA	90	88	90	97	NA	NA	NA	NA	NA
Functional leg length	906	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RSH*	0.49	0.53	0.53	0.52	0.53	0.55	0.53	0.53	0.48	0.51	0.54	0.54	0.54	0.55	0.52

Table 3: Mean values of important standing and sitting anthropometric dimensions of female agricultural workers of different countries.
Measurement unit: mm, unless otherwise specified. *Ratio of sitting height to stature (unitless)
a: MacLeo [15]. b: Barroso, et al. [16] c: Hanson, et al. [17] d: Lin, et al. [18]e: Syuaib [19]. f: Obi, et al. [20].
NA: no data available

Conclusions

Total 382 healthy female agricultural workers were selected as subjects for taking anthropometric data. They were in the age group of 22-54 years. During the survey, all together 38 body dimensions were precisely recorded from each subject. The segmental proportions of anthropometric data as a function of stature, in standing posture namely knee height, elbow-elbow breadth and hip breadth; and in sitting posture namely elbow rest height increased considerably with measure of stature from 5th to 95th percentile. It was observed that there was a large variation in the anthropometric data when the results were compared with the anthropometric data of different states of India. The selected subjects were taller than female agricultural workers from north-eastern and eastern states of India but shorter than the northern states of India. The similar trend was observed for most of the body dimensions. When anthropometric data compared to the American, British, Portuguese, Swedish, Turkish and Nigerian female workers it can be seen that Indian female population are shorter in stature, sitting height, buttock knee length, buttock popliteal length and hip breadth. The large difference found in anthropometric dimensions of different population groups indicated that a distinctive nature of the anthropometry. Therefore, there is requirement of suitably modifying or redesigning of existing farm equipment before introducing these to the Indian farm workers.

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